# WFNS Spine Committee
# *Textbook of*
# Surgical Management of Lumbar Disc Herniation

Given the whole spine, because of its vulnerability, most spinal problems occur in the lumbar spine than anywhere else

No one likes to have back pain. But it comes like an unwelcome visitor at most inappropriate times without warning. It remains for a long time and once the friendship is established, it returns very frequently.

# WFNS Spine Committee
# *Textbook of* Surgical Management of Lumbar Disc Herniation


*Editor-in-Chief*

**PS Ramani** MD MSc DSc
Senior Consultant, Neuro and Spinal Surgeon
Lilavati Hospital and Research Centre, Mumbai, Maharashtra, India
Retired Professor and Head
Department of Neuro and Spinal Surgery
Lokmanya Tilak Municipal Medical College and Hospital
University of Mumbai, Mumbai, Maharashtra, India
Chairman, World Federation of Neurosurgical Societies (WFNS) Spine Committee
President, Neuro and Spinal Surgeons' Association of India
Chief Editor, SPINE (Indian Edition)
Editor-in-Chief, Journal of Spinal Surgery

*Co-Editors*

**Chun-Kun Park** MD
Professor and Chairman
Department of Neurosurgery, College of Medicine
The Catholic University of Korea
Seoul, South Korea

**Christopher M Loftus** MD Dr hc (Honorary) FACS
Chairman, American Association of Neurological Surgeons (AANS)
International Outreach Committee
Assistant Treasurer—WFNS
Professor and Chairman, Department of Neurosurgery
Assistant Dean for International Affiliations
Temple University School of Medicine, USA

**Junichi Mizuno** MD PhD
Director and Neurosurgeon
Center for Spine and Spinal Cord Disorders
Southern Tohoku General Hospital
1-2-5, Satonomori, Iwanuma, Miyagi, Japan

**Abdul Hafid Bajamal** MD
Professor and Head
Department of Neuro and Spinal Surgery
Dr Soetomo General Hospital
Medical Faculty of Airlangga University
Surabaya, Indonesia

**Enrique Osorio-Fonseca** MD
Professor
Department of Neuro and Spinal Surgery
El Bosque University
Bogotá, Colombia

**Sushil Patkar** MD
Honorary Associate Professor
Department of Neuro and Spinal Surgery
Bharati Vidhyapeeth Medical Hospital
Pune, Maharashtra, India

*Forewords*

**Yong-Kwang Tu**
**Peter Black**



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Fax: +91-11-43574314
**Email: jaypee@jaypeebrothers.com**

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**Email: joe.rusko@jaypeebrothers.com**

Jaypee Brothers Medical Publishers (P) Ltd.
17/1-B, Babar Road, Block-B, Shaymali
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## Dedication

*The best way to learn an operative technique in spinal surgery is to get lessons and then practice it in the cadaver workshops. I have been conducting cadaver workshops not only in country but also in several parts of the world imparting knowledge of practice of spinal surgery. I dedicate this book to the departed souls whose mortal remains have helped us to achieve excellence and to innovate newer techniques in such a way as to make life safe and comfortable for the patients.*

# Contributors

**A Bambang Darwono**
Division of Orthopedic and Spine
Gading-Pluit Hospital, Boulevard Timur Raya
Kelapa Gading, Jakarta Utara 14250, Indonesia

**Abbas Amirjamshidi**
Professor
Department of Neurosurgery
Sina Hospital
Tehran University of Medical Sciences
Tehran, Iran

**Abdul Hafid Bajamal**
Professor and Head
Department of Neuro and Spinal Surgery
Dr Soetomo General Hospital
Medical Faculty of Airlangga University
Surabaya, Indonesia

**Adil Chagla**
Professor and Head
Unit 2, Department of Neurosurgery
Seth Gordhandas Sunderdas Medical College and
King Edward Memorial Hospital
Mumbai, Maharashtra, India

**Aldo Calaça**
Department of Neurosurgery
School of Medicine—FAMEPLAC and Hospital Lago Sul
Brasilia, DF, Brazil

**Alok Agarwal**
Neuro and Spinal Surgeon
Department of Neuro and Spinal Surgery
Bombay Hospital, Jabalpur, Madhya Pradesh, India

**Benjamin Hoch**
Department of Orthopedic Surgery
University Hospital, Uppsala, Sweden

**Ben Roitberg**
Associate Professor
Department of Surgery
University of Illinois Medical Center, Chicago, USA

**Bong-Soo Kim**
Assistant Professor
Department of Neurosurgery
Temple University School of Medicine
Philadelphia, USA

**Christian Andrés Chalita Pérez-Tagle**
Department of Neurological Surgery
Instituto Mexicano de Neurociencias
Hospital Ángeles de Las Lomas
Mexico

**Christopher M Loftus**
Chairman
American Association of Neurological Surgeons (AANS)
International Qutreach Committee
Assistant Treasurer—WFNS
Professor and Chairman
Department of Neurosurgery
Assistant Dean for International Affiliations
Temple University School of Medicine, USA

**Christopher WK Mak**
Department of Neuro and Spinal Surgery
Prince of Wales Hospital
Chinese University of Hong Kong
Sha Tin, NT, Hong Kong, China

**Chun-Kun Park**
Professor and Chairman
Department of Neurosurgery and Radiology
Kangnam St Mary's Hospital
President
International Society for the Advancement of Spine Surgery
The Catholic University of Korea
Seoul, South Korea

**Cumhur Kilincer**
Associate Professor
Department of Neurosurgery
Trakya University Medical Faculty
Edirne, Turkey

**David TF Sun**
Associate Consultant
Department of Neuro and Spinal Surgery
Prince of Wales Hospital
Chinese University of Hong Kong
Sha Tin, NT, Hong Kong, China

**Deepak Ranade**
Professor and Head
Department of Neurosurgery
Padmashree Dr DY Patil Medical College
Hospital and Research Centre
Pune, Maharashtra, India

**Eko Agus Subagio**
Neuro and Spinal Surgeon
Department of Neuro and Spinal Surgery
Dr Soetomo General Hospital
Medical Faculty of Airlangga University
Surabaya, Indonesia

**Enrique Klériga-Grossgerge**
Department of Neurological Surgery
Instituto Mexicano de Neurociencias
Hospital Ángeles de Las Lomas, Mexico

**Enrique Osorio-Fonseca**
Professor
Department of Neuro and Spinal Surgery
El Bosque University
Bogotá, Colombia

**Futoshi Suetsuna**
Clinical Professor
Department of Orthopedic Surgery
Hirosaki University, School of Medicine, Hirosaki
Vice President and Director
Department of Orthopedic Surgery
Hachinohe Municipal Hospital
Hachinohe, Japan

**Gabriel Oswaldo Alonso**
El Bosque University
Bogotá, Colombia

**George Dohrmann**
Professor
Department of Neurosurgery
University of Chicago Medical Center
Chicago, Illinois, USA

**Gerardo Francisco Zambito-Brondo**
Department of Neurological Surgery
Instituto Mexicano de Neurociencias
Hospital Ángeles de Las Lomas, Mexico

**Javed Khader Eliyas**
University of Illinois Medical Center
Chicago, USA

**Jay Kotecha**
Section Incharge (CT)
Department of Imaging
Lilavati Hospital and Research Centre
Mumbai, Maharashtra, India

**Jesús Carlos Bustamante-Vidales**
Department of Neurological Surgery
Instituto Mexicano de Neurociencias
Hospital Ángeles de Las Lomas, Mexico

**Jin-Sung Kim**
Department of Neurosurgery and Radiology
Kangnam St Mary's Hospital
The Catholic University of Korea
Seoul, South Korea

**João Flávio G Madureira**
Department of Neurosurgery
School of Medicine—FAMEPLAC and Hospital Lago Sul
Brasilia, DF, Brazil

**Jorge Felipe Ramírez**
El Bosque University
Bogotá, Colombia

**José Gabriel Rugeles**
El Bosque University
Bogotá, Colombia

**Junichi Mizuno**
Director and Neurosurgeon
Center for Spine and Spinal Cord Disorders
Southern Tohoku General Hospital
1-2-5, Satonomori
Iwanuma, Miyagi, Japan

**K Sridhar**
Head
Division of Brain and Spine Surgery
Senior Consultant Neurosurgeon
Global Hospital
Chennai, Tamil Nadu, India

**Kourosh Karimi Yarandi**
Assistant Professor
Department of Neurosurgery
Sina Hospital
Tehran University of Medical Sciences
Tehran, Iran

**Kyeong-Sik Ryu**
Department of Neurosurgery and Radiology
Kangnam St Mary's Hospital
The Catholic University of Korea
Seoul, South Korea

**Makarand Kulkarni**
Incharge
Department of MRI
Lilavati Hospital and Research Centre
Mumbai, Maharashtra, India

**Manoj Deshmukh**
Incharge
Department of CT
Lilavati Hospital and Research Centre
Mumbai, Maharashtra, India

**Marcos Masini**
Department of Neurosurgery
School of Medicine—FAMEPLAC and Hospital Lago Sul
Brasilia, DF, Brazil

**Martin TN Knight**
The Spinal Foundation, Sunnyside
Highfield Road
Congleton, Cheshire, UK

**Matthew J Tait**
Department of Neurosurgery
King's College Hospital
NHS Foundation Trust, Denmark Hill
London SE5 9RS, England, UK

**Mehmet Resid Onen**
Department of Neurosurgery
Umraniye Teaching and Research Hospital
Istanbul, Turkey

**Mehmet Zileli**
Professor
Department of Neurosurgery
Ege University Faculty of Medicine
Bornova, 35100 Izmir, Turkey

**Michael Cui**
University of Illinois Medical Center
Chicago, USA

**Mohammad Shirani Bidabadi**
Department of Neurosurgery
Sina Hospital, Tehran University of Medical Sciences
Tehran, Iran

**Motoi Shoda**
Head
Department of Neuro and Spinal Surgery
Fujita Health University
Toyoake, Aichi 470-11, Japan

**Muhammad Faris**
Neuro and Spinal Surgeon
Department of Neurosurgery
Dr Soetomo General Hospital
Medical Faculty of Airlangga University
Surabaya, Indonesia

**Nassir Mansour**
University of Chicago Medical Center
Chicago, Illinois, USA

**Nicholas WM Thomas**
Department of Neurosurgery
King's College Hospital, NHS Foundation Trust
Denmark Hill, London SE5 9RS, England, UK

**Palak Popat**
Department of Imaging
Lilavati Hospital and Research Centre
Mumbai, Maharashtra, India

**PD Kulkarni**
Associate Specialist Spinal Neurosurgeon
Department of Neurosurgery
King's College Hospital
NHS Foundation Trust
Denmark Hill, London SE5 9RS, England, UK

**Pragnesh Bhatt**
Consultant Neurosurgeon and Honorary Senior Lecturer
NHS Grampian
Scotland, UK

**PS Ramani**
Senior Consultant, Neuro and Spinal Surgeon
Lilavati Hospital and Research Centre
Mumbai, Maharashtra, India
Retired Professor and Head
Department of Neuro and Spinal Surgery
Lokmanya Tilak Municipal Medical College and Hospital
University of Mumbai, Mumbai, Maharashtra, India
Chairman, World Federation of Neurosurgical Societies (WFNS)
Spine Committee
President, Neuro and Spinal Surgeons' Association of India
Chief Editor, SPINE Asian Edition
Editor-in-Chief, Journal of Spinal Surgery

**Pulak Ray**
Resident
Department of Neurosurgery
Temple University School of Medicine
Philadelphia, USA

**R Kemal Koç**
Department of Neurosurgery
Erciyes University
School of Medicine, Kayseri, Turkey

**Reza Sanjari**
Department of Neurosurgery
Sina Hospital, Tehran University of Medical Sciences
Tehran, Iran

**Richard Kim**
Resident
Department of Neurosurgery
Temple University School of Medicine
Philadelphia, USA

**Rogério Safatle Barros**
Department of Neurosurgery
School of Medicine—FAMEPLAC and Hospital Lago Sul
Brasilia, DF, Brazil

**S Phanikiran**
Department of Neurosurgery
Global Hospital
Chennai, Tamil Nadu, India

**Sait Naderi**
Professor
Department of Neurosurgery
Umraniye Teaching and Research Hospital
Istanbul, Turkey

**Shradha Maheshwari**
Department of Neuro and Spinal Surgery
Lilavati Hospital and Research Centre
Mumbai, Maharashtra, India

**Shunji Asamoto**
Department of Neurosurgery
Mita Hospital, International University of Health and Welfare
1-4-3 Mita, Minato-Ku
108-8329 Tokyo, Japan

**Sudhendoo Babhulkar**
Department of Neuro and Spinal Surgery
Lilavati Hospital and Research Centre
Mumbai, Maharashtra, India

**Sumeet Pawar**
Department of Neuro and Spinal Surgery
Lilavati Hospital and Research Centre
Mumbai, Maharashtra, India

**Sushil Patkar**
Honorary Associate Professor
Department of Neuro and Spinal Surgery
Bharati Vidhyapeeth Medical Hospital
Pune, Maharashtra, India

**Taito Itabashi**
Hachinohe Municipal Hospital
Hachinohe, Japan

**Vehbi Gülmen**
Department of Neurosurgery
Ege University Faculty of Medicine
Bornova, 35100 Izmir, Turkey

**Wellingson Silva Paiva**
Department of Neurosurgery
School of Medicine—FAMEPLAC and Hospital Lago Sul
Brasilia, DF, Brazil

**Wolfgang Rauschning**
Research Professor
Clinical and Applied Anatomy and Pathology
Professor
Department of Orthopedics
Uppsala University Hospital, Sweden

**Yasuhiko Nishimura**
Department of Neurosurgery
Spinal Surgery Centre
Medical Inc. Koyo Hospital
Wakayama, Japan

# Foreword

As a unique global organization of neurosurgery, the World Federation of Neurosurgical Societies (WFNS) carries out several important functions. The most important of these functions are, to my point of view, knowledge and experience sharing and the education of our next generation of neurosurgeons. As the future President-Elect of the WFNS, I believe these two issues will be the challenges that I am going to focus on most intensely.

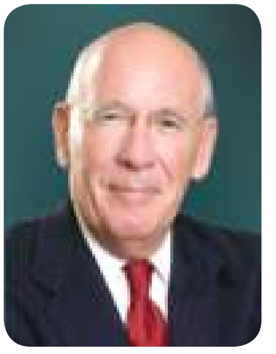
Inside the organization of the WFNS, there are more than 15 scientific committees formed according to various subspecialties in neurosurgery. In order to promote increased communication and sharing as well as to enhance further education, I plan, in my future capacity as the President of the WFNS, to encourage our scientific committees not only to organize advanced education courses in their subspecialties, but also to publish textbooks and to establish clinical guidelines to be used as a resource by neurosurgeons everywhere around the world.

Under the strong leadership of its Committee Chairman, Dr PS Ramani, the WFNS Spine Committee, has been one of the most active WFNS scientific committees in the past years. Since 2009, the WFNS Spine Committee has organized several very successful education courses and in 2011, published a textbook concerning the *Surgical Management of Cervical Disc Herniation*. *Textbook of Surgical Management of Lumbar Disc Herniation* is the second textbook published by the WFNS Spine Committee. The publication of these two textbooks, as well as the very successful organization of these education courses, provides a very fine example for other WFNS scientific committees to follow in the future.

I would like to express my most sincere congratulations to Dr Ramani and all my colleagues on the WFNS Spine Committee for the outstanding work which they have done assimilating their experience into this very valuable textbook. I am looking forward to seeing more textbooks published by the WFNS Spine Committee in the years ahead.

**Yong-Kwang Tu** MD PhD
President-Elect
World Federation of Neurosurgical Societies (WFNS) 2013
Taipei, Taiwan

# Foreword



The World Federation of Neurosurgical Societies (WFNS) does much of its international education through its committees. The spine committee is one of the most active committees of the WFNS. Under the capable leadership of Dr PS Ramani, it has created comprehensive management paradigms for most spine disorders. Two years ago, the committee created a textbook of cervical spine disorders which was very well received. This textbook on lumbar spine disorders is an appropriate companion to the previous book. It represents an international multidisciplinary approach to the management of lumbar spine problems of all kinds ranging from simple disc rupture to complex spondylolisthesis.

We, in the WFNS are very proud to have *Textbook of Surgical Management of Lumbar Disc Herniation* as a representation of our community. We congratulate Dr Ramani and his group for its creation.

**Peter Black** MD PhD
President
World Federation of Neurosurgical Societies (WFNS)

# Preface

Low back pain sufficient to require medical attention occurs in over 80 percent of the population and 35 percent of them require medical attention. The number of patients seeking treatment for low back pain is steadily increasing all the time. The anatomical enigma of spine is that it degenerates. Today, spinal degenerative disorders have advanced disproportionately possibly due to changing lifestyle.

Although the *Homo sapien*s have been striding across for over 50,000 years, the nerve root irritation as the cause of sciatica was not implicated, until the beginning of 20th century. Herniation of lumbar intervertebral disc as the cause of low back pain and sciatica was discovered only in the early 1930. Since then, spinal surgery for degenerative disorders of the spine including herniated lumbar intervertebral disc has advanced significantly, and younger generation of spinal surgeons are all the time looking for newer techniques to surgically treat a patient of lumbar disc herniation.

The history of minimally invasive spinal surgery started in 1955 with Leonard Mallis introducing a binocular microscope and bipolar coagulation and, Williams in an attempt to send the show girls back to dancing quickly, introduced microlumbar discectomy. With these developments, the era of long incisions, maximum curettage of disc, immense morbidity and loss of earning power died very quickly. Ascher in 1984 was the first to utilize Laser (Nd:YAG) to ablate the herniated nucleus pulposus through an 18-gauge spinal needle.

Kambin advanced the work of Ascher and introduced a new and safe pathway (Kambin's triangle) and percutaneous discectomy under two-dimensional vision of endoscope.

Today, herniation of lumbar intervertebral disc is so common that it is accepted as the common cause of low back pain and disability. Fifteen percent cases eventually need surgical intervention. Today's younger generation of spinal surgeons are interested in providing optimal care to the patients suffering from herniated lumbar disc. It is the perception of these scientists that make textbook such as this interesting and absorbing, in spite of the fact that volumes have been already written on the subject.

Creating an up-to-date textbook of innovative field of minimally invasive spinal surgery is truly a challenge for the Editor-in-chief. Contributions were requested from leading surgeons from all over the world, and the extensive information gathered in outlined in 49 Chapters based on their cumulative experience.

It is our hope that the book will find widespread appreciation all over the world.

**PS Ramani**
**Chun-Kun Park**
**Christopher M Loftus**
**Junichi Mizuno**
**Abdul Hafid Bajamal**
**Enrique Osorio-Fonseca**
**Sushil Patkar**

# Acknowledgments

It is impossible to acknowledge personally the support from various corners of the world in preparing this treatise as it is simply vast.

I gratefully acknowledge the encouragement, guidance and cooperation from our President of WFNS, Dr Peter Black and President-Elect, Dr Yong-Kwang Tu. Both of them found time to write a few words of wisdom as foreword to this book.

Dr Yoko Kato, Chairman, Education Committee (WFNS) has been cooperative in providing valuable guidance during the preparation of the book.

I sincerely thank my colleagues and editors of the book for their kind gesture of sparing enough time to be with me so that the book becomes complete and interesting.

If, it were not for the cooperation of, Shri Jitendar P Vij (Group Chairman), Mr Ankit Vij (Managing Director), Mr Tarun Duneja (Director-Publishing) and KK Raman (Production Manager) of M/s Jaypee Brothers Medical Publishers (P) Ltd, New Delhi, India, then the book could not have been released in time when we wanted in spite of a big line-up of books for publishing.

I thank all the contributors for sparing time to indulge in writing promptly their chapters so that I could realize my dream of a beautiful book being born.

Finally, I sincerely thank all my office staff Priya, Sumeet, Swati, Shailesh, Santosh, Ajit, Nikita and others who have directly or indirectly contributed to the publication of the book.

I also thank WFNS Spine Committee for keeping faith in me in bringing out such a useful textbook.

**PS Ramani**
*Editor-in-Chief*

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# Section 1

# Historical Evolution of Lumbar Disc Herniation

## Section Outline

1

# Back Pain, Sciatica and Herniated Lumbar Intervertebral Disc Historical Anecdote

*PS Ramani*

Our knowledge of herniation of lumbar intervertebral disc is relatively new. Until 1930 we did not know that a lumbar disc herniation can cause back pain and sciatica. The first authentic monogram recognizing the importance of herniation of lumbar intervertebral disc in causing symptoms of back pain and sciatica was published by Mixter and Barr in 1934.[1] However, there are a few early records describing massive disc herniation following trauma. Middleton and Teacher[2] in 1911 described a case of paraplegia following an effort to lift a heavy weight from the floor. The patient had died and postmortem examination had shown a piece of fibrocartilage lying in the extradural space thought to have come from T11/T12 intervertebral disc. Reports of chondromas causing compression of nerve roots have occasionally appeared in the literature. Elsberg in 1928 listed eleven such cases in his series of 46 extradural tumors. He opined that seven had come from intervertebral disc. In the same year (1928) Stookey described cartilaginous compressions seen by him during surgical procedures as chondromas. He carefully described clinical presentations of the patient to correlate with a particular nerve root compression by a chondroma. During the same period Schmorl was studying pathological change in the intervertebral disc. He along with Junghans carried out pioneering work and described the modern concepts of intervertebral disc. Their classical work, "The human spine in health and disease" was available in English language in 1971.[3] Junghans concept of motion segment in the spine was an eye opener.[4,5]

In 1934 Peet and Echols were the first to suggest that what was hitherto been referred to as chondromas or ecchordosis was really a herniation of intervertebral disc. The paper in 1935 by Mixter and Iyer describing results of surgery in three patients gave important clinical and precise scientific information. In 1957 Payne and Spillane[6] carried out autopsy studies and Ramani[7] in 1976 carried out radiological studies to conclude that neural compression was more likely to occur if the disc protrusion occurred in a congenitally narrow canal. Since then rapid strides were made in explaining the factors leading to herniation of a given lumbar intervertebral disc. Addition of knowledge of biomechanics of functioning of the spine has helped us to understand the weight bearing principles of spine and how a given intervertebral disc can degenerate if these principles were violated. The addition of better understanding of anatomy of lumbar spine by CD Schneck[8] (1983) and its correlation with degenerative changes in the lumbar spine describing evolution of lateral recess stenosis.

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# 2

# History of Lumbar Disc Disease and Herniation

*Pragnesh Bhatt*

Back pain has overwhelmed humans for thousands of years and one can find its reference in scientific literature from all corners of the world.

Sushruta (800 BC), the father of surgery in India and Charaka, the great physician of India identified the condition of sciatica and named it *gridhrasi*. They attributed the pathogenesis of this condition to *vata dosha* wherein the local factors of blood, muscles, tendons, ligaments and bones are each involved in a vicious manner. [1]

Review of early Egyptian (1550 BC), Greek, Roman and Arabic textbooks reveal ongoing interest in spinal disorders however symptoms of sciatica were often grouped with pain originating from the hip joint. Similarly, though the description of lumbago and sciatica are seen in the Bible and in the writings of Hippocrates,[2] the scientific evolution of lumbar disc disease as a surgical disorder began in 1934 when Mixter and Barr[3] published their original report of lumbar disc herniation as the cause of leg pain.[4]

Looking at the evolution of our understanding of lumbar disc disease one can divide it in the following phases.

## Prior to 20th Century

Hippocrates (circa 460-370 BC) was probably the first to formally study and mention sciatica and low back pain. He is therefore also considered the 'Father of Spinal Surgery' (Fig. 2.1).[5,6] Galen is also credited for having described the same during the second century AD.[7,8]

In 4th Century AD, Caelius Aurelianus made the first clinical description of sciatica. He also described its association with heavy lifting, the radiation of pain to buttock and leg, and the muscle wasting in advanced cases.

In the 15th century, Sabuncuoglu, a Turkish physician from Amasya described treatment of spinal disorders in his treatise *The Imperial Surgery* which was still considered a landmark. He treated sciatica with medical and heat cauterization.[9,10]

Andreas Vesalius (1514–1564) was the first to describe the intervertebral disc. His famous monogram *De humani Corporis Fabrica* (1543) had plate depictions of the spinal column and the intervertebral disc spaces.[11]

Domenico Cotugno (1736–1822) mentioned sciatica as a clinical entity, related the pain in the leg to disease of the sciatic nerve, and published his findings in a monograph, *De ischiade nervosa commentarius*. Since then sciatica was known as Cotugno's disease for many years.[12]

AG Smith was the first to perform a laminectomy in 1829 in the United States.[7,13]

Probably the first description of a traumatic rupture of an intervertebral disc was made by Rudolf Virchow (1821–1902) in 1857. Virchow published a discussion of disc pathology that included ruptured disc then known as 'Virchow's tumor'.[11]

Luschka in 1858 observed degenerative processes of the disc in autopsy specimens.

Ernest Lasegue (1816–1883) in 1864 commented on the physical signs of patients with sciatic neuritis and then recognized the association between sciatica and low back pain. Since then the maneuver he described is known as Lasegue's sign.

Kocher identified a disc displacement at L1-2 in an autopsy on an individual who had fallen from a height of 100 feet and made the earliest report of posterior displacement of intervertebral disc material in 1896.[14]

Concepts concerning the biomechanics of lumbar spine were studied by Weber (1827), Rauber (1876) and Messerer (1880).

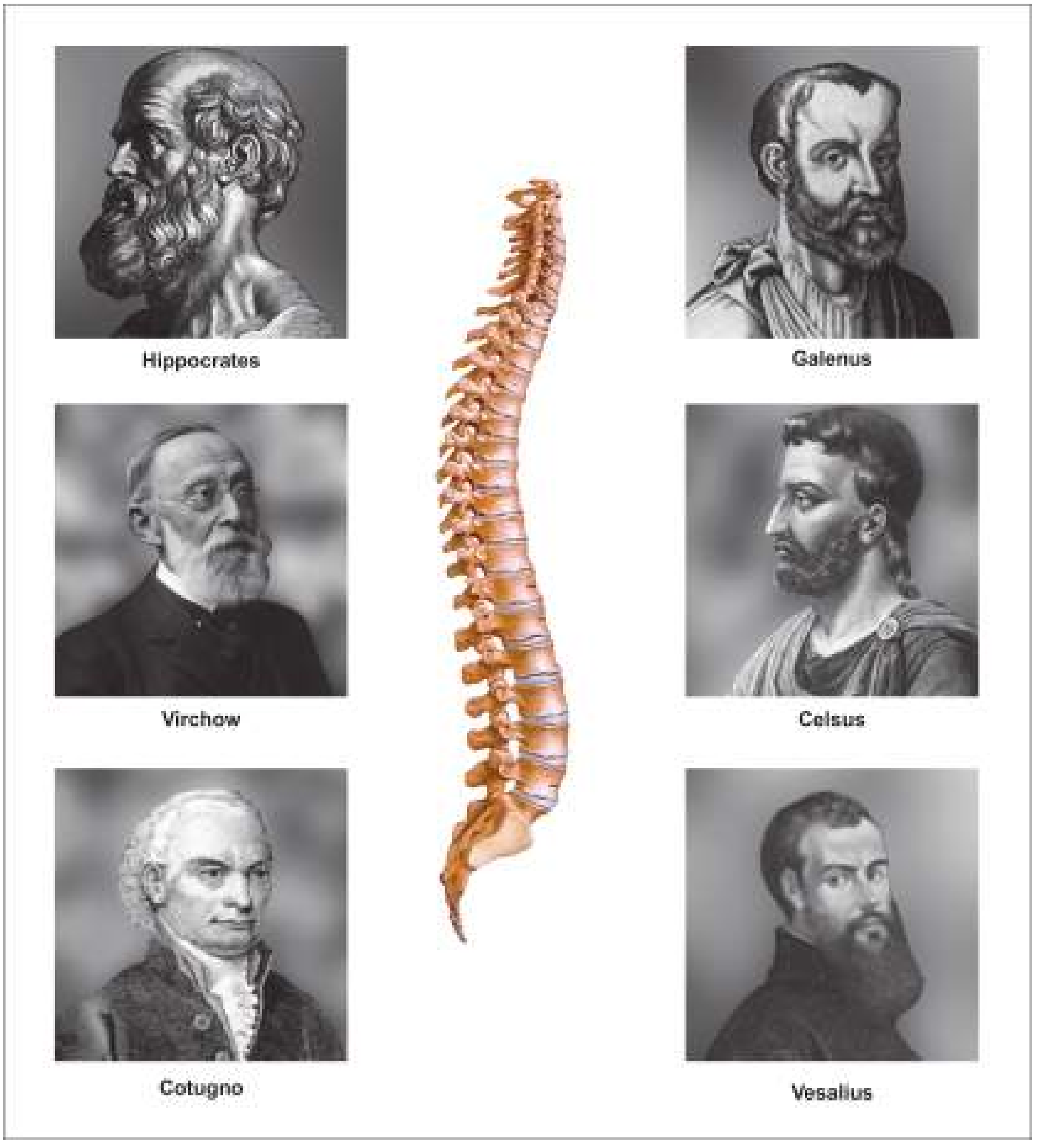


**Fig. 2.1:** A composition showing some of the pioneers around a spinal column, as depicted by Vesalius in *De humani Corporis Fabrica* [reproduced with kind permission from Dr Jose Alberto Landeiro MD Arq Neuropsiquiatr 2005;63(3-A):701-6]

Since 1895 with the discovery of X-rays by William Conrad Roentgen (1845–1923), imaging in general and the evolution of diagnosing spinal disorders in particular, entered a new era. Initially only anteroposterior views were used till Davis obtained lateral radiographs in 1925. This was further enhanced following the introduction of myelography in 1930.

## 20th Century—First Half

An Italian physician Bonomo was the first one to suggest the transdural approach to remove a disc in 1902.[15]

Fedor Krause in 1909 probably made the first successful removal of a ruptured disc. He published with Oppenheim a description of a removal of what can be regarded with certainty as a ruptured disc. The lesion resected transdurally was thought to be an 'enchondroma'.[16]

Schmorl and Andrea (1927–1929) established the modern basis for understanding of the intervertebral disc by providing very clear discussions of herniations as well as degenerations.[9,13,16]

Walter Dandy attributed cauda equina syndrome to material derived from the intervertebral disc.

William J Mixter, a neurosurgeon at Harvard Medical College, and his orthopedic colleague Joseph Barr elucidated the pathophysiology of lumbago and sciatica, and in 1934 described an intradural approach for removal of offending ruptured discs.

Love introduced the intralaminar extradural approach for discectomy between 1937 and 1939.[17]

Discography was described by Lindblom in 1948 which provided an insight into the pathology of degenerative disc disease.

## 20th Century—Second Half

The concept of chemonucleolysis was demonstrated in a rabbit model by Smith in 1964 which was later applied in humans.

The introduction of MRI in 1970s revolutionized the management of lumbar disc disease.

Hijikata from Japan described an endoscopic approach for discectomy in 1975.[18]

The technique of microsurgical discectomy was described in 1977 by Yasargil in Switzerland, Caspar in Germany[19] and William in the United States.

Ascher and Heppner introduced the concept of percutaneous laser-assisted discectomy with Nd: YAG and carbon dioxide laser in 1984.

McCall described the radiological findings in a variety of disc disorders in 1987.[20]

Tubular microdiscectomy using a tubular retractor system was popularized in 1990s wherein a smaller incision was made with muscle splitting (MED, MEDRx systems) rather than subperiosteal dissection.

Foley and Smith in 1997 described microendoscopic discectomy as a minimally invasive procedure for lumbar disc herniation.[21]

Saal and Saal described the concept of intradiscal electrothermal therapy in 2000.

## Artificial Disc Technology

Despite 50 years of research and development there has been slow progress in artificial disc technology due to structural and functional complexity of the disc and the debate continues between replacing the entire disc or a portion of it, i.e. its nucleus.

The concept of a disc prosthesis was first set forth by a French surgeon van Steenbrugghe in 1955. However, it was not until 1973 when Urbaniak et al. reported the first disc prosthesis that was prototyped and implanted into chimpanzees. Froning patented an artificial disc in 1975 but never implanted it.

On the other hand, Fernstrom in the late 1950s initiated clinical use of a spherical endoprosthesis consisting of a stainless steel ball without any animal experiments.

Variety of designs focusing on viscosity and elasticity were attempted by Nachemson (1956), Oyen (1974), Roy-Camille (1978), Kuntz (1980) and Edeland (1981).

In 1980s Schellnac and Buttner-Janz designed the SB Charite device which was first implanted by Zippel in 1984 and was later abandoned. This has been subsequently improvised to SB Charite III in 1987 and became widely popular in Europe.

Bao and Higham pioneered research into using hydrogel material for intervertebral nucleus replacement in 1990.

## Conclusion

Understanding the concept of intervertebral disc degeneration and herniation is of recent onset. Techniques for excision of herniated disc have made tremendous progress from open to minimally invasive or percutaneous techniques. Biomechanical understanding and accepting the concept of instability has helped to evolve techniques for fusion.

The progress in science is now oriented towards nanotechnology, genetic understanding and stem cell therapy.

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# 3

# Evolution and Progress of Concept of Minimally Invasive Surgical Management of Herniated Lumbar Intervertebral Disc

*PS Ramani*

## Evolution

Low back pain is common in the society. It is found that 80 percent of the adults, sometime or the other, will have low back pain which needs medical attention[1] and 35 percent of these patients will develop sciatic pain.[2] Since the scientific knowledge of back pain and sciatica is of recent origin, its incidence was not recorded in our forefathers. However, even in earlier times it was well known that animals on four legs do not suffer from back pain or sciatica and that human being in erect posture creates axial loading on the spine and the intervertebral discs. Bending forwards reduces the intradiscal pressure by 50 percent but sitting increases it by 40 percent, lifting weights in forward bending position increase the pressure by 100 percent and rotation in bent position causes the pressure to rise to 400 percent.[3,4] Hippocrates[5] was the son of a priest physician born in 460 BC. His father was absolutely devoted to the God and believed that god cures while he treated. He wanted his son to follow the same principles. But Hippocrates followed more scientific medicine. Although he devised treatment for several spine ailments he was not aware that prolapsed disc caused sciatica. In fact sciatica as a symptom was first described by an anatomist D. Cotunnius in the 18th century.[6] Virchow in 1857 described lumbar disc herniation.[7] In 1913 Elsberg[8] did lumbar laminectomy and removed intradural chodromatas not knowing that it was a herniated disc.

## Progress

Only in 1934 Mixter and Barr[9] and Peet and Echols[10] scientifically described the cause and effect relationship between back pain, sciatica and herniated intervertebral disc. Laminectomy and discectomy was the standard surgical management devised. It became popular universally as back pain and sciatica due to herniated lumbar intervertebral disc was extremely common. Certain modifications like hemilaminectomy, partial laminotomy and interlaminar approach was described by some surgeons but even today, for want of better facilities laminectomy is uniformly practiced in several places as standard treatment for herniated lumbar intervertebral disc.

## Minimally Invasive Concepts

Microscope was introduced (binocular) by Mallis in 1955.[11,12] Williams then introduced microlumbar discectomy and published his series in 1978[13] and Ascher[14] in 1984 introduced Nd:YAG laser to ablate nucleus pulposus through no. 18 gauge spinal needle. In 1960 Rees[15] performed percutaneous bilateral rhizolysis to give relief from back pain if not sciatica. Shealey in 1974 first introduced[16] percutaneous RF facet joint rhizotomies. Goebert in 1960[17] recommended that open surgery should not be performed. In fact in 1959 he used extensively injection of a mixture of procaine and hydrocortisone into the epidural space to obtain relief from back pain. The result was many times dramatic and even today, in certain patients with back pain steroid injection into the epidural space is commonly practiced to give, albeit, short term relief to the patient. Hirsch[18] recommended use of chymopapain for chemonucleolysis of herniated disc by injecting the enzyme percutaneously into nucleus pulposus through a spinal needle.

## Progress in Minimally Invasive Surgical Techniques

Technological progress advanced in leaps and bounds. Multiplanar magnetic resonance imaging (MRI) is able to image entire spinal canal, the spinal cord and the nerve roots in sagittal, coronal and axial views. Intraoperative interactive MRI will guide the surgeons in accurate explorations and more recently introduction of O-arm as an advance over C-arm to intensify the spinal images more conveniently to the spinal surgeon has really revolutionized the minimally invasive spinal surgery concepts.

Kambin[19] described Kambin's triangle as safe entry point for endoscope into the intervertebral disc. He advanced the work of Ascher[14] Hijikata[20] and Onik[21] to percutaneous endoscopic discectomy, reduction in intradiscal pressure, power shaving and laser ablation. Low energy, nonablasive holmium laser helped to shrink and tighten the intervertebral disc by doing thermodiscoplasty.[22] Today it is possible to enlarge the bony foramen with specialized rasps or side firing laser.[23]

Endoscopic excision of herniated disc no longer requires interaction between patient and surgeon. Robotic assistance is gaining popularity.

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# Section 2

# Basic Knowledge in Lumbar Disc Herniation

## Section Outline

# 4

# Applied Anatomy and Normal Functions of Lumbar Spine

*Eko Agus Subagio*

## Applied Anatomy

### Spine

The human spine, also known as vertebral column, is made up of individual units called vertebrae. The name vertebral column is derived from its appearance when viewed from the front. It really looks like a column with individual vertebrae stacked neatly on one another like wooden blocks (Fig. 4.1).

### Curvatures of Spine

It is gently curved to provide maximum flexibility (Fig. 4.1). In the cervical region it is curved with convexity forwards so that the neck looks long and smart. In the lumbar region its lordotic curve anteriorly provides better stability during weight bearing in the legs.[1] In the thoracic region the spine is gently curved posteriorly. It has 7 vertebrae in the cervical region, 12 in the thoracic region, 5 in the lumbar region and the sacral five vertebrae are fused together to form the sacrum which provides central binding force posteriorly for the two pelvic joints.[2] At the end is the tail bone or coccyx which is really a remnant of the coccygeal vertebrae and does not have a specific role in human beings.

### Vertebra

There are five lumbar vertebrae.

Vertebra having three functional components: the vertebral bodies, design to bear weight; the neural arches, designed to protect the neural elements; and the bony process (spinous and transverse), design as outriggers to increase the efficiency of muscle action.[3]

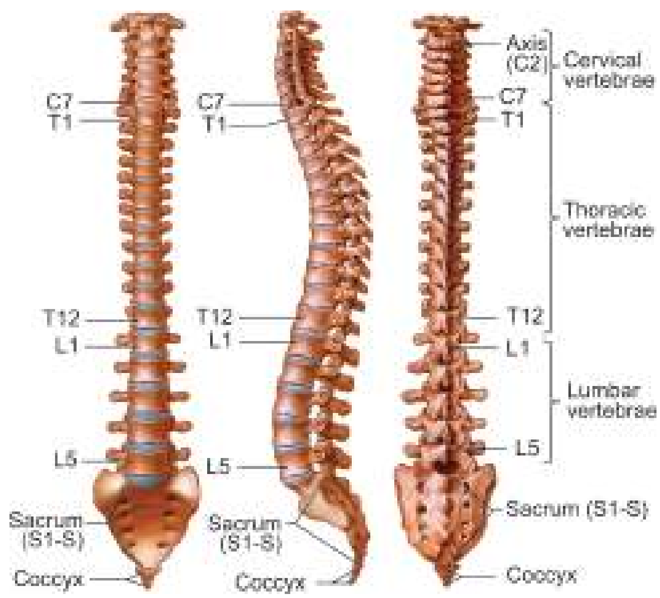



**Fig. 4.1:** The human spine is gently curved when viewed from side to provide maximum flexibility. The curvature in the lumbar spine is a natural lordotic curve

Each lumbar vertebra is well developed to bear the weight of the body and transmit it to the legs. The lumbar vertebra is the strongest portion of the spine. It forms the center of pivot where weight of the body is well balanced, supported and transmitted to the legs. Unlike animals, lumbar spine is the sheet anchor of strength in human beings walking on two legs. Inversely the stress on the spine is maximum in lumbar region in comparison

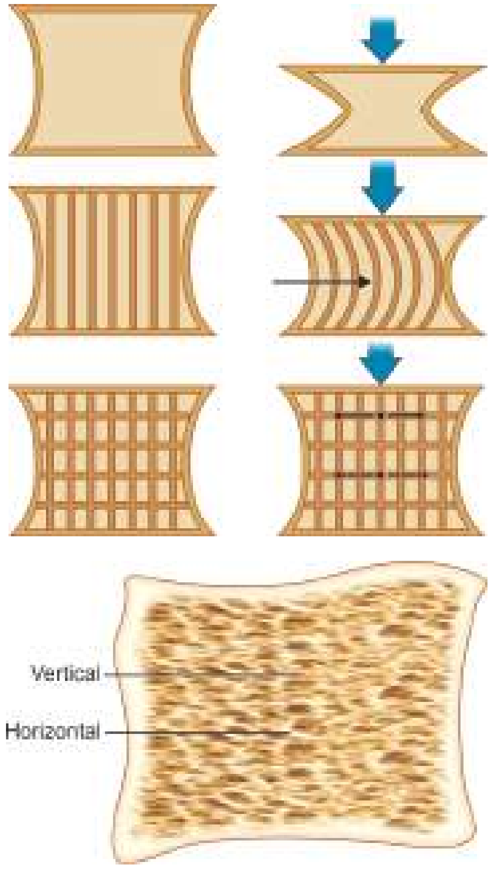


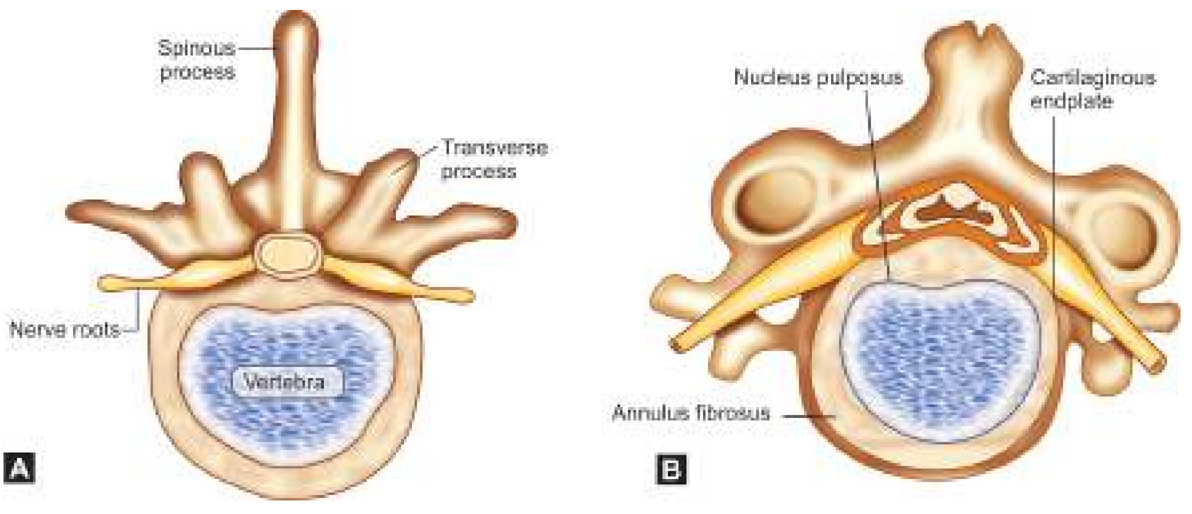

**Fig. 4.2:** Internal architecture of vertebra body. A vertebra body is like a box, with a shell of cortical bone. It will collapse when a load is applied. Internal vertical struts brace the box, and bow when compressed. Transverse connection prevent bowing and increase the load-bearing capacity (Reproduced from Bogduk[4] p.13 )

with any other portion of the spine. It is the seat of backache and sciatica which are discussed in this book. Compression loads on the vertebra come from the weight of the thorax and any load carried in the upper limbs. To sustain the axial loads, vertebra has an outer shell of cortical bone and reinforced internally by trabeculae (Fig. 4.2). The trabeculae consist of vertical part that act like columns that transmit compression loads from the upper surface of the vertebral body to its lower surface. The horizontal trabeculae prevent the vertical one from buckling side away under large compression loads.[3]

On either side of the spinous process are the facet joints which serve as hinges between the vertebra above and the one below. The facet joint is like any other joint. It has a covering capsule and it is lubricated by synovial fluid, the function of these joints is to provide smooth gliding movements and restrict the range of motion (ROM) when it goes beyond limits. Facet joint is not designed to carry excessive body weight.

Each individual vertebra has a solid portion in front known as the body (Figs 4.3 and 4.4).

On either side are the pedicles. Arising laterally from the pedicle are the transverse processes. The superior facet arises from the top and the inferior facet is connected to pedicle through pars interarticularis. The laminae arise medially and curve posteriorly to unite to form the bulbous spinous process posteriorly. All bony elements help to transmit weight. All the posterolateral bony elements of the spine converge on the pedicle which is short and stocky. It has a thick cortical bone and rich cancellous bone in the center. It is the strongest portion of the vertebra (Wolfe's law). In keeping with the lordotic curvature of the lumbar spine the lie of the pedicles vary being more laterally inclined from L1 to L5 vertebrae. This helps to transmit the weight smoothly to the legs and at the same time maintains the extreme mobility that is present in this portion of the spine. Of the five lumbar vertebrae the last two vertebrae help to transmit the weight laterally and yet maintain maximum mobility. These




**Figs 4.3A and B:** Each individual vertebra consists of body, the pedicles, the transverse process, the facet joints, the lamina and the spinous process. These structures encircle the space which eventually forms the bony lumbar canal. Each intervertebral disc has three parts: The nucleus pulposus, the annulus fibrosus and the cartilaginous endplate lying in apposition with the cortical endplate of the vertebra

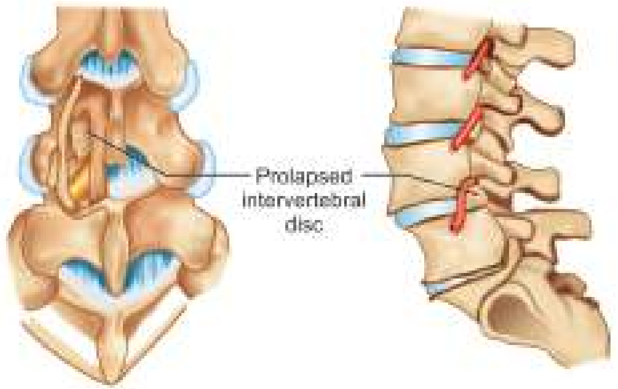



**Fig. 4.4:** The lumbar spine. Each of the five lumbar vertebrae are well developed to bear and transmit the weight of the body. The posterior arch consisting of facet joints, the laminae and the spinous processes protect the neural structures from behind

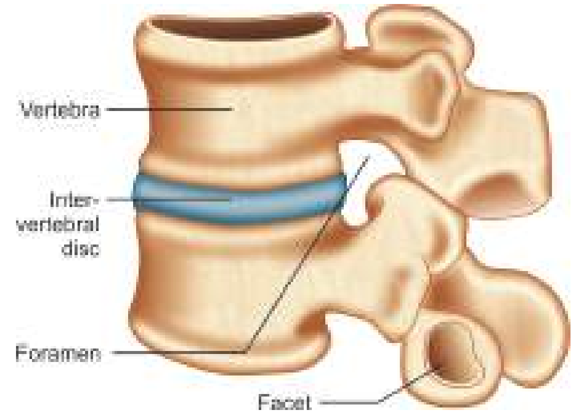



**Fig. 4.5:** The intervertebral disc shows individual variation but the composite thickness constitutes one-fourth of the height of the lumbar spine. The facet joint is an important component of the posterior motion segment

two vertebrae bear the greatest stress in the body and thus are the source of maximum wear and tear. Backache and sciatica is extremely common arising from these two vertebrae.

## Intervertebral Disc

The 20 mm embryo shows clear division of the intervertebral disc into an outer and inner zone. The inner zone is derived from chordal cells after the obliteration of the notochord and forms nucleus pulposus. The outer zone is derived from the cells of the caudal portion of each spinal segment and forms the tight fibrous ring, the annulus fibrosus. During development the blood vessels reach the tight fibrous ring. They are most abundant in the posterolateral compartment and are all obliterated by 4th year of life leaving structural looseness in this area. This region shows decreased resistance and hence conducive to rupture or prolapse in later life. This is one of the reasons why disc rupture is more common posteriorly.[5] The disc then derives its nutrition by permeation through fine openings in the cartilaginous plates lying between the disc and the adjacent vertebral bodies. The thickness of the disc varies and in adult life it is roughly one-third the thickness of the adjacent vertebral body. The individual disc shows variation in thickness in their anterior and posterior parts. This variation helps to form the curvatures of the spine which gives the shape to the human body (Fig. 4.5).

## Parts of the Disc

A normal disc has three parts: (i) The nucleus pulposus. (ii) The annulus fibrosus and (iii) The cartilage plates (Fig. 4.3)

The cartilage plates are of hyaline cartilage which merge on one side with the cancellous bone of the vertebral body and on the other side with the nucleus and the annulus. The plate covers the upper and lower surface of the vertebral bodies except its raised peripheral margin which forms a rim around the plate. The latter is derived from the annular epiphysis.

The nucleus pulposus is the core of the disc and comprise soft but resilient fibrocartilage (Fig. 4.5). It presents a white glistening surface and in the lumbar region its center is a little behind the center of the disc. It is readily deformable but virtually incompressible. It contains loose network of fine fibrous strands between which are connective tissue and cartilage cells. When compressed this semi-fluid mass expands in a radial fashion. The radial movement is resisted by the surrounding annulus fibrosus. This mechanism maintain the stiffness of the annulus against compression loading passively.[4]

The volume of lumbar disc is estimated to be 10 $cm^3$ and nucleus which is about 15 percent, to be 1.5 $cm^3$.

The annulus fibrosus is seen on transverse section as the collar like portion of the disc. All the strength and tenacity of disc lies in this portion. It serves for the transmission of tension through the spine. It is formed of numerous layers at least 12 in the lumbar region lying concentrically (Fig. 4.6). The outer lamella consists of tough fibrous tissue with very few cartilage cells. The deeper layers pass into the marginal lip of the vertebral body and the outer layers merge with the periosteum. In front and at the sides the superficial layers of the annulus mingle with the fibers of the anterior longitudinal ligament so that the two systems provide a powerful but flexible connection between the vertebrae. In health the bone is likely to fracture rather than the ligament will tear. So strong is the bond.[6]

## Functioning Unit

Although it is possible to distinguish various portions of the disc as described above and to recognize that these modifications are specialized for distinctive functions, in health there is no discontinuity between various structures. For example, cartilage plate merges centrally with nucleus and peripherally with annulus. The nucleus merges with annulus and is perfectly enclosed between annulus and the cartilage plate (Fig. 4.7). The

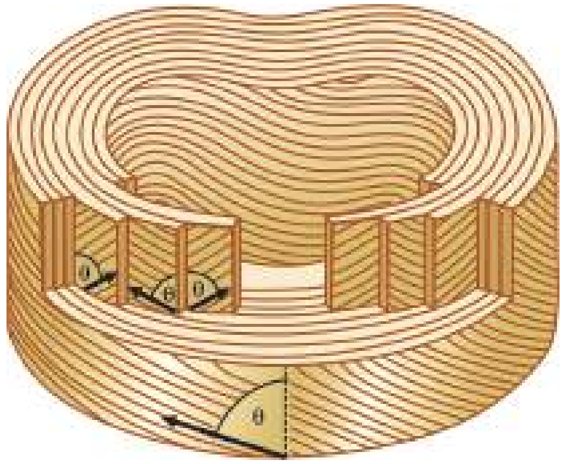



**Fig. 4.6:** The detailed structure of the annulus fibrosus. Consist of 10–20 concentric circumferential lamellae. The orientation of fibers alternate in successive lamellae, but the orientation with respect to the vertical (θ) is always the same, and measures about 65°. (Reproduced from Bogduk 1997)

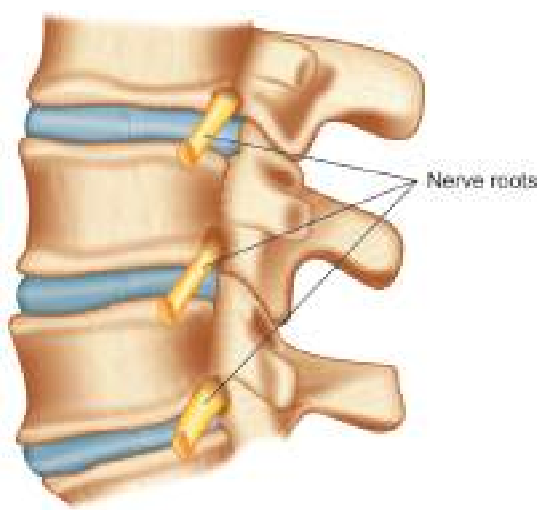



**Fig. 4.7:** The dural sac lies comfortably in the bony lumbar canal

disc is thus a functioning unit and along with vertebrae provides strength and flexibility to the spine as a whole.[7]

## Nutrition

The nutrition of the disc is largely by diffusion. This is derived through the cartilage plate from the adjacent vascular cancellous portion of the vertebra where narrow vessels abound. The dependence upon diffusion is responsible for radiological changes seen in tuberculosis which destroys the vascular tissues adjacent to the cartilage plate. Damage to the endplate through injury or disease process may decrease the diffusion of nutrients to the disc with resulting degradation of the disc.[8]

## Nerve Supply to the Intervertebral Disc

Anterior and posterior longitudinal ligaments are well innervated and the intermingling fibers of the annulus may share this nerve supply. Free nerve endings have been identified in the peripheral fibers of the annulus but none in the nucleus. The posterior annulus and the PLL are the most highly innervated structures in the functional spine unit, undoubtedly helping to explain the production of low back pain associated with disc herniations.[9]

## Functional Relationship

The physical characteristics of the intervertebral disc bear directly on its functions and on the pathological or degenerative changes that it undergoes. *In situ*, the disc is very slightly compressible. The nucleus has a considerable intrinsic pressure estimated by some workers at 60 kg/cm$^2$ in the lumbar region.[10] Quickly exerted pressure produces an immediate change in shape thus contributing to easy adaptability. The disc is truly a dynamic system wherein its mass is in constant motion. It forms a part of the motion segment as described by Junghans.[11]

Besides physical stress the disc is also subject to chemical changes for example increased concentration of hyaluronidase causes disc to swell and results in tear and wear of its fibers. The mucopolysaccharide of the disc decreases with age and glycoprotein may increase. It is believed that such chemical changes are responsible for disc degeneration or herniation in elderly people.

## Muscles

It is believed that most back sprains result from injury to the back muscles. The paraspinal muscles lie on either side of the spinous process vertically. Although looking like one big muscle, the paraspinal muscles are made up of smaller individual groups like vertebrae in keeping with dermatomal pattern. Each individual muscle spans at the most two or three individual vertebrae. The main function of the paraspinal muscles is to maintain the spine erect. In erect human being these muscles have a tremendous role to maintain erect posture and thus are under constant stress. The more these muscles are toned through exercises, more beautiful remains the shape of the body. The importance of these muscles to maintain erect posture can be judged on looking at the extremely well-developed muscles in fisherfolk.

The abdominal muscles anteriorly have significant influence on the spine. Their good contraction give added strength to the spine and helps to maintain posture in human beings. Lax abdominal muscles, protuberant belly creates bad posture and lays the foundation for backache. Chronic backpain and sway back are extremely common in such individuals. In people with a protuberant belly, the so called prosperity paunch, the spine arches forwards creating imbalance in weight bearing.

The quadriceps muscles of the thigh are known as powerhouse of the body. Stronger the quadriceps, less is the stress on the spine while lifting the weights from the ground. Strong quadriceps transmit less and less weight to the spine. While lifting weights by proper posturing, the burden of weight should be transmitted to the thighs and the spine should be spared. That is where the saying goes: Lift your weight by bending the knees rather than bending the hips.

When the muscles become weak and cannot cope with the incoming stress then the extra stress is transmitted to the ligaments. Under normal circumstances it is not the function of the ligaments to be participating in the transmission of weight. However, under abnormal conditions when the ligaments are subjected to abnormal stress they start giving way. They become lax and loose. Under sustained pressure they then lose their ability to maintain proper posture.

The lumbar spine is covered both anteroposteriorly and laterally with strong muscles. The muscles become stronger at the lumbosacral junction to maintain erect postures in the normal lordotic lumbar spine.

Till now we have paid scant attention to musculature of the lumbar spine, Now with MRI imaging used mainly to investigate problems in the lumbar spine, the musculature is clearly defined.

The strength of the whole spine lies in its muscles.[12] Stronger the muscle, stronger and healthy is the person. Efforts are made to tone up muscles of the spine so that both anteriorly and posteriorly the spine is maintained in correct posture with the help of muscles.

During surgery the subperiosteal resection of the paraspinal muscles should be carried out so that the musculature and its blood supply is handled to the minimum.

More operative procedures are being carried out on the lumbar spine from behind and posterior musculature of the spine is subjected to the insults of inappropriate handling in comparison to anterior muscles particularly the psoas muscles which is really the horsepower of the spine and the body.

Retraction of the paraspinal muscles over long periods forcefully can cause obliteration of its vascular supply causing necrosis and fibrosis in the muscles. The MRI studies on spinal musculature following surgery have demonstrated weakening in the muscles following fibrosis due to operative procedures.

A common example is lumbosacral musculature. In an unstable lumbosacral junction the musculature of the spine in this region is subjected to the stress resulting in fibrosis as a result of the operative procedure. At times, as it happens the implants have not been adequate to maintain stability at lumbosacral region. The problem faced lies in the fact that the procedure has become inadequate and as a result of operative intervention the musculature has become weak. The system is bound to fail.

With the advent of MRI scanning the knowledge of weakness, necrosis and fibrosis in the paraspinal muscles specially in surgeries like correction of scoliosis where long incisions have to be taken and where one finally depends on strong musculature, will be studied and certain remedial measures for appropriate handling of the muscles will evolve. It is better to remember not to handle muscles roughly but to treat them with due respect and not to keep them retracted for long hours under great pressure. Toning of the muscles, during postoperative period will go a long way in doing away some of the deleterious effects of surgery.

## Bony Lumbar Canal

The conus medullaris ends at the lower border of L1 vertebra. Beyond that the dural sheath contains only the cauda equina. The shape of the bony lumbar canal varies significantly from L1 to L5. At L1 it is almost round as seen in the figure. At L5 it is trifoliate.[13,14] The well developed lateral recesses due to this transformation are well seen at L4 and L5 vertebrae. Lateral recess pathology can be maximally seen in these two vertebrae. The sagittal diameter of the canal varies from 15 to 25 mm. A canal of 20 mm is capacious. Measurements between 12 and 15 mm are suggestive of small canal and below 12 mm the canal is developmentally narrow causing spinal stenosis (Figs 4.8 to 4.10).

Direct measurements on X-rays need correction for magnification. It is better to take indirect evidence by measuring the distance of the vertebral bodies and the distance of the canal and then expressing the canal as a ratio, e.g. a ratio of 1:2.5 is a


1:2.5 = Broad normal canal
1:4.5 = Narrow normal canal

**Fig. 4.8:** The anteroposterior diameter of the canal can be indirectly measured by the formula as shown in the figure

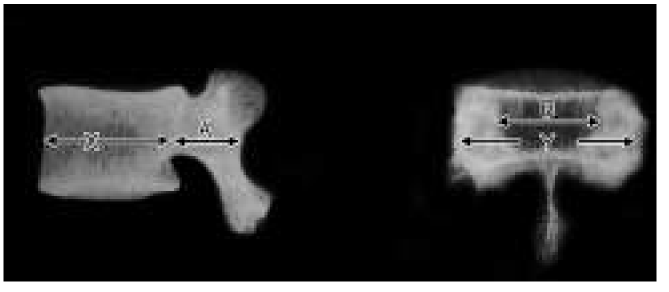



**Fig. 4.9:** To define the canal the insertion of pedicle in the body as well as the point of junction of lamina with the spinous process needs to be clearly defined

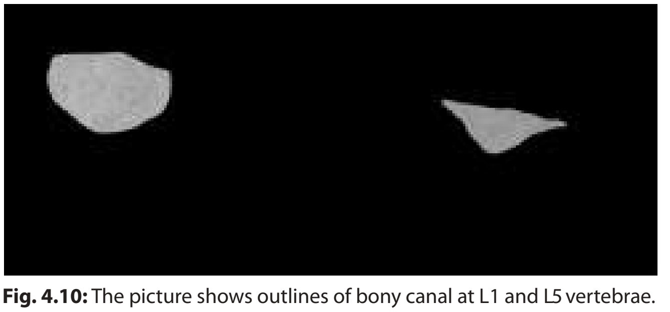


**Fig. 4.10:** The picture shows outlines of bony canal at L1 and L5 vertebrae. At the level of L1, the outline is practically round. At L5, it is trifoliate

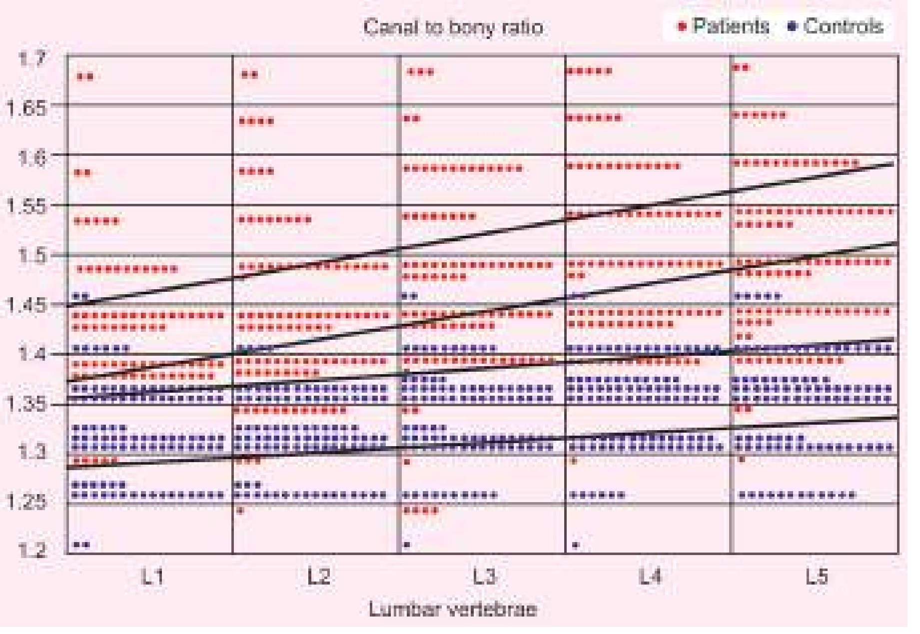



**Fig. 4.11:** Analysis of 100 patients and 100 controls. A ratio of 1:2.5 represents broad canal

broad canal. A ratio 2.5 to 4.5 is suggestive of stenosis and a ratio of 1:4.5 is definitely a narrow lumbar canal.[15-23] Measurements are taken from the posterior surface of the vertebral body to the junctional point between the lamina and the spinous process. This point is not always easy to define and one has to resort at times to tomography to define this point. Acquired stenosis is more common at the level of L4/5 and L3/4.

In a given case of PIVD coming for surgery the canal tends to be developmentally narrow. Such measurements are not necessary now and the canal can be directly measured on MRI studies of the spine.

The bony lumbar canal can also be developmentally narrow. This was first pointed out by Dr H Verbiest.[21,23] Several studies done later has confirmed the findings of Verbiest but there was no study corelating canal measurements with a given case of prolapsed lumbar intervertebral disc.

The author believed that persistence of symptoms of backache and sciatica may be due to developmentally narrow canal. A well controlled study was carried out by the author using lateral X-rays of lumbar spine on 100 patients suffering from prolapsed lumbar intervertebral disc and 100 controls (Fig. 4.11). The age ranged from 14 years to 72 years. Comparison between the two groups showed that from L1 to L5 (throughout the lumbar spine) there was a trend towards canal being narrow in patients with prolapsed intervertebral disc coming for surgery.

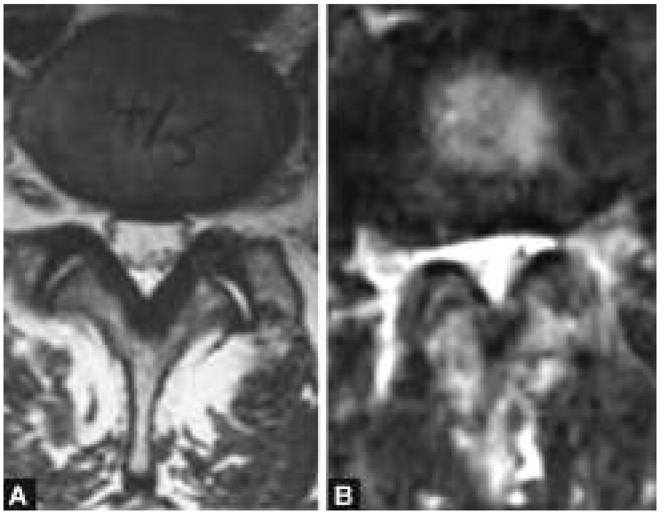
Statistical analysis showed that at each level the difference observed between patients and controls (Ramani 1976)[14] was highly significant ($P<0.0001$). There was a real difference between the two groups which cannot be explained by random sampling errors associated with relatively large variation from patient to patient.

The study established that in patients with prolapsed lumbar intervertebral disc requiring surgery the bony lumbar canal tends to be narrower than normal. The narrowing of the canal enhances the effect of disc protrusion and leads to the persistence of symptoms of backache and sciatica.

## Ligamentum Flavum

It is commonly believed that ligamentum flavum hypertrophies and then it becomes thick and adds to the symptomatology of prolapsed disc by causing compression on the roots or the cauda equina (Figs 4.12A and B).

The author[23] carried out a comparative study of the ligamentum flavum. The ligamentum flavum removed during surgery




**Figs 4.12A and B:** MRI axial cuts showing normal and narrow lumbar canal at the level of L4- L5. (A) Normal canal; (B) Stenotic canal

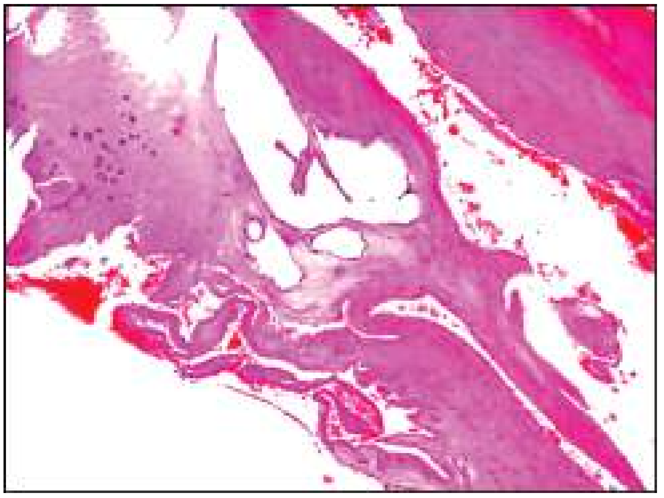


**Fig. 4.13:** A comparative histological study of the ligamentum flavum showed that the ligament does not change its characteristics with advancing age

by fenestration approach for prolapsed disc was studied and compared with the ligamentum flavum removed from cadaveric spines of those who had no history of having suffered from significant backache in life. Same technique was used to remove the ligaments from cadavers.

The age of the patients varies from 17 to 62 years. Age of the cadavers varies from 11 to 68 years. The thickness was measured after fixing the ligaments on histopathology slides. The sections were stained with various stains for histopathological studies (Fig. 4.13).

## Thickness

At the level of L4/5 the thickness of the ligament in the control group was 6.13 mm (SD I.59). In the operative group the mean thickness was 6.18 (SD 1.70). The mean thickness of the ligament at L5/S1 in the control group was 5.22 (SD 1.73) and in the operative group it was 6 mm (SD I.94).

There was no statistical difference in the thickness between the two groups at both L4/5 and L5/S1 levels.

## Content of Elastic Tissue

The content of elastic tissue was 50 percent mean (SD 14.2) in the control group. In the operative group the mean percentage was 53 (SD 12.7). This collaborates well with Evans and Nachemson who had assayed the contents of elastic tissue chemically and found it to be 50 to 60 percent.

Histological studies were also carried out on collagen contents of the ligament. There is no truth in the common belief that ligamentum flavum hypertrophies or its collagen content increases with age and the elastic content decreases.

The ligamentum flavum does not hypertrophy in the true sense and the content of elastic tissue does not decrease with age.

In spinal stenosis the facets hypertrophies forming thick bone. The posterior facet is also rotated medially into the spinal canal. The superior facet is also displaced backwards narrowing the lateral recess. All these changes narrow the available space in the central and lateral part of the bony canal significantly. The ligamentum flavum is then incurled and is fitted into the tight space that is left behind.

## Anatomical Concepts of Referred Back Pain

Referred pain in backache is common. The concept of referred pain is crucial to the differential diagnosis of sciatica from compression of a nerve root. The sole objective of conventional disc surgery is to relieve sciatic pain. Kellgren[11,23] (1938) had shown that stimulation of connective tissue can produce pain in areas remote from the actual site of stimulation. One year later (1939) he also showed that the radiation of such pain was less precise than that expected from known dermatomal patterns of sciatic nerve and its mechanical compression. When the nerve root is mechanically compressed, e.g. by a prolapsed disc the pattern of radiation of pain and or paraesthesias is very clear cut as to allow recognition of the level of the lesion from the narration by the patient of his symptoms.

Referred pain can also arise from skeletal structures. This was first shown by Inman and Saunders (1944).[24] Much earlier in 1933, Gormley (cited by Mooney, 1988)[11] had recognized skeletal pain. He had coined the term “Facet Syndrome” when he felt that the pressure on the nerve root was the source of sciatica. Badgley (1941) demonstrated that in referred pain in most cases there is no neurological deficit; that the pain could be relieved by infiltration of local anesthetics in the ligaments or muscles in the back. This was also demonstrated by Kellgren (1939) and Steindler (1948).[11,23]

Much later (1976) Mooney and Robertson[25] injected small amounts of hypertonic saline in the facet joints of patients suffering from backache and healthy volunteers. In both the groups the pain was felt in the buttock (referred pain). There was no sciatica. By increasing the quantity of fluid injected into the joint the referred pain could be made to travel further in the thighs and into the calf musculature.

It is important to understand this concept of referred pain as it is arising many times from sources other than the prolapsed disc. Excision of disc will not produce relief from such pains. If the surgeon is locked into the fallacy that all lumbosciatic syndromes are entirely due to mechanical compression of the nerve root and that decompression of the nerve root will relieve the pain once for all there will be failures.

Spinal stenosis is a common problem. Derangement of facet joints is significantly contributing to the concept of spinal stenosis. Referred pain is common in such conditions and significantly enough many such cases have associated true nerve root compression from narrowing of the lateral recess.

## Facet Joint

Little attention is paid to this joint even in major textbooks of anatomy. While dealing with backache one realizes the extreme importance of this joint as an important element of posterior part of the motion segment and clinically an important contributor to back pain. The joint is formed with two facets coming together.[13]

The superior facet which comes down and posteriorly from the pars interarticularis lies posteriorly. Its anterior or joint surface is not flat but is concave. The inferior facet coming up from the upper surface of the pedicle below lies anteriorly. Its posterior surface or the joint surface is convex and fits snugly with the concave surface of upper facet. The joint formed is a simple synovial joint and the capsule merges imperceptibly with the ligamentum flavum medially. The articular capsule is thin and loose. It is attached just peripheral to the margins of the articular surfaces of the facets. The capsule is most loose in the cervical region. Less loose in the lumbar region and least loose in the thoracic region. The normal laxity of the capsule speaks of the range of motion that is capable in a given region. The range of motion is maximum in the cervical region. Because of the shape of the facets the outer margin of the joint which is so important clinically is neither lateral nor posterior. It can best be seen on the oblique views of X-rays. At times the lateral joint surface is clearly seen on AP X-rays. The facet joint has abnormally rotated. This happens in abnormal motion and it is known as tropism of the facets. It indicates pathology in the joints.

The movements possible in this joint are flexion, extension and rotation. The range of movement at each joint is restricted due to limited range but the summation of these movements from each segment gives a relatively wide range to the vertebral column as a whole.

The earliest pathological change is synovitis. Cartilage destruction leads to instability and subluxation. Hypertrophy of the facets resulting in its thickening causes encroachment on the central and lateral part of the canal. The superior facet following such changes can nearly bisect the canal horizontally with inner edges approaching the midline. The inferior facet following subluxation migrates upwards encroaching on the intervertebral foramen and compressing the outgoing nerve root.

## Facet Joint Syndrome

Facet joint syndrome bears closest resemblance to referred pain. There may be pain in the leg (sciatic or otherwise). The referred pain is worse in the buttocks and radiation distally rarely goes beyond knee joints. When the pain is felt even in the calf muscles as described above it is more diffuse and cannot be accurately related to a specific dermatome.[25]

The facet joint is a synovial joint. Its derangement is associated with local tenderness and morning stiffness. Patient takes time to get out of bed in the morning. But once he is up and about he seems to be all right. Sitting for any length of time is uncomfortable and he keeps shuffling in his chair all the time. At times he prefers to stand than sit. Surrounding soft tissues can also produce similar referred pain but pain from the facet joints is more severe. Extension of the spine is more painful than flexion. Straight leg raising is limited but it is essentially due to pulling sensation in the back that is felt while doing the attention sign.

Derangement in the facet joints is secondary to the degeneration in the intervertebral disc. Degeneration in the disc can be just a normal process of aging. The first cracks in the annulus starts appearing after the age of thirty years. These changes can be spotted radiologically by decreases in disc space, formation of osteophytes or black disc on MRI scan. Consequently changes in the facet joints are responsible for more backache and referred pain in the buttocks than true sciatic pain of prolapsed disc.

Disappointment following surgery sometimes awaits the patient who has a disc prolapse and associated facet joint arthritis when the patient may not get the anticipated benefit from surgery of discectomy.

The expression on the face of the patient walking while in pain gives ample indication about the nature of his backache problem. The patient who shuffles in wincing at every step, but has full straight leg raising is unlikely to have nerve root compression due to prolapsed disc. Inappropriate signs in a patient with severe discomfort may not be always functional. He may be having facet joint syndrome.

Early in process, the radiological finding may reveal minimal changes or even normal. The diagnosis of facet syndrome must be made clinically and is confirmed by the injection of a local anaesthetic into the joint under fluoroscopic guidance.[26]

## Sacroiliac Joint

The anatomical configuration of the sacroiliac joint is such that the joint is extremely stable and not usually subject to many ailments. The inherent stability of the joint is further reinforced by powerful posterior interosseous ligaments and strong accessory ligaments like ileolumbar, the sacrotuberous and the sacrospinous ligaments. Backache due to prolapsed lumbar intervertebral disc is common between the ages of 30 and 50. During this period the anterior capsule of sacroiliac joint is calcified and in many it is ossified adding further stability to the joint. And yet we find that the manifestation of so called sacro iliac joint pain is common. The common finding is of pain over the sacroiliac joint region usually on one side and is usually associated with tenderness over the joint.

Most of the times this is a referred pain from the prolapsed intervertebral disc. It can arise from either 4th or 5th lumbar disc degeneration or prolapse. The pain into the sacroiliac joint is not associated with pain over the pubic symphysis. Ileum has a bucket handle type of joint like ribs anteriorly and posteriorly. Pain in the posterior joint must also be felt anteriorly. True sacro iliac joint pain is also felt anteriorly. Discography of 4th and 5th lumbar discs produces typical sacroiliac joint pain.

## Motion Segment

Junghans in 1932 introduced the concept of motion segment.[11] The spine is made up of several vertebrae. Each vertebra is a piece of bone and is unyielding. The motion is produced by all the structures holding the two vertebrae together. Compounded motion of different segments results in harmonious movements of the spine. Since movement in the spine occurs segmentally between two vertebrae, the structures involved in holding the two vertebrae together constitute the motion segment. The importance of this segment was appreciated by Junghans even before the concept of prolapsed intervertebral disc was known.

The motion segment consists of anterior longitudinal ligament: The intervertebral disc, the intervertebral foramen, facet joints, interlaminar ligamentum flavum, interspinous ligaments and supraspinous ligaments (Fig. 4.14). Each structure mentioned

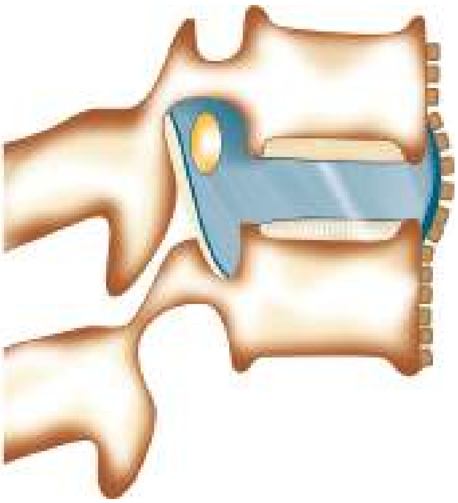


**Fig. 4.14:** The motion segment of the spine: Intervertebral disc; Intervertebral foramen facets; Interlaminar space; Ligamentum flavum; Inter- and supraspinous

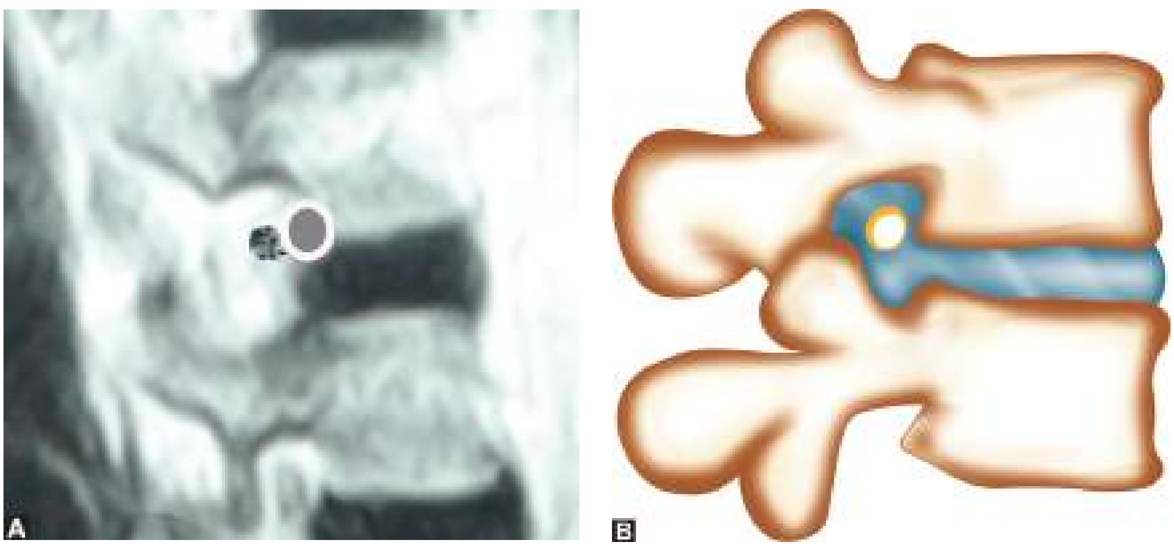
here is capable of contributing motion. It may be noted that the intervertebral foramen is not an anatomical foramen. It is a dynamic foramen formed when the disc and the vertebral bodies anteriorly, the pedicles superiorly and inferiorly and capsule over the facet joint posteriorly. They enclose a space for the nerve root to pass through (Figs 4.15A and B). It is dynamic and capable of motion. Even the slightest stress on one point in the motion segment will produce tension throughout the motion segment. Following degeneration even the slightest (0.2 mm) settlement in the disc space will produce stress on all the structures in the motion segment.

Stress produces abnormal movement and lays the foundation for instability which in turn gives rise to backache with or without sciatica. At first the epiphyseal ring is maximally stressed among all the structures in the motion segment. The outermost fibers of the undersurface of the epiphyseal ring are attanced about 2 mm above the vertebral body edge. The stress is manifested by the formation of the traction spur. The traction spur differs radiologically and anatomically from osteophytes. Arising 2 mm away from the edge of the vertebra it lies horizontally and is small. Its presence signifies instability. A small traction spur is clinically significant as it indicates the presence of instablity. The large traction spurs or osteophytes with at times formation of joint between them indicates that the segment at one time was unstable but now it has become stable with fibrosis. Segmental instability is dangerous. The spine is susceptible to trauma and subluxation can occur easily.

## Normal Functions of the Lumbar Spine

### Intervertebral Disc

The function of the disc is to render the spine flexible, resilient and strong. The disc is a part of the motion segment of the spine. The amount of mobility between each vertebra is small in comparison with the total range achieved and varies with different parts of the spine for different movements. The cervical and the lumbar portions of the spine are more mobile although rotation between lumbar vertebrae is very slight. The annulus provides great strength with some mobility. The nucleus keeps the vertebrae apart and provides a friction free mechanism. It also absorbs shock and its incompressibility enables the disc to transmit force through the axis of the spine. The cartilage plate besides providing nutrition to the disc, also transmits force between nucleus and bone and distributes them over the surface of the bone. It also protects the bone. Thus all parts of the disc play important role in its healthy functioning and the relative




**Figs 4.15A and B:** The intervertebral foramen transmits the nerve root. There is normally ample space in the foramen for the nerve root to be lying very comfortably

amounts of those parts are equally important. Weakening of the structures or failure to maintain relative proportions lead to morbind changes (Northfield 1968).

## Spine

The spine as a whole has important functions to perform. It transmits the weight of the head and upper limbs along with that of thorax to the pelvis. Human erect posture has resulted in increased stress on the lumbar spine and the intervertebral disc. The amount of movement that takes places in the lumbar spine is maximum at lumbosacral junction, the point of maximum weight transmission. This will explain the maximum incidence of the disc prolapse at this level.

The mobility and curvature of the lumbar spine varies with race. The African spine is more mobile than the European (Levy 1967). The spine in Indians and the people of Orient is also more mobile, where most people squat on the floor and do most work by bending forwards (Ramamurthy 1954).

The segmental arrangement of the discs serves as an excellent shock absorber against multidirectional forces. It also permits some tortion of the spinal column. The “S” shaped curvature of the spine helps to transmit forces without much stress. The disc is the largest mobile segment of the spine.

## Normal Movements of the Lumbar Spine

The functions of the lumbar spine are the flexibility of motion, to support the body weight and protect the nervous structures. Degeneration, trauma, tumors, surgery, etc. may potentially produce unstable conditions in the spine leading to backache and sciatica. Abnormal motion is a classical sign of instability.[10] For evaluating abnormal motion it is necessary that the normal movements of lumbar spine are known.

Lumbar spinal movements have been studied *in vitro* on cadaver spines, clinically on normal human beings without backache and finally radiologically using X-rays or computer assisted study motion (Fig. 4.16).

Left lateral bending; Right axial torque; Left axial torque.

Three motion parameters have been defined as:

*Neutral Zone (NZ):* This is the displacement at zero load point from neutral position. Represent the portion of the ordinary physiologic motion, which motion is produced with little internal resistance.

*Elastic Zone (EZ):* Extending from the end of the neutral zone up to the end of physiologic loading. This is still part of the physiologic loading of the structure.[27]

*Range of motion (ROM)* is the displacement from neutral position to maximum load point.

Clinically, the neutral position is difficult to define.

It is possible *in vitro* to study under experimental condition pure forms of movements. What is clinically important the three dimentional movement which occurs in the spine normally. Unfortunately, the three dimensional movements of the whole lumbar spine have not been studied systematically *invitro*.

Besides more natural movements of the spine include lumbar lordosis and the integrity of the ligaments. Representative values of lumbar motion were studied by Pearcy[3] by using the technique of stereoradiography.

Normal movements at each level are shown in the accompanying diagram.

The range of motion in the lumbar spine is influenced by such factors as age and degeneration (Table 4.1). Progressive decrease in range of motion with age has been demonstrated by Quinnel.[28]

Figures obtained clinically have large variations. The reason being the load distribution may be different in different individuals. Using different methods is also the cause of large clinical variation.

**Table 4.1:** Range of motion: Mean values in degrees of range of motions (ROM) of the lumbar spine (Punjabi et al. 1994)

| Level | Flexion-extension | Axial rotation | Lateral bending |
|---|---|---|---|
| L1/2 | 10.1 | 2.1 | 4.9 |
| L2/3 | 10.8 | 2.6 | 7.0 |
| L3/4 | 11.2 | 2.6 | 5.7 |
| L4/5 | 14.5 | 2.2 | 5.7 |
| L5/S1 | 17.8 | 1.3 | 5.5 |

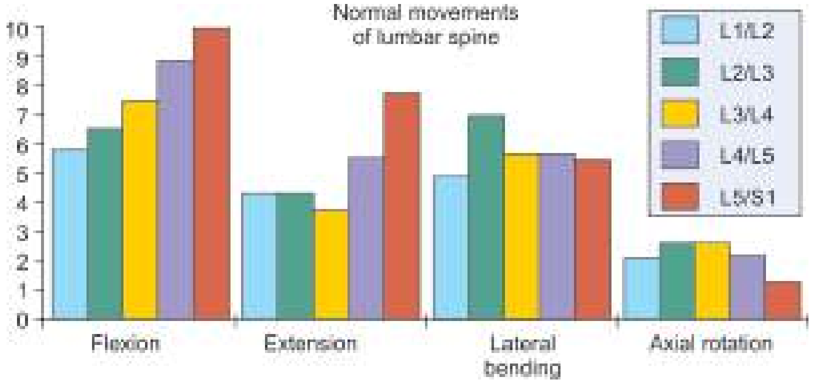



**Fig. 4.16:** Normal ranges of motions of the lumbar spine obtained from fresh cadaveric lumbar spine specimens due to application of 10 nm of moments

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# 5

# Microanatomy of Degenerative Disc Disease

*Wolfgang Rauschning, Benjamin Hoch*

## Introduction

The cascade of lumbar motion segment degeneration includes internal disc disruption, disc dysfunction due to the delamination of the annulus fibrosis, and also slackening and incompetence of the outermost annulus, longitudinal ligaments, inter- and supraspinous ligaments and instability–subluxation of the facet joints, all reflecting the dysfunction of the spinal segment. In the early stages of degenerative disc disease (DDD), these stabilizing structures are anatomically intact, although relaxed, and therefore not functioning properly due to altered mechanics and insertion sites.

Intradiscal therapy and genetic engineering with the aim of decelerating, halting or even reversing this degenerative cascade, such as disc cell culture injection, may become alternative to fusion surgery. The biological acceleration of fusions would appear to be an alternative option. The problem with such biological options, however, is the deleterious impairment of the segmental spinal mechanics that exerts enormous forces on the stabilizing anatomical elements.

In degenerative disc disease, the impairment of nutrition pathways into the disc and the inability of the disc to dissipate toxic metabolic products create an extremely hostile intradiscal environment with low pH, the formation of protease, cytokinins, prostaglandins, hypoxidity, dehydration, loss of proteoglycans and thereby turgors (swelling pressure). This toxicity leads to irritation of the fine nociceptive nerve endings which over the age of 50 penetrate the miniscule crevices of the endplate which thereby becomes painful. The toxic environment also causes the necroptosis of the disc cells. Disc cell cultures injected into the degenerated discs have a rather limited number of life cycles. It therefore has been stated that biochemical and biological treatment should be complemented with the mechanical measures that restore some of the normal kinetics and biomechanics of the motion segment.

In early stages, the internal disruption of the disc and early endplate changes reflect the disturbance of fluid transport through the endplate, and also a disequilibrium between the intradiscal and the intravertebral-intraosseous pressure. In subsequent stages, the crosslinkages between the annular collagen lamellae are progressively broken by a combination of malnutrition and mechanical attrition. Later stages of the disease encompass gross delamination of annular lamellae, sometimes with vacuole formation and the separation of the inflamed outermost annulus fibrosus from the remainder of the disc.

When tears of fissures sever the outermost annulus fibrosus, blood vessels are sprouting into the disc, frequently accompanied by nociceptive pain fibers (neovascularization). Larger and long-standing annular tears are typically sealed by a callus-type cellular granulation tissue which is richly vascularized and innervated. This granulation tissue is the pathoanatomical substrate of the high intensity zone (HIZ) that is frequently observed in the posterior central portion of degenerated discs on MR scans of patients complaining of nondermatomal (mechanical) low

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back pain, discogenic pain, but also in subjects without any such symptoms at all. Endoscopic and other minimally invasive treatment options for the various stages of DDD are discussed along with the pathoanatomical changes.

In the lumbar and lumbosacral spine, the cascade of DDD is demonstrated in view of currently available surgical treatment options. The pathoanatomy of low back pain and radiculopathy is mirrored against current treatment options, ranging from chemonucleolysis, percutaneous disc ablation, a variety of laser disc ablation options, coablation and IDET to hydrogel nucleus prosthesis, PDN, a wide array of fusion techniques such as cages for PLIF and ALIF applications, femoral ring and precision crafted allograft fusions, and artificial disc prosthesis. As an intriguing alternative, the concept of neutral dynamic distractive stabilization of the lumbar spine in painful mechanical instabilities and spinal stenosis in younger patients must be considered.


**Fig. 5.1:** Thoracolumbar vertebra at midpedicle level, composed of tan-red cancellous bone with interconnecting trabeculae (B), anteriorly covered by thick anterior longitudinal ligament (L), venous channels traversing vertebral body and cortical bone posteriorly (V)

**Fig. 5.2:** Closer axial view, thecal sac displayed at level of outpouchings of dura, bounded by the dorsal sublaminar veins and more prominent ventral internal veins

The senior author also conducted a cadaveric experimental study pertaining to posterior percutaneous or endoscopic surgical approaches to the intervertebral discs. The study clearly showed that any uni- or biportal approach to the lower lumbar spinal discs carries potential risk for injury or violating blood vessels or neural structures, in particular, the delicate dorsal root ganglia.

## Uppsala Cryoplanning Technique

Sectioning frozen and undecalcified spine specimens creates sequences of highly detailed anatomical images in perfect pin registration. Each section is a few micrometers thick, trimmed from the frozen and embedded tissue block. The anatomy of spinal structures is undistorted because the spatial relationships of soft tissues to the vertebral columns are fixed. Each slide is presented in natural colors and texture to provide exquisite clarity and detail.

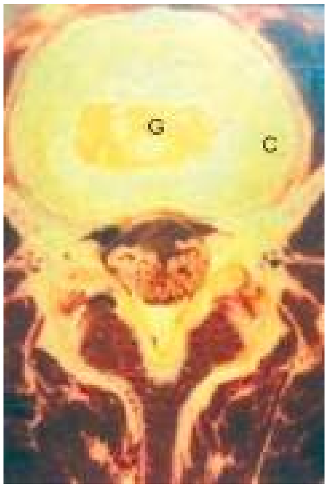



**Fig. 5.3:** Cross-section from young adult with gelatinous disc (G) and collagenous fibers of annulus beginning to replace nucleus as evidenced by increased tan collagenous tissue (C)


**Fig. 5.4:** Central canal bounded by disc (D) anterolaterally and thickened ligamentum flavum (L) posteriorly attached to the facet joint capsule and contributing to spinal stenosis


**Fig. 5.5:** Cross-section through lumbar spine. Note normal relationships between inferior articular process of facet (I), ligamentum flavum, and central canal, and relationship between superior articular process of facet (S), ligamentum flavum, and root canal

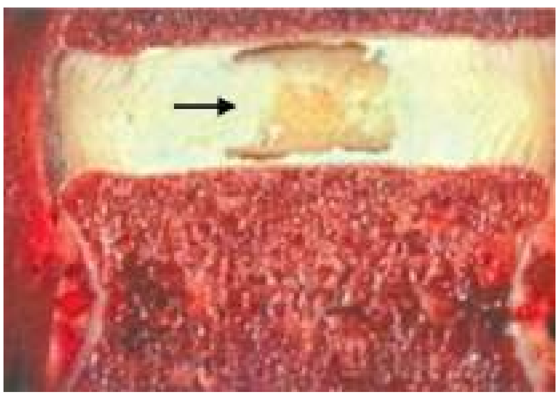


**Fig. 5.6:** Coronal section through intact disc of normal height. Note circumferential collagen fibers of annulus appearing as uniform parallel arrays and partial replacement of the nucleus with collagenous tissue (arrow) that lacks architecture of outer annulus

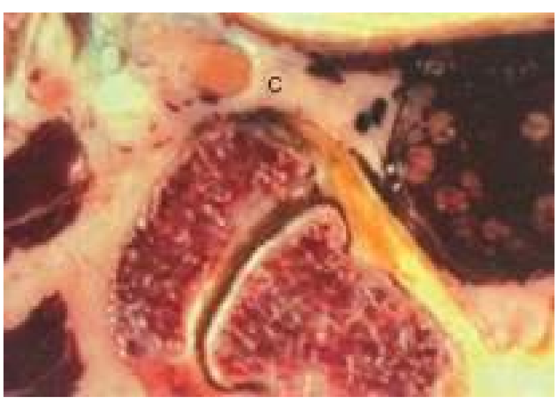



**Fig. 5.7:** Closer view of facet joint with minimal degenerative changes, articular cartilage varied in thickness but intact, root canal (C) bounded by posterolateral disc anteriorly and superior articular process and attached ligamentum flavum posteriorly

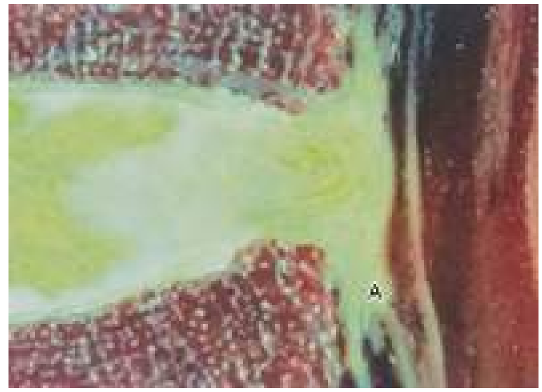



**Fig. 5.8:** Posterior longitudinal ligament attached to disc near insertion of annular fibers beyond the apophyseal ring (A). Note endplates are normally of uniform thickness


**Fig. 5.9:** The nucleus pulposus (N) compressed with marked extension of the spine


**Fig. 5.10:** Insertion of disc seen adjacent to the ventral venous plexus (V). Note trabecular bone of vertebral body and red marrow are well visualized

**Fig. 5.11:** Relationships between posterior longitudinal ligament, annulus, and venous plexus are demonstrated with bulging of the disc in extension


**Fig. 5.12:** Sagittal section of normal lower lumbar spinal column. Note large venous vascular foramen at midportion of posterior cortex of vertebral bodies of L4 (V) and at this foramen communication between veins of vertebral body and ventral internal venous plexus


**Fig. 5.13:** Sagittal section displaying slight posterior convexity as outermost fibers of annulus attach beyond apophyseal ring. Note ligamentum flavum attaching to lamina superiorly along sharp ridge (R) and thinning at lumbosacral level compared to sections above

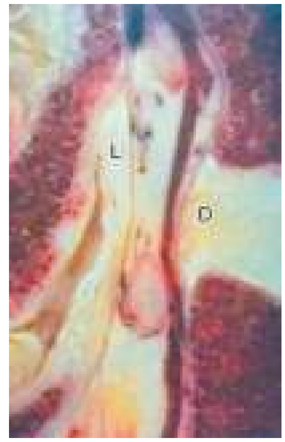



**Fig. 5.14:** Closer view of contours of lateral recess composed of posterior concavities of vertebral bodies, posterior convexity of disc (D), and sloping border of opposing ligament (L)


**Fig. 5.15:** Sagittal section showing segmental root bundles (R) converging towards each intervertebral foramen. Discs show little or no gross degenerative changes, and ligamentum flavum is very thin at posterior arch equivalents of the first and second sacral segments

**Fig. 5.16:** Magnified ventral internal plexus within vertebral concavity showing relation between posterior aspect of disc, flat contour of ligamentum flavum, and nerve root bundles


**Fig. 5.17:** Traversing nerve root normally passes through channel formed anteriorly by posterolateral aspect of disc and posteriorly by ligamentum flavum; with degeneration, disc bulges posteriorly and ligamentum flavum thickens, narrowing lateral recess for nerve root (R)


**Fig. 5.18:** L5-S1 and L4-L5 discs demonstrate early degenerative changes characterized by internal disruption of disc as irregular pattern of buckling annular collagen fibers and central depressions in endplates (D). Note laminae are oriented posteroinferiorly


**Fig. 5.19:** With relatively normal disc height, lumbar neuroforamina are fairly voluminous (N). Note early degeneration of facet joint (F), but no significant impingement on nerve

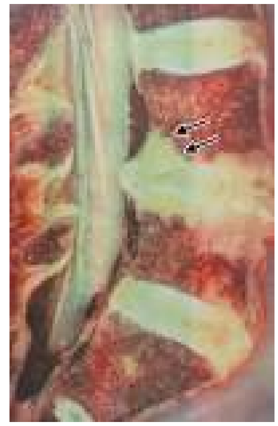


**Fig. 5.20:** Disc disruption. Note extension of endplate cartilage into sclerotic subchondral bone, anterior rim osteophytes formation, and posterior bulging of the disc characterizing degeneration of this L4-L5 segment (arrows)

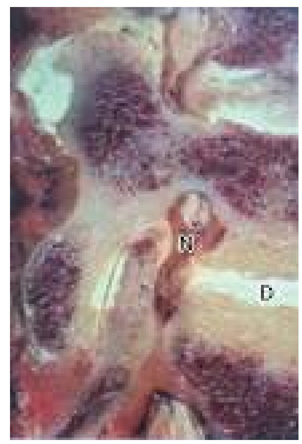



**Fig. 5.21:** Lumbar disc almost completely resorbed (D), loss of height results in subluxation of facet joint contributing to compression of neuroforamen (N) and thinning of cartilage

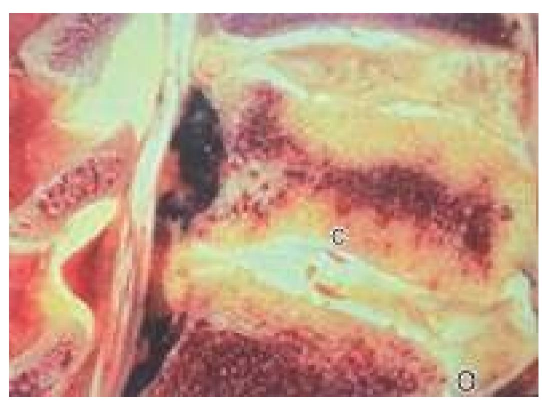



**Fig. 5.22:** Central cleft (C) has formed in degenerated disc. Disc material has extruded posteriorly and there is anterior osteophyte (O) growth as the disc protrudes anteriorly


**Fig. 5.23:** Traversing root compressed by rotation induced retrolisthesis of L4 on L5 causes disrupted disc (D) to move posteriorly. Medial aspect of L5 superior facet (F) moves anteriorly and compresses L5 root. Posterior osteophyte (O) and hypertrophied ligamentum flavum (L)


**Fig. 5.24:** Section of lumbar vertebra showing narrowing of canal by posteriorly extruded annulus (A) compressing nerve root against thickened ligamentum flavum and joint capsule


**Fig. 5.25:** L5-S1 foramen showing loss of disc with juxtaposition of endplates and thick white-tan subchondral bone (B), outer annular layers of remaining disc extruded posteriorly into root canal, dorsal root ganglion abutting pedicle (P), loss of disc height resulting in subluxation of facet, osteophyte growth (O) on superior facet eroding into pars interarticularis


**Fig. 5.26:** Lumbar spine at level of pedicle. Disc retains normal texture of lamellae of lateral annulus. Subpedicular notch contains nerve root and associated vascular structures (V). Foramen is bounded by bone superiorly, ligamentum flavum posteriorly, and disc inferiorly


**Fig. 5.27:** Sagittal section through L4-L5 spinal segment. Disc is disrupted with horizontal cleft formation (C) and loss of height. The lateral recess is obliterated by the bulging outer annulus and thickened ligamentum flavum

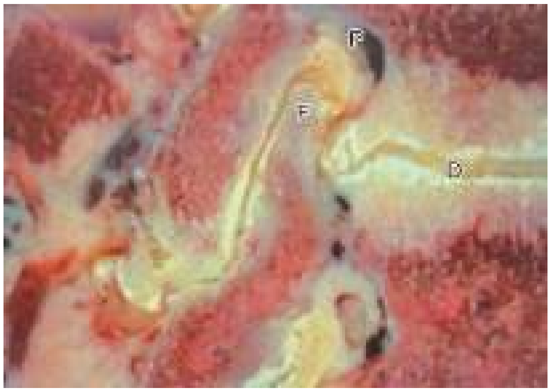



**Fig. 5.28:** L4-L5 spinal segment showing more severe degenerative changes. Disc (D) has become thin band of myxofibrous material. L4 pedicle (P) drops down upon nerve root producing stenosis along with osteophytic superior facet (F) of L5 impinging on canal from below


**Fig. 5.29:** Section of L5 body demonstrating large foraminal herniation of L5-S1 disc (D). The herniation displaces and flattens L5 dorsal root ganglion (G) laterally and superiorly

**Fig. 5.30:** Closer view of herniation (arrows) which may be seen in isthmic spondylolysis

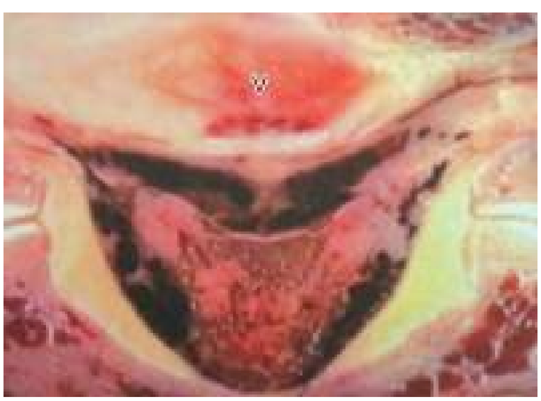



**Fig. 5.31:** As the disc ruptures posteriorly, reparative fibrous tissue and neovascularization surround the disc, grossly seen as red-pink areas due to number of vessels present (V)


**Fig. 5.32:** Severely degenerated facets showing thinning of articular cartilage and marked peripheral osteophyte growth producing, ball-and-socket configurations (B) with enlargement of inferior (I) and superior (S) articular processes and narrowing of central canal

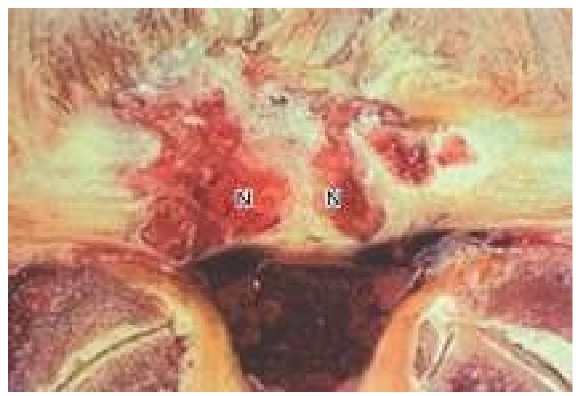



**Fig. 5.33:** Closer view of previous section. On both sides of midline, irregularly lobulated red-tan areas of peripheral neovascularization (N) at sites of clefts and defects in annulus

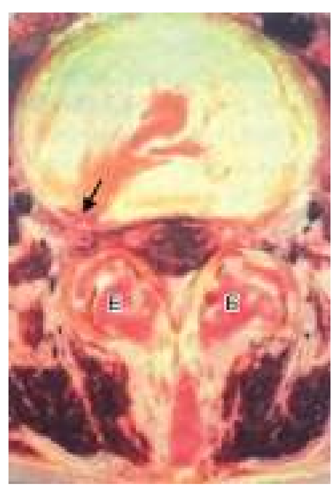



**Fig. 5.34:** Loss of most of articular cartilage of facet with effusions (E). Nucleus pulposus material has protruded laterally (arrow) through disrupted annulus

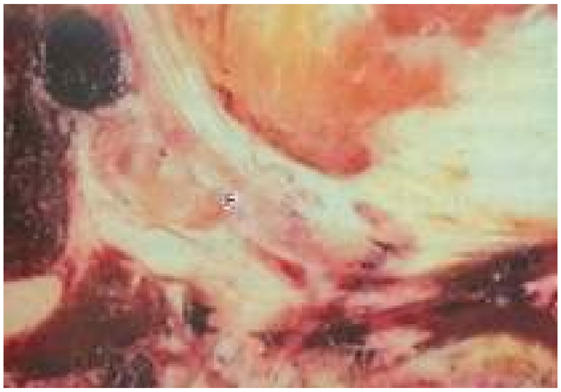



**Fig. 5.35:** As nucleus protrudes outward laterally, there is surrounding compressed annular fibers and reactive fibrovascular tissue (F), all of which compress the nerve root

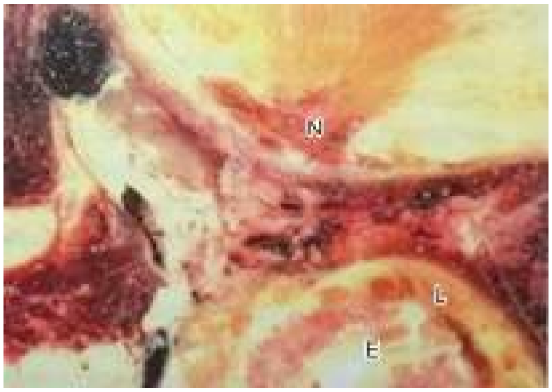



**Fig. 5.36:** Closer view of previous section showing neovascularization (N) around laterally bulging disc, degenerated facet with effusion (E), and thickened ligamentum flavum (L)

# 6

# Natural History of Degenerative Changes in Lumbar Spine

*S Phanikiran, K Sridhar*

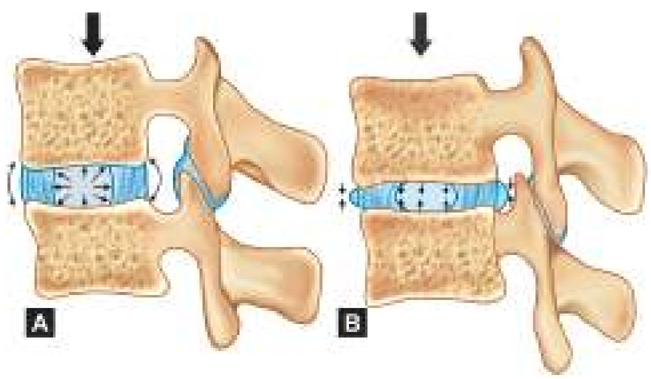
## Introduction

Understanding the factors involved in the evolution of the disease process is imperative for an early and accurate diagnosis and developing better treatment modalities. There has been a tremendous progress in the understanding of the pathophysiology of degeneration of the intervertebral disc over the last two decades. Magnetic resonance imaging (MRI) based studies over the past decade have improved the understanding of the degeneration process of the disc and its clinical implications.

The following pages are written in an attempt to put into correct perspective what is known or suspected about the degenerative process in the lumbar spine. Although natural phenomena occurring during life do have an effect on the degenerative changes in the lumbar spine, genetic components have been shown to have a strong influence on disc degeneration over the past decade.

## Relevant Anatomy

The intervertebral disc consists of a gelatinous nucleus pulposus in the center surrounded by lamellar collagen fibers of the annulus fibrosus. The nucleus pulposus acts as a fluid-filled balloon which tends to expand outwards in a horizontal plane under compressive load and is responsible for dissipating the compressive forces on the disc by exerting a hydrostatic pressure on the annulus fibrosus. The annulus fibrosus resists this expansion of the nucleus by tensile stress and transfers the load to the lower endplate[1] (Fig. 6.1A).




**Figs 6.1A and B:** (A) The nucleus pulposus acts as a fluid-filled balloon. The annulus fibrosus resists expansion of the nucleus pulposus by tensile stress and transfers the load to the lower endplate; (B) Degeneration leads to bulging of the annulus under axial compression and also stimulates formation of osteophytes

The annulus fibrosus consists of up to 70 percent (percent dry weight) of collagen type I and II whereas the nucleus pulposus only contains 20 percent of collagen. On the other hand, the nucleus pulposus consists of up to 50 percent of proteoglycans (percent wet weight), whereas the annulus fibrosus only contains 20 percent proteoglycans.[2]

The major proteoglycan in the disc "aggrecan", which forms 70 percent of dry weight of the nucleus and 25 percent of dry weight of the annulus, helps in maintaining the swelling pressure in the disc by attracting and retaining water within the matrix.[1] The most significant biochemical change that is noticed in the degeneration of disc is the loss of the proteoglycans. The nutrition for the chondrocytes within the disc is through diffusion from the capillaries originating in the vertebral bodies, terminating just above the cartilaginous endplate. The outer layers of the annulus of each disc are innervated by the fibers of sinuvertebral nerves arising from the ventral ramus at that level and the level below.

A functional spinal unit (FSU), described by Schmorl and Junghanns is the smallest mobile segment of the spine consisting of two adjacent vertebrae and the intervertebral disc, facet joints and the intervertebral ligaments that connect them. In a normal FSU, eighty percent of axial load is transferred through the anterior structures while the facet joints bear the rest of the 20 percent load.[2,3]

## Etiology and Pathogenesis of Disc Degeneration

### Disc

At birth, the nucleus pulposus is gel-like substance in which notochordal type cells are suspended in a ground substance made up of a mesh work of collagen fibrils and protein polysaccharide complexes. It contains 88 percent water. The highly negatively charged proteoglycans are crucial in maintaining the hydration of the disc. As age advances, drying process starts and disc loses water. There is significant loss of mucopolysaccharides as age advances and gradual increase in noncollagen glycoprotein.[4] Collagen types I, III, V and VI are components of the normal annulus fibrosus, and the normal nucleus pulposus contains collagen types II, IX and XI. While the overall collagen content in the nucleus pulposus remains fairly constant over the years that of the annulus fibrosus decreases with advancing age. Matrix metalloproteinases (MMPs) and aggrecanases are the enzymes that play a major role in matrix degradation.[2,5] These changes in the disc contents occur due to various factors:

1. *Genetic effects:* Recent studies point towards a strong influence of genetic factors on the disc degeneration. Polymorphisms of the vitamin D receptor gene, aggrecan gene or the matrix metalloproteinase gene and mutations of collagen genes have been implicated. These genetic defects, in presence of other environmental factors, eventually lead to changes in disc matrix, disc function and result in degeneration of the disc.[6-10]
2. *Age and gender:* Great variability in degenerative findings exists within age groups. With respect to gender, degenerative changes in women appear to lag behind those found in men by approximately ten years. Aging will lead to degenerative changes starting with subtle biochemical alterations followed by microstructural and finally gross structural changes of the spinal unit, the end result being degenerative disc disease (DDD).[5]
3. *Failure of disc nutrition:* Any time after the age of 25 years, the cartilaginous endplate starts getting mineralized and by the age of sixty only a thin layer of bone separates the disc from the vascular channels which were in contact with cartilage before.[11,12] The walls of the vascular channels also become thick as a result of atherosclerosis. With mineralization of the endplates the nutrition of the disc suffers and chondrocytes are exposed to low $pO_2$, low glucose concentrations and low pH due to higher lactic acid production. The ability of the disc cells to synthesize and maintain matrix components is impaired and the disc starts degenerating. Altered metabolism triggers a proinflammatory cascade, which involves cytokines like TNF-α, interleukin-1β, interleukin-6 and prostaglandin-E2. These cytokines along with agents like NO, substance-P, lactic acid and other waste products sensitize the nerve endings in the annulus and produce back pain.[2,13]

   Smoking has been implicated as a factor for degenerative low back pain in many epidemiologic studies. It has been shown to adversely affect the microcirculation feeding the disc. Sickle cell anemia, Gaucher's disease and Cassion's disease affect the blood supply to the vertebral body and lead to significant increase in disc degeneration.[1]
4. *Abnormal mechanical loads:* Studies by Nachemson and Morris on intradiscal pressures on L3-4 disc showed that sitting pressures are greater than standing pressures and that while sitting or standing with 20 degrees flexion, the pressure is about 200 percent of total body weight.[14] Repetitive torsion stresses, associated with rotation and bending have been shown to cause maximum deformation of the annulus. Eventually, the annulus develops tears and there is a prolapse of the nucleus pulposus through the tear. Although heavy physical work, driving, weight-lifting have been implicated as risk factors, the recent MRI based studies shown that they have little influence on the pattern of disc degeneration. In a large population-based study, Samartzis D et al. have found that individuals with an elevated BMI values indicating being overweight or obese had a greater extent and increased global severity of degenerative disc disease.[15]

### Bone of the Vertebra

As a natural process of aging, there is loss of bone. For both sexes gradual loss of bone of 3 percent per decade can be expected. In women after menopause a 9 percent decrease in cortical bone has been demonstrated. After the third decade of life, a 6 to 8 percent bone loss can be expected for both sexes. These changes weaken the load bearing capacity of the spine. This decreases to about 35 percent after the age of 40. Bone strength decreases more rapidly than bone quantity. This happens because of loss of vertically oriented trabeculae. Endplates then bend away from the disc and develop endplate fractures. Thinning and microfractures of the endplate lead to rapid exudation of fluid from the cartilage endplate on loading, making the hydrostatic pressure mechanism ineffective and causing nonuniform loading of the annulus.[16]

### Sequelae of Disc Degeneration

At any level of a functional spinal unit, the motion segment is made up of three joints, the intervertebral disc and the two facet joints. The three joints are anatomically linked and mechanically balanced so that any stress or trauma to one joint will automatically spread to the other two joints through changes in the mechanical behavior of the construct.[11]

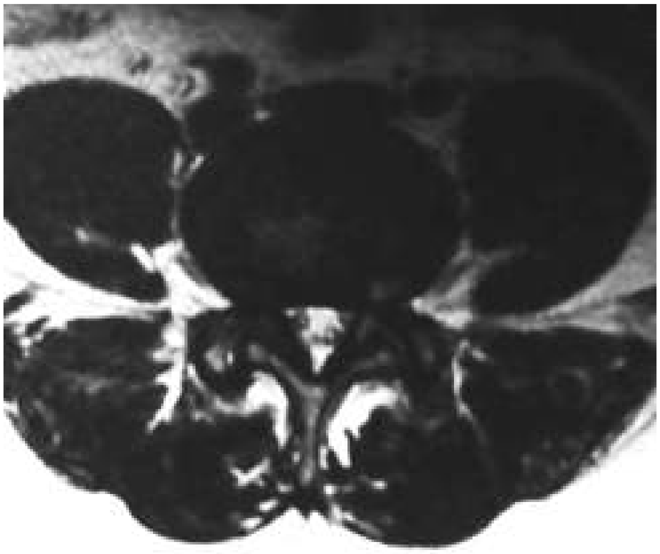


**Fig. 6.2:** Degeneration leads to facetal arthritis, ligamentum hypertrophy and canal stenosis

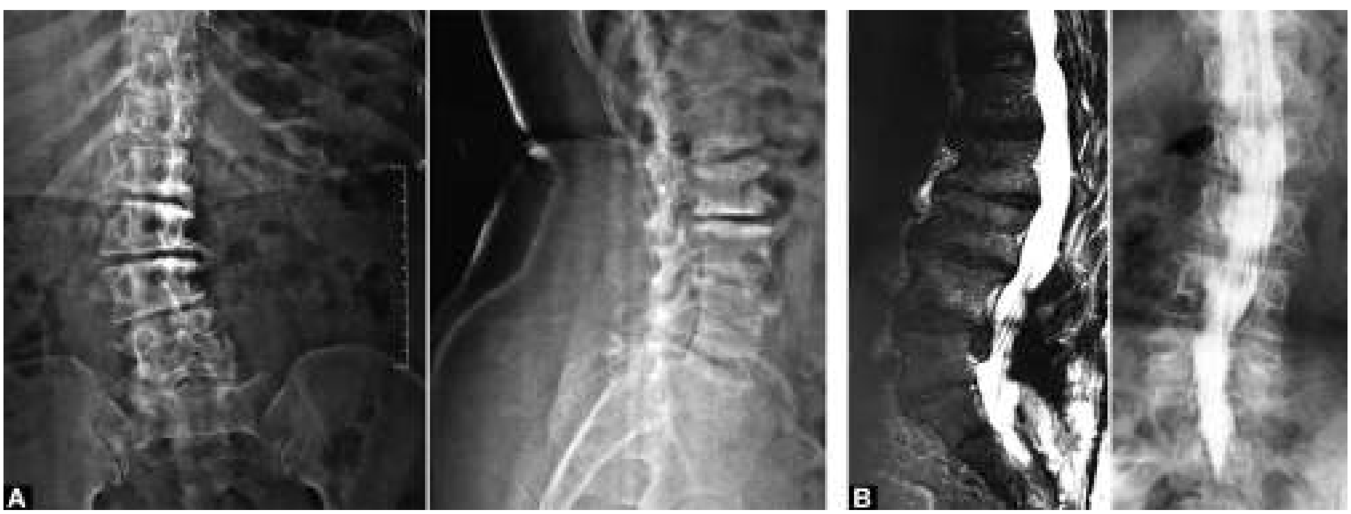
Degeneration in disc is the harbinger of the other degenerative changes in spine. As the nucleus pulposus loses the turgor and the ability to transfer the load, the annulus is subjected to abnormal axial loads, leading to formation of cracks and fissures in the annulus. This leads to bulging of the annulus under axial compression and also stimulates formation of osteophytes (Fig. 6.1B) The reduction of disc height results in abnormal loading characteristics of the facet joints and loss of competency of the joint capsule. It has been shown that a 0.2 mm settlement of the disc will cause stress in the facet joints. Facetal arthritis, hypertrophy and ligamentum flavum thickening eventually ensue leading to canal stenosis (Fig. 6.2).

Facet joint arthritis and disc space narrowing may also lead to subluxation of the facet joints and abnormal mobility causing instability and anterolisthesis or retrolisthesis of the upper vertebra over the lower one at that segment (Figs 6.3A and B). Degenerative spondylolisthesis causes a dynamic lumbar canal stenosis as the vertebra slips forward in upright position. Degeneration involving multiple levels with asymmetrical collapse of the disc space may lead to degenerative scoliosis of the lumbar spine[17] (Figs 6.3A and B).

Recent studies have shown the presence of nociceptive nerve fibers in the annulus and inner nucleus of the degenerated disc. Annular fissures allow ingrowth of blood vessels and nerve fibers into the degenerated disc making it pain sensitive. The nucleus pulposus may prolapse posteriorly through the annular tears, bulging or extruding into the spinal canal causing radicular compression. Even though mechanical compression itself does not cause severe radicular pain, the inflammatory response produced by the cytokines like TNF-$\alpha$, interleukin-1$\beta$, interleukin-6 and prostaglandin-E2 sensitize the nerve root and the dorsal root ganglion causing severe radicular symptoms.[1,18]

## Phases of Degeneration

Human tissue has its own potential for healing. When a joint becomes unstable the nature tries to stabilize it by increasing the surface area of the joint or by immobilizing the joint by natural process of muscle spasm. If the extent of tissue damage is severe as to exceed the local healing potential, then degenerative changes will set in. In the first phase when there is trauma to the joint and the natural healing powers are competent then the behavior of joint function will return to normal after some time. Severe or repeated trauma can cause permanent damage and will push the motion segment into the phase of instability. Normal biomechanical function prevents abnormal motion by tissue restraints. Due to excessive degeneration, when the natural restraints by capsule of the joints, the ligaments and the muscles cannot stop the abnormal motion then the phase of restabilization starts when osteophytes form around the three joints and increases the load bearing surface and decrease the




**Figs 6.3A and B:** Degeneration leads to instability of the joints leading to varying degrees of listhesis and scoliosis

motion. The motion segment becomes less painful but it becomes stiff. Joint response of spine is the same as elsewhere. Depending on if the capsule or the synovial membrane or the cartilage or bone is damaged the reaction starts. Early joint response is synovitis. Chronic synovitis and joint effusion stretches the capsule. The synovial membrane undergoes hypertrophy and forms folds, which get entrapped in the joint and initiate cartilage degeneration, which in turn causes damage to the bone.

The nature tries to restabilize the unstable disc by forming osteophytes around facet joints and traction spurs along disc margin. The facet joint enlarges both in the ventral as well as dorsal aspect. This process does stabilize the joint but it produces the complication of lateral recess stenosis. Disc herniation is also found during the phase of instability and in the same phase degenerative spondylolisthesis occur when laxity predominates in the posterior restraining ligaments and retrolisthesis when laxity predominates in the disc itself. Degenerative thickening in the facet joints at multiple levels can lead to lumbar canal stenosis. Degeneration in the disc also leads to coronal orientation of the facets presumably an act of restraint to stop abnormal motion in the functional segment. Coronal orientation by itself leads to narrowing of the lateral recess.

The protrusion of the disc into the spinal canal was first described by Luschka just as rupture of disc into the vertebral body was described by Schmorl.

The degenerative process of the spine has been divided into three phases by Kirkaldy-Willis and Farfan:[19]

1. *Dysfunction:* In this phase, the disc develops radial and circumferential tears and the facet joint develops synovial reactions and cartilage degeneration. Clinical manifestations in this phase include those of disc herniation and facet syndrome.
2. *Instability:* With advancement of degeneration, disc space narrowing and internal disruption develop. The facet joint capsular laxity and subluxation develop causing degenerative spondylolisthesis and dynamic stenosis.
3. *Stabilization:* Instability stimulates osteophyte formation in the vertebral bodies and the facet joints, which tend to stabilize the segment and cause stiffness. There is increased narrowing of the disc space leading to buckling of the ligament flavum and foraminal stenosis. The lateral recesses and central canal become stenotic causing neurogenic claudication.

## Clinical Manifestations

### Low Back Pain

Low back pain caused by disc degeneration has become a significant medical and social problem only recently it has been found that 59 to 65 percent of all people have suffered from low back pain (LBP) at some time. The proportion increases to 80 percent in manual laborers but 90 percent of low back attacks are of short duration. However, 60 percent of people having once experienced LBP will suffer from further attacks later on. Only 1 percent of LBP becomes chronic.[20] The two main entities causing discogenic back pain are internal disc disruption (IDD) and degenerative disc disease (DDD).[1]

**Fig. 6.4:** Dark disc an early indicator of disc degeneration

Internal disc disruption was a term coined by Henry Crock, who defined it as a painful increase in biologic activity of the intervertebral disc after injury in patients with normal radiographs, CT scans and myelograms but with abnormal discograms. MRI shows a dark disc with normal height, with no herniation or prolapse (Fig. 6.4).

There is no radiologically demonstrable instability in IDD. Concordant back pain on discography is necessary to make a diagnosis of IDD. The usual presentation is in a younger patient, between 20 and 50 years of age with chronic low back pain without radiculopathy. They often have sitting intolerance and aggravation of pain on forward flexion, and when rising from flexed position.

Degenerative disc disease presents in relatively older age group with chronic persistent low back pain, with radiation to buttocks and posterior thighs as a referred pain. The pain worsens on prolonged walking or standing. Radicular pain may be present in patients with disc prolapse or foraminal stenosis due to osteophytes and disc space narrowing. Lumbar canal stenosis may present with claudication type of leg pain. The natural history of DDD is yet to be clearly established as there are a high percentage of asymptomatic individuals with radiological features suggestive of DDD.

### Natural History of Prolapsed Intervertebral Disc

The natural history of sciatica is generally benign. In most cases, an acute episode of sciatica takes a brief course, normally followed by a subacute or chronic period of residual symptoms. Most patients recover within 1 month, but the recurrence rate is approximately 10 to 15 percent. In most patients with an extruded or sequestered herniation, the symptoms disappear with the herniation within a few weeks or months.

Studies comparing operative treatment and nonoperative treatment for symptomatic disc herniation show that the results of surgery are better at 1 year follow-up but with a longer follow-up of 5 years and 10 years, the results were similar in both groups. This suggests that the benefits of surgery for symptomatic disc prolapse are better in the early period.

The prolapse of the intervertebral disc in the lumbar region is most frequently found at the lowest two levels in 90 percent of the cases. In a series of 400 patients of one level disc prolapse in the lumbar region, the highest incidence as shown in the table was found at the level of L5/S1 or 5th lumbar disc prolapse.[21]

The frequency of disc prolapse is less at the level of L3/4 but not rare. It is more common in the elderly than in the young people. Disc prolapse at L2/3 level is not uncommon and in all the four cases of L1/2 disc prolapse, recent history of trauma in middle-aged patients was available. Not included in the above series but encountered at the same time were 18 percent of the cases with two level disc prolapse. Of them 4th lumbar disc prolapse was associated with 3rd lumbar disc prolapse in 3.5 percent of the cases and in all of them, there was significant evidence of spinal stenosis.[21]


**Fig. 6.5:** Modic type 1 changes seen on MRI

## Natural History of Lumbar Canal Stenosis

The patients with congenital lumbar canal stenosis present in their 30s and 40s whereas those with degenerative spinal stenosis present in their 50s and 60s. Low back pain is present in 65 percent of the patients and leg pain is reported in 80 percent of the patients. Studies on the nonoperative management of lumbar canal stenosis show that the disease follows a benign and protracted course. Over the long-term, the disease causes slow deterioration as the degeneration of the motion segment progresses causing a worsening of the stenosis. Thirty to fifty percent of patients treated nonoperatively in various studies showed improvement, especially those with mild or moderate symptoms. Patients with severe stenosis, with a complete block on myelogram did poorly with nonoperative management and surgical treatment has been suggested as a better option in them.[21] Severity of pain, motor strength and the degree of disability affecting the quality of life should be considered while determining the mode of treatment. A meta-analysis on natural history of degenerative spondylolisthesis revealed that 32 percent patients showed symptomatic improvement without treatment. There was no correlation between progression of slip and clinical deterioration.

## Role of MRI

The use of MRI has resulted in a significant advancement of the understanding of natural history of the degeneration of lumbar spine. As it is based on the proton density of the tissues, it allows the determination of disc hydration as well as annular tears. Loss of disc hydration is an early indicator of degeneration and can be identified as a "dark disc" on the T2-weighted images (Fig. 6.4). Annular tears are identified as a high intensity zone on spin-echo T2-weighted images, usually in the posterior annulus (Fig. 6.4). The annular tears can be concentric, radial or transverse.

MRI based grading systems of degenerative changes in the intervertebral disc have been developed and used in the recent studies. Pfirrmann et al. examined and characterized intervertebral disc pathology using MRI and the degree of disc degeneration were graded I through V.[22] Schneiderman et al described grading for disc degeneration on T2-weighted sagittal magnetic resonance images of the lumbar spine.[23]

| *Grade* | *Description* |
|---|---|
| Normal | No signal changes |
| 1 | Slight decrease in signal intensity of the nucleus pulposus |
| 2 | Hypointense nucleus pulposus with normal disc height |
| 3 | Hypointense nucleus pulposus with disc space narrowing. |

Modic et al. have described the stages of endplate changes associated with disc degeneration on the MRI. Stage 1 represents endplate edema and appears as decreased signal intensity on T1 and bright signal on T2 images (Fig. 6.5).

Stage 2 indicates fatty degeneration in the bones adjacent to endplates and appears as bright signal intensity on T1 images and intermediate signal on T2 images. Stage 3 changes indicate advanced degeneration with endplate sclerosis and appear as hypointense signal on both T1 and T2 images.[24]

# Conclusion

Although a significant advance has been made in the last two decades in understanding the processes involved in degeneration of the intervertebral disc, the natural history of degenerative disc disease still remains unclear to a great extent. The lack of long term randomized studies in the literature is a major drawback in establishing the natural history of disc prolapse, lumbar canal stenosis and degenerative spondylolisthesis. Most of the conclusions are based on the results of nonoperatively treated groups in existing comparative studies evaluating surgical versus nonsurgical treatment. Understanding the natural history of disc degeneration and its manifestations has become very important in the context of evaluation of the results of various spinal fusion techniques, resolving the issue of adjacent segment degeneration after fusion and the results of newer techniques like dynamic stabilisation methods and disc replacement.

The establishment of genetic influence on disc degeneration has triggered a number of research studies into this area, including exploration of therapeutic use of this knowledge using stem cell-based therapies, growth factors and gene transplants. Gene transductions aimed at interfering with the degenerative processes and even induce disc regeneration are being evaluated by researchers.[6]

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# Clinical Biomechanics Related to Lumbar Disc Degeneration and Herniation

*Kourosh Karimi Yarandi, Abbas Amirjamshidi, Mohammad Shirani Bidabadi, Reza Sanjari*

## Introduction

The true features of the spinal biomechanics and its relation to lumbar disc disease and low back pain is not easy to assess. Although experimental *in vitro* examinations, animal studies, and cadaveric experiments have been helpful to reveal some unknown aspects of spondylosis and its relation to the spinal biomechanics, some other effective variables such as genetic inheritance, psychosocial factors, the effects of muscle activity and pain, and unique bipedal position of the human beings can hardly be analyzed by these methods.

## Basic Biomechanical Principles

Biomechanical analysis evaluates the effects of energy and forces on biologic systems such as human spine by using physics and physical principles that have well-accepted definitions. As the first step, some basic principles about measurement of the force and moment and kinematics of spine are discussed.

### Measurements of Force and Moment

To understand the spinal biomechanics the physician should be familiar with the concepts of moment arm, bending moment, and instantaneous axis of rotation (IAR). Forces applied to the spine can be simplified into component vectors (oriented in a fixed and well-defined three-dimensional direction). These vectors in turn act on a lever (which is the moment arm) to create a bending moment. Moment is defined as the tendency of a force to twist or rotate an object. This force is relative to a fixed point in space, which is called the IAR, and results in rotation—or the tendency to rotate—about this axis. Moment arm is the perpendicular distance from the point of rotation to the line of action of the force (Fig. 7.1). In the spine, the moment arm can be assumed as the perpendicular distance between the IAR and the force vector. With respect to the spinal column, the IAR is the axis about which each motion segment rotates at any particular point in time and is the center of the x-, y-, and z-axes of the Cartesian coordinate system (the point in which these axes encounter each other). The IAR can also be considered as a dynamic fulcrum of movement that changes in response to applied forces.

The precise location of IAR is different among various spinal levels and migrates during intervertebral motions. The flexion-extension IAR of a cervical or lumbar motion segment is slightly dorsal and caudal to the center of the caudal vertebral endplate

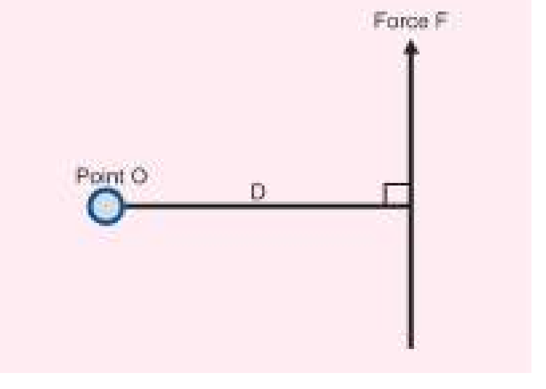



**Fig. 7.1:** The moment (*M*) is equal to the force (*F*) multiplied by its perpendicular distance (*D*) from the IAR (point O): $M = F \times D$

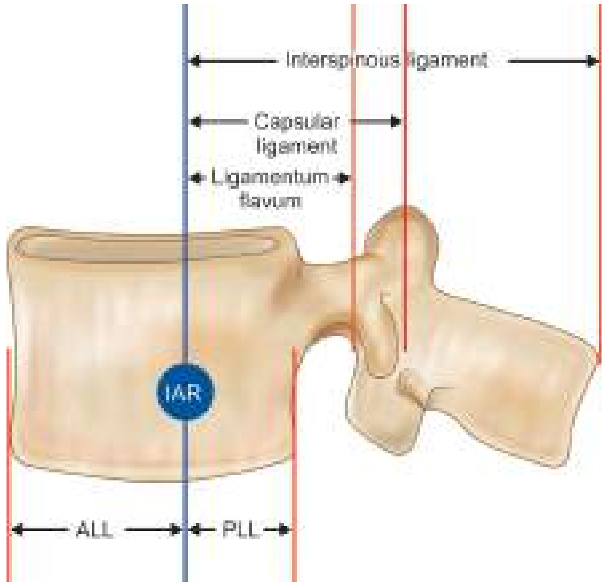



**Fig. 7.2:** The flexion-extension instantaneous axis of rotation (IAR) of a lumbar motion segment is slightly dorsal and caudal to the center of the caudal vertebral endplate. The amount of resistance that a ligament provides is proportional to its distance from the IAR

(Fig. 7.2). L5-S1 level is an exception. At this level, the IAR lies within the disc space instead of below the caudal endplate. Changes in the IAR are important because they can result in excessive facet joint or posterior ligamentous loading.

### Kinematics and Stability

Kinematic behavior of the spine is nonlinear and can be characterized by two distinct phases. The first phase, termed neutral zone (NZ), occurs within small changes from a neutral position when a slight load is applied. The resistance of the spine is very low in this phase and the spine deforms easily. The second phase, known as the elastic zone, is characterized by an increase in stiffness as the magnitude of the load increases.

The inherent structure of the spine provides a physiologic and functional degree of freedom of motion. Normal range of motion (ROM) includes translation and rotation about the three anatomic axes to provide six potential movements known as degrees of freedom. Segmental motions at the various spinal levels are generally determined by facet orientation, bony anatomy, associated ligaments, and supporting structures. Instability is the inability to limit excessive or abnormal spinal displacement in any plane. Instability is not an all-or-none phenomenon but rather a spectrum of increments ranging from stable to grossly unstable. Range of motion of the spine can be directly proportional to instability. In other words, when ROM is abnormally increased, instability will be expected. Chronic instability may be a sequel of an acute process, but it may also result from degenerative changes. Chronic instability may be subdivided into glacial instability (in which the deformity progresses slowly) or dysfunctional segment motion. In the latter there is no progression of the deformity, but rather a pain syndrome generated by dysfunctional motion. This is synonymous with "mechanical instability".

True assessment of lumbar spine kinematics is difficult. Traditional experimental methods are unable to study the kinematics of whole lumbar spine under physiologic compressive preloads because the spine without normal surrounding musculature buckles under low magnitudes of vertical load.[1]

## Biomechanically Related Anatomy and Physiology

Spinal stability is maintained by a variety of osseous and ligamentous structures that have evolved to provide resistance against deforming forces. Each level of the spine is a three-joint complex consisting of one intervertebral disc and two facet joints, with complex load sharing between the three joints.

The vertebral body is the main axial load-bearing structure of the spine. The lumbar vertebrae have a cylindric shape and contain strong elements including peripheral cortical bone and rostrocaudal endplates. The width and depth of vertebral bodies increase as one descends in the spine to accommodate increased axial load. The only exception in lumbar region is L5.

The relative weakness of the L5 vertebra can be explained by the asymmetry in height between the ventral and dorsal cortical walls.

The human spine should consistently withstand different compressive and distractive loads. Intervertebral discs are anatomical structures made of cartilaginous tissue, which mostly assist in even distribution of compressive loading across the intervertebral endplates and serve as shock absorbers. When the discs are healthy they are able to resist forces even greater than the surrounding bone.[2] They also provide the flexibility of the spine. The intervertebral disc is composed of a central gelatinous nucleus pulposus (a hydrated core of proteoglycans suspended in a loose collagen network) located in the posterocentral area of the disc and the annulus fibrosus (a fibrocartilaginous ring designed to provide structural support). The structure of the annulus is highly layered and oriented. The concentric fibers of the annulus fibrosus are oriented radially and in opposite directions throughout several layers (Fig. 7.3). In other words, the orientation of annular fibers changes between successive layers. The annulus resists the lateral forces created by compression of the nucleus pulposus during weight bearing. In both nucleus and annulus low cell populations and collagen fibers are embedded in a gel mostly made of proteoglycan and water. Since nucleus pulposus is highly hydrated, it is capable of exerting a fluid pressure on the surrounding annulus fibrosus and vertebral bodies. When the disc is loaded, water is extruded from the disc while the lateral forces are restrained by the collagen fibers of the annulus fibrosus. When the disc is unloaded, the osmotic gradient between the disc and plasma causes water to return to the disc. Thereby, the disc would be prepared to dissipate load forces again. According to this well-validated model, the disc behaves rather like a car tire which loses height and bulges radially when compressed.[3] Therefore, any reduction in the water content and

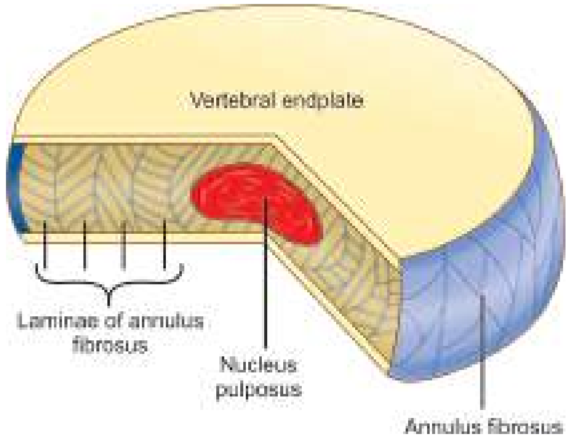
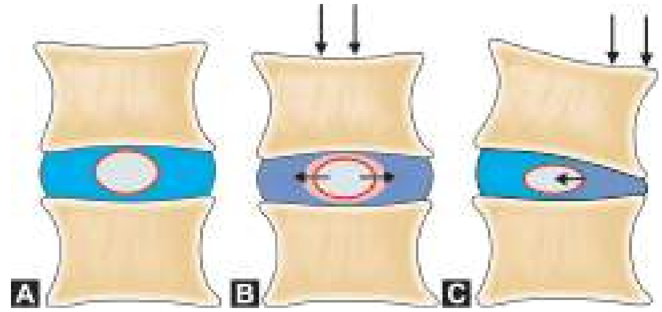



**Fig. 7.3:** The intervertebral disc is composed of nucleus pulposus and annulus fibrosus. The structure of the annulus is highly layered and oriented. The concentric fibers of the annulus fibrosus are oriented radially and in opposite directions throughout several layers

the total volume of the nucleus pulposus would be similar to "letting air out of the tire", leading to increased compressibility of the disc and increased loading applied to the bulging annulus.[4] Unlike nucleus pulposus, which generally acts as a fluid and exhibits hydrostatic pressure, the annulus fibrosus and articular cartilages are fibrous solids with considerable rigidity.

If nucleus volume decreases during several hours of sustained loading or following years of age-related degenerative changes, more compressive loads will be transmitted to the annulus. This will endanger the annulus especially in young adults, who are at higher risk of disc prolapse[5] probably because of two reasons: (1) The adjacent bony and ligamentous tissues need a considerable amount of time to gradually prepare for participation in load-bearing. (2) The annulus fibrosus is not stiff enough at least at the early stages of degeneration.

The loads that different lumbar structures must tolerate cyclically throughout the life are tremendous. The magnitude of load which is distributed to each intervertebral level depends on posture. During normal walking, the compressive loads on the lumbar intervertebral discs are 1.0 to 2.5 times body weight. Although the portion of the body above the L3 level only weighs as much as 60 percent of the total body weight, standing in 20$^{o}$ flexion results in a load of 250 percent of total body weight at that level.[6] Holding a 20 kg mass in the standing position can result in a spinal load equivalent to 300 percent body weight.[6] During the lifting of 14 to 27 kg objects, axial compressive loads in the lumbar spine can increase up to nearly 10 times body weight, with anteroposterior shear loads approaching double body weight. The intervertebral discs can support such large loads with the hydrostatic pressure within the nucleus pulposus. The mean value of the compressive stress increases with flexion or lateral bending. Nevertheless, the compressive stress is reduced during extension because in this position, a larger portion of the load is transferred through the facet joints. It is also shown that the overall torsional stiffness of the lumbar spine is increased in extension (when these ligaments are more involved in load-bearing and the intervertebral discs are relatively unloaded).[7] Concentric axial loads cause equally distributed forces within the disc, whereas eccentrically placed loads result in bulging of the annulus on the side of the applied force along with associated displacement of the nucleus to the opposite side (Figs 7.4A to C). This results in a relatively symmetrical distribution of the stress in normal discs even in the presence of eccentric forces (Fig. 7.5). It should




**Figs 7.4A to C:** (A) A schematic diagram of normal annulus fibrosus and nucleus pulposus; (B) Concentric axial loads cause equally distributed forces within the disc. The nucleus pulposus deforms according to the magnitude and direction of the load; (C) Eccentrically placed loads result in bulging of the annulus on the side of the applied force along with associated displacement of the nucleus to the opposite side

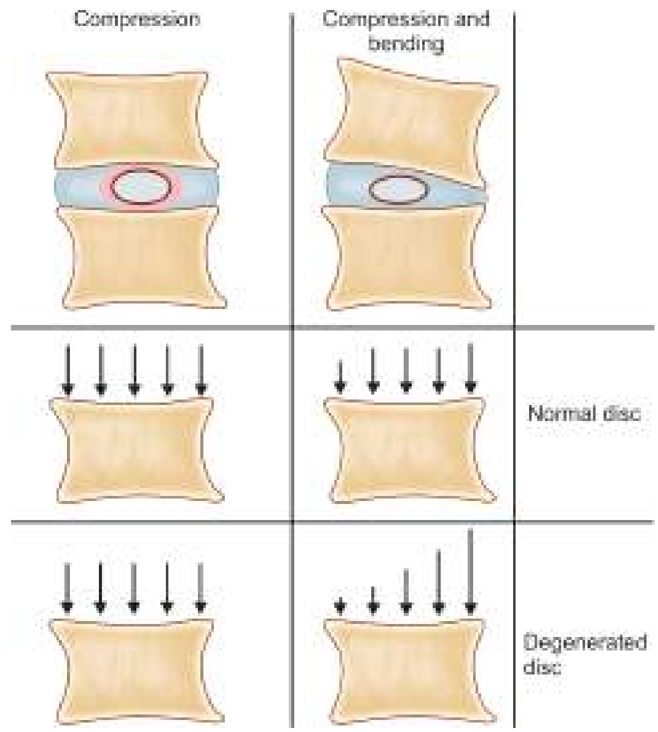



**Fig. 7.5:** The distribution of forces in a normal disc is relatively symmetrical even in the presence of eccentric forces. While a healthy nucleus pulposus shows a hydrostatic pressure, the pressure distribution within a degenerated disc is not uniform and mainly depends on the direction. This asymmetry in pressure distribution is significant during eccentric compressive forces

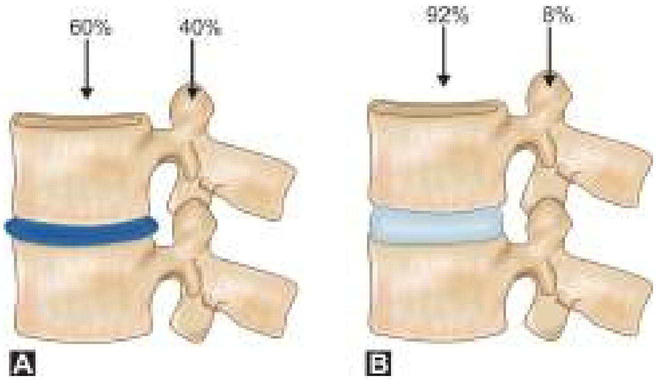
be reminded that when eccentric forces are applied even in a normal disc, the stress is more distributed to the periphery of the intervertebral disc in areas underlying annulus fibrosus.[8] Fibers of the outer region of annulus fibrosus are stiffer than those in inner regions. Accordingly, the stiffer outer layer converts compressive loads into hoop stresses while the inner layers mostly act as a shock absorber.[9] When compressive forces are applied combined with axial rotation, the posterolateral regions of inner annular zones of the intervertebral disc withstand the largest intradiscal pressure increase and centripetal pressure gradients.[10-12] Asymmetrical loads (rotation) combined with postural changes in the sagittal plane can increase these gradients, and may be responsible for a chronic mechanical overload of these regions.[10]

Shearing and rotational forces are mainly resisted by the annular fibers rather than the nucleus pulposus. In a normal disc the shear loads are usually transferred peripherally through the annulus.[13] Disc pressures in shear are significantly lower than those under compressive loading, demonstrating a minimal contribution of the nucleus pulposus in shear.

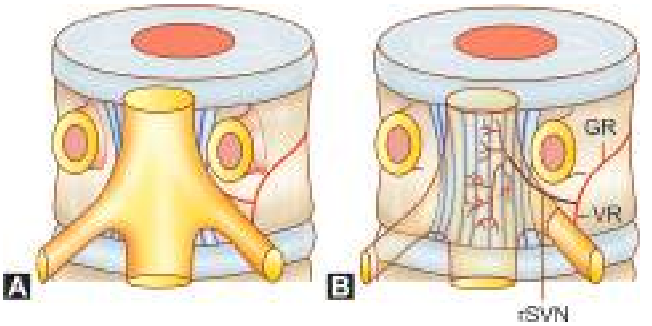
In conjunction with the intervertebral disc, the facet joints provide additional load-bearing and stabilizing functions between segmental levels. Approximately 80 percent of the compressive force is tolerated by the intervertebral discs and vertebral bodies, whereas the facet joints support about 18 percent of the compressive load in the segment. The apophyseal joints stabilize the lumbar spine by restraining shear and torsion. They also participate in resisting compressive forces when the spine is bent backwards. The orientation of the facets serves to facilitate or limit degrees of motion and therefore plays a crucial role in spinal stability. The lumbar facets are sagittally oriented (with the exception of L5–S1) and consequently resist rotation while allowing significant flexion and extension.

As discussed earlier, the percentage of load transferred through the posterior elements is highly dependent on spinal posture. Both extension and ventral translation tend to load facets, whereas flexion and dorsal translation unload them. Alterations in sagittal alignment, degeneration of the intervertebral disc, and loss of disc height can result in greater load transfer to the facet joints (Figs 7.6A and B).

The spinal ligaments provide passive stabilization of the vertebral column. Their elastic properties allow them to serves




**Figs 7.6A and B:** Degeneration of the intervertebral disc can result in greater load transfer to the posterior vertebral elements including facet joints. (A) Degenerated disc; and (B) Normal disc




**Figs 7.7A and B:** (A) A schematic posterior view of a lumbar vertebral body along with thecal sac. The posterior bony elements including spinous process and laminae and pedicles are removed; (B) The same view with removal of thecal sac. The ventral rami (VR) of the somatic nervous system accompanying with the gray rami (GR) of the sympathetic nervous system form the fibers of recurrent sinuvertebral nerve (rSVN). Recurrent sinuvertebral nerve enters PLL and forms a plexus within this ligament and annulus fibrosus

as both tension band and translational support. Intervertebral ligaments resist most of the bending and posterior ligaments are important in resisting flexion moments. The posterior spinal ligaments seem to react as a continuous complex instead of individual ligaments.[14] The amount of resistance (counterbending moment) that a ligament provides is also proportional to its distance from the IAR (Fig. 7.2).

The paraspinous muscles (and associated abdominal musculature) span multiple segments. The primary function of these muscles is to stabilize the spinal column rather than produce motion. The action of the erector spinae muscles when arising from a forward flexed position can be considered as an exception. In general, any imbalance in muscular forces causes movement about an axis. Conversely, a balancing of muscle and other intrinsic forces about an axis results in no net movement. The ventral abdominal musculature is important in counterbalancing the erector spinae muscles to provide stability.

The ventral rami of the somatic nervous system accompanying with the gray rami of the sympathetic nervous system form the fibers of recurrent sinuvertebral nerve. Recurrent sinuvertebral nerve enters the posterior longitudinal ligament (PLL) and forms a plexus within this structure (Figs 7.7A and B). This plexus is believed to innervate PLL and the annulus fibrosus. The lateral and anterior regions of the annulus are mainly supplied by autonomic nerves. Immunohistochemical studies have demonstrated that throughout the annulus, sinuvertebral nerve mainly innervates the outer regions. The inner regions of the annulus and the nucleus are not innervated by this nerve. In severely degenerated and painful discs, an abnormal increase in innervertion and vascularity occurs. Nerves and accompanying capillaries can grow straightly into the center of the nucleus pulposus in these pathologic circumstances.

## Spondylosis and Degeneration

Degeneration is defined as a deteriorate ion of the tissue or replacement of it by a less competent structure. Genetic inheritance[15] and aging are important risk factors for disc degeneration. Spondylotic changes of the spine include disc degeneration, facet joint osteoarthritis, vertebral body degeneration and ligament degeneration. Initial degenerative changes in the lumbar spine most commonly occur within the intervertebral disc and more specifically, within the nucleus pulposus. Degenerative changes in the intervertebral disc significantly affect load-bearing and kinematic patterns on the lumbar spine. The exact cause of degenerative changes within the disc space is not clearly understood, but a decrease in the nutrition of the disc, presence of degenerative enzymes or inflammatory mediators, apoptosis, vigorous loading of the spine, and the process of aging have been proposed as potential mechanisms.[16,17] Degenerative process of the disc usually starts before age 20 years, and can be distinguished from normal aging by the presence of physical disruption. Degenerated discs have a decreased height due to the reduced hydration capacity and a more fibrotic appearance of the nucleus pulposus. The water and proteoglycan content is decreased with degeneration, particularly in the center of the disc, and the compressibility of the nucleus is increased.[18] Also, the number of fibers in the nucleus pulposus increases in such cases. Correspondingly, intradiscal pressure is lower in a degenerated disc in comparison with the healthy ones and even falls below the surrounding atmospheric pressure[19,20] and a degenerated disc loses pressure in the nucleus and bulges radially outwards, like a flat tire. As a consequence, the percentage of the axial force transmitted through the disc decreases when the fluid content within the disc is reduced.[21] As mentioned, the stiffness of annulus fibrosus increases during the process of degeneration as well,[22,23] but in the early stages, the degenerated disc is more vulnerable and herniates at lower pressures than the normal disc.[12] While a healthy nucleus pulposus shows a hydrostatic pressure, the pressure distribution within a degenerated disc is not uniform and mainly depends on the direction.[20,24] This asymmetry in pressure distribution is more evident during eccentric compressive forces (Fig. 7.5). Little et al. (2007) showed that development of annular lesions alone (prior to degeneration of the nucleus) has minimal effect on disc mechanics, while the effect of lost disc stiffness following reduced hydrostatic pressure in the nucleus is very significant.[25] The transfer of the loads to the peripheral regions is aggravated with degeneration of the disc[26] and the forces can be transmitted even through the posterior spinal elements in the advanced stages of degeneration (Fig. 7.6).[27] Degenerative disc disease can also induce higher tensile and shear deformations in the adjacent discs.[28]

The effects of disc degeneration on the spinal stability are also interesting. It has been proposed that in the presence of disc degeneration, the range of motion transiently increases.[29,30] With further progression of the disease, the range of motion in flexion/extension and lateral bending will be reduced, but according to the results of some publications, the amount of axial rotation would be increased.[31,32] Since compressive loads can be transferred to the neural arch in the later stages of the disc disease, disc degeneration is often accompanied by arthritic changes in the facet joints, which can be an important cause of such an increase in range of axial rotation. By using the finite element method, Rohlmann et al. (2006) realized that intersegmental rotations are all increased in a mildly degenerated disc. With further increasing of the disc degeneration, the movements for flexion, extension and lateral bending will be restricted. According to their results for axial rotation, intersegmental rotation increases for mildly and even moderately degenerated discs but decreases when the disc is severely degenerated.[19]

For lateral bending, even a mildly degenerated disc has a heavy influence on maximum stresses in the annulus fibrosus. The highest stresses are calculated at the posterior disc rim for the forces applied in flexion and extension and at the lateral posterior disc rim for the loads applied in lateral bending and axial rotation.[19] In the latter stages of disc degeneration, The inner annulus expands, and the margin between the nucleus pulposus and annulus fibrosus becomes less distinct. As the disc deteriorates, its isotropic load transfer properties are lost and load transfer becomes concentrated at the periphery (annular insertion) of the vertebral endplates. As mentioned before, the contribution of nucleus pulposus in tolerating the shear forces is minimal. Simulated degenerative models (nucleotomy) have also shown little effect on the behavior of the disc in shear loading.[33]

In summary, disc degeneration decreases the compressive load transferred through the nucleus. Instead, this process increases the load transferred through the annulus fibrosus, whereas in shear there is no significant change in loading patterns. Increased innervation and vascularity can also occur in a degenerated lumbar disc. With progression of disc degeneration, the contralateral facet joints should also accept increased forces during axial rotation.[19] With further progression of disc degeneration, the forces in the ligaments close to the vertebral body (ALL, PLL and ligamentum flavum) decrease.[19] In the later stages of spondylosis, vertebral osteophytes appear and the cross-sectional area of the adjacent vertebral endplates increase.

According to the previous data including some of the studies mentioned before, three clinical stages of spinal degeneration have been proposed: dysfunction, instability, and stabilization.[34] Fujiwara et al. (2000) tested flexibility of the spine in flexion, extension, lateral bending, and axial rotation. They found that segmental flexibility is increased with moderate disc degeneration (instability phase) and then decreased with further deterioration (stabilization phase).[35] As a new definition, dysfunctional segmental motion (DSM) is defined as a type of instability related to disc interspace and vertebral body degenerative changes,[36] which can be reversed by the growth of osteophytes in the later stages of degeneration. It should be reminded that the boundaries that divide each of these stages are not definite and the sequence of various radiologic and biologic phenomena is not the same in different individuals; thus, the duration of these stages and the probable overlapping of each on the other can be quite variable.

## Loading History

Matrix stresses depend on age and degeneration. Additionally, these stresses can also depend on several other factors including loading history, posture, and injuries.[37] Intense repetitive loading and abnormal low level of loading can both be harmful for bony and cartilaginous structures,[38-42] whereas modest or gradual increases in disc loading may even have some beneficial effects.[43,44] The outer part of annulus, in particular, is able to adapt its strength to mechanical demands[45] probably because of its highest cell density[46] and adjacency to the peripheral blood supply. Fatigue damage induces both anatomic and catabolic responses leading to reduction of disc height, loss of cellularity, and annular disorganization.[17,47] It is known that disc degeneration is more common and generally worse in people with physically demanding occupations.[43,48] Avascular cartilage has a restricted ability to repair itself and accordingly, it will gradually fail against vigorous loadings. This damage can accumulate in the intervertebral disc. Excessive sudden movements can also damage the spine. Torsion and backward bending can injure the apophyseal joints, hyperflexion can disrupt posterior ligaments, and a combination of bending and compression can cause a disc to prolapse. It is proposed that static loading of the discs induces more degenerative alterations than cyclic loading.[49] On the other hand, there are some animal studies suggesting that intervertebral disc herniation may be more linked to repeated flexion-extension motions than applied joint compression.[50]

The effect of repetitive movements on the human disc is an attractive subject. Repetitive injury to chondroid tissues is able to initiate a "vicious circle" of abnormal matrix stresses, abnormal metabolism, weakened matrix, and further injury.[37] Many of the investigators have suggested an association between low back problems and occupations involving exposure to shock and vibration.[51,52] Some vehicle operators suffer from musculoskeletal problems in the low back due to the shock and vibration that they encounter during their work. Viswanathan et al. (2006) suggested that the use of an additional lumbar seat support that can cyclically inflate and deflate, may effectively reduce the development rate of low back discomfort experienced by operators of heavy earth-moving equipment throughout the work day.[52]

Abnormal low levels of loading can also weaken muscle, cartilage, and bone.[53] So, it can indirectly endanger the discs of lumbar spine.

## The Aging Spine

Aging, by itself, weakens the spinal tissues and the degeneration associated with aging has a significant impact on the fundamental biomechanics of the spinal column. It has an accumulative effect on different elements in spine. Facet joint osteoarthritis, dehydration of the intervertebral disc, and loss of normal spinal alignment can gradually occur. Degenerated adult human intervertebral discs lose 1 to 3 percent of their height per year[54,55] and their radial buldging also increases by 2 percent per year.[55]

In elderly people, compressive overload may lead to collapse of the anterior portion of the vertebral body to form a wedge shaped appearance. Consequently, the load is distributed to the adjacent normal structures such as neural arch (stress-shielding), which in turn, can cause pain.

The undesirable effect of aging on intervertebral discs can be produced by millions of load cycles throughout the functional life span of an individual motion segment; however, this deterioration is also accelerated by an age-related decline in transport of metabolites within the avascular matrix. Many of the changes associated with age start at the microscopic level. Chemical composition, texture, and histology of the lumbar disc gradually change. The functional proteoglycans in cartilage decrease significantly with age. Biomechanical changes in aging cartilage include reduced tissue's water-binding properties and an associated decrease in its shock-absorbing ability combined with increased collagen content and tissue stiffness.[18] These changes are more evident within the nucleus pulposus. As a result, younger spinal columns are more flexible and exhibit a significantly greater range of motion than do their older counterparts. Cell function can also deteriorate over time. This impaired function would make the disc more vulnerable to, and less able to recover from mechanical damage.

The aging process is also commonly associated with a gradual decrease in bone mineral density that can lead to osteoporosis and fracture. Because, these changes are generally initiated in cancellous bone, the vertebral bodies of the spine are often involved. In addition, since with disc degeneration the loads can be transferred to the posterior elements of spine, the vertebral bodies become relatively unloaded. Consequently, focal bone loss can accompany spondylosis. As an adaptive response to decreased bone mineral density, the trabecula of the bone remodel and the ratio of vertical to horizontal trabecular orientation increases. Such an increase can lead to greater ability of the vertebral body to resist axial loads. However, the decrease in horizontal trabecula results in a decrease in elastic modulus and strength in the transverse direction and an increased vulnerability to forces other than pure axial.

### Spinal Alignment

Aging and postural changes related to it and degeneration of the discs can affect the relative orientation of adjacent vertebrae and mechanical milieu of the vertebral bodies and profoundly alter stress distributions within the apophyseal joints and intervertebral discs producing a complex and poorly understood biomechanical environment. Theoretically, a straight spine would be ideal to withstand axial-loading, but this posture would tolerate eccentric loads poorly and provide limited flexibility. The spine has therefore evolved to adopt a curvilinear sagittal conformation. The thoracic region has a kyphotic curve, while the cervical and lumbar areas are mostly lordotic. These sagittal orientations make a balanced configuration necessary for a bipedal upright posture. Any increase in thoracic kyphosis (or loss of lumbar lordosis) leads to an increased moment arm (i.e. perpendicular distance from the IAR to the gravitational force vector), which generates a greater bending moment at each vertebral segment. As the deformity evolves, the length of moment arm also grows proportionally. Therefore, a vicious cycle will be produced and in this case "deformity can produce further deformity".

### How is Low Back Pain Related to Disc Degeneration?

Low back pain is believed to be one of the most significant symptoms of lumbar spondylosis. Degeneration has long been described as an important cause of low back pain;[56-59] however, the exact relationship between these two and the mechanisms of discogenic pain generation are poorly understood.[60] It is shown that degenerated discs are often observed in individuals without back pain, while structural defects such as disc extrusions, complete radial fissures, endplate defects, and loss of annulus height are more likely to be associated with pain.[61]

According to the results of different publications, frequent sites of severe low back pain are posterior annulus,[62] apophyseal joints,[63] ligaments,[64] and sacroiliac joints.[65] Perhaps the most important elements in the lumbar region which are capable of producing significant low back pain are the paraspinal muscles. The rehabilitation strategies in these cases should cover the erector spinae muscles located in the lumbar region as well as the thoracic area.[66] Severe and chronic discogenic pain often arises from the periphery of intervertebral discs. There are some recent reports suggesting that the presence and the severity of low back pain associated with spinal degeneration cannot be described by the biomechanics of the spine alone, and the pain can be mostly related to genetic inheritance[67] and psychosocial factors such as depression and anxiety.[68] On the other hand, there are recent evidence suggesting that the excessive mechanical loading[53] and dysfunctional segmental motion[36] can still be regarded as the chief preventable causes of spinal degeneration and pain.

As discussed before, the recurrent sinuvertebral nerve contains both somatic and autonomic fibers and can be regarded as one of the most important sources of discogenic pain. Although structural degenerative changes such as Schmorl's nodes, internal disruption of intervertebral discs, and disc prolapse are likely to be associated with pain, even these changes can be found in asymptomatic people. Thus, it seems that pain perception requires additional mechanisms other than visible structural changes as well. Cell-mediated changes and the effect of soluble mediators, ingrowth of nerves and vessels into the outer regions of annulus fibrosus, and stress-shielding are some of these mechanisms.[69-71] As mentioned before, stress shielding occurs when the original load-bearing tissue becomes incompetent. In this situation the adjacent healthy tissues participate in load-bearing or even undertake the whole responsibility. A good example for this phenomenon is the significant shift in load-bearing from the intervertebral disc to the neural arch following degeneration. The life style and careful attention to the optimal alignment of the spine is also important. It is shown that "bad" posture could also lead to spinal pain, even in the apparent absence of degenerative changes in the affected tissues.[53]

## Biomechanics of Intervention

Spinal surgery includes three main components to reduce pain and disability: decompression, stabilization, and correction of deformity, if needed. Each component can have significant effect on the biomechanics of the lumbar spine.

### Discectomy

As previously described, nucleus pulposus is a very important element in disc mechanisms. While discectomy is used as a method to alleviate pain, the long-term biomechanical effect of an unstable disc is a matter of interest. Removal of this material increases disc deformation and radial bulging in response to compressive loading. Also, disc height and intradiscal pressure is decreased in such cases comparing with the intact discs.[72-74] The quantity of the removed nucleus pulposus is also important. A relatively linear relationship exists between the mass of the removed tissue and the reduction in disc height.[74-77] After partial removal of the nucleus pulposus, when the motion segments undergo compressive loading the inner annulus layers bulge inward. This suggests an increased radial stress within the annulus after partial nucleotomy.[78-80] The neutral zone also increases following removal of the nucleus pulposus.[74] Facetectomy and discectomy together with posterior annulus resection result in increased kinematics and loss of stabilizing strength of the lumbar vertebra. Less motion is induced by subtotal discectomy in comparison with total disc evacuation.

### Minimally Invasive Methods

The injection of chymopapain temporarily increases the disc height as well as the intradiscal pressure. The stress distribution and motion segment mobility remain unchanged after chymopapain injection.[81] Automated percutaneous discectomy is reported to reduce the height of the disc and the intradiscal pressure. This intervention can lead to an increase of the radial bulge of annulus.[82]

### Iatrogenic Spinal Destabilization

A surgeon's appreciation of the biomechanical properties of the ligamentous and osseous structures of the spine is vital to avoid destabilization during ventral and dorsal spinal exposures. During dorsal decompression, the risk of iatrogenic destabilization can be minimized by preservation of the facet joints, interspinous ligaments, and uncovertebral joints. The surgeon is allowed to resect approximately one-third to half of the facet joint, thus it is always recommended to use optimal trajectory during surgery and preserve pars interarticularis during normal discectomies. It is important to know that in the lumbar spine, the instability associated with lumbar facet disruption is typically glacial and does not promote a significant risk for the immediate development or progression of translational deformities. Although the interspinous ligament is relatively weak, it has biomechanical advantages related to its long moment arm. This ligament is usually deficient at L4-L5 and usually absent at L5-S1.

During ventral decompression, the anterior longitudinal ligament (ALL), posterior longitudinal ligament (PLL), annulus fibrosus, and vertebral body, all of which contribute to stability, are often sacrificed to some extent. Since ALL is extensively wide, it is not usually significantly disrupted during such surgeries. Ventral annulotomy during anterior lumbar interbody fusion (ALIF) is an exception and may significantly disrupt ALL. ALL provides a tension band-like effect, which is an especially important contributor to postoperative spinal stability secondary to its position ventral to the IAR. Thus, when ALIF is done as the sole stabilization procedure for the patient, normal PLL and dorsal elements are required to provide adequate tension banding. The PLL resists flexion/distraction and has far less biomechanical strength because of its weak intrinsic mechanical properties and short moment arm in relationship to the IAR.

## Biomechanics of Nonfusion Implants and Dynamic Stabilization

Recently, with the improvement of new technologies, nonfusion implants and dynamic stabilization have been introduced.

The aim of such surgeries is to modify the biomechanics of the affected lumbar segment (dysfunctional segmental motion) by replacing the disc or reducing the load on it, with simultaneous reduction of the disadvantages that are usually attributed to the loss of motion created by fusion. As non fusion devices gain popularity, an understanding of their biomechanical effect on the implanted and adjacent motion segments will be crucial. Ideally, they should mimic the IAR and range of motion of the normal functional unit, which varies by level and individual. Currently, nonfusion devices fall into three categories: nuclear implants, total disc replacement (TDR), and posterior stabilization devices. Arthroplasty is a relatively new option for treating degenerative disc disease. It consists of the implantation of an artificial disc in order to alleviate pain by restoring relevant functionalities of the degenerated disc. Marketed arthroplasty implants have a broad range of biomechanical and kinematic properties. FDA-approved arthroplasty devices for lumbar application can be unconstrained and semi-constrained.[83] Implantation of such devices often requires considerable surgical resection of the bone and ligaments. For the arthroplasty to be effective, postarthroplasty ROM should be at least proportionally equivalent to normal. Currently, we have little understanding of the effect of artificial discs on spinal biomechanics and only few researchers have evaluated their biomechanical properties. Interestingly, their conclusions seem to be conflicting. Some results are very encouraging. It is shown that these devices can preserve the disc height[84] and reverse the destabilizing effect of discectomy.[85,86] Also, minimal kinematic changes can affect adjacent motion segments after insertion of such implants[84,85,87,88] and after fatiguing, the artificial devices are claimed to behave identical to the adjacent levels.[85] These data suggest a normal load-sharing structure after arthroplasty.[85,87] Although this technique is considered as a popular method to decrease adjacent level degeneration following surgical interventions, some serious criticisms have also been made regarding its ultimate effect on the spinal biomechanics. Denoziere and Ku (2006) compared the biomechanical alterations of the lumbar spine after fusion with these changes following implantation of a movable artificial disc under severe loading conditions. According to their results, they predicted unstable mobility at the level implanted with the artificial disc and a significant increase in mobility at the level adjacent to the treated level. They also reported significant loads on the articular facets and intervertebral ligaments following arthroplasty which may exceed their ultimate strength. This will probably put the facet joints at further risk of degeneration. Their model predicted that total disc replacement involves greater risk of instability and prospective further degeneration relative to fusion.[89] There are other reports confirming these negative biomechanical effects of arthroplasty.[90-93]

Again, there are some contradictory results about the rate of subsidence following total disc replacement. Denoziere and Ku (2006) calculated the stress on the vertebral endplates following arthroplasty. They realized that this stress is usually greater in the implanted level. This result suggests that an artificial disc with stiff metallic endplates may subside into the adjacent vertebral bodies.[89] However, Dooris et al. (2002) reported no implant extrusion or endplate fracture in the fatigue test.[85] It should be noted that choosing relatively small sample sizes and evaluating different systems may be the main reasons of such a controversy in the literature.

Arthroplasty devices are articulating ball-and-socket joints in which motion is provided by the sliding of one surface relative to the other. As a consequence, the intervertebral disc has an inherent resistance to motion, which these devices do not have. On the contrary, in the axial direction, these devices are rigid, providing little or no shock absorption. Accordingly, there have been some attempts to mimic the exact biomechanical properties of the natural disc by using a flexible elastomeric prosthesis. A type of these new devices was assessed but unfortunately met with early mechanical failure, very poor clinical outcomes, and removal from the market.[94] Partial disc replacement with nucleus pulposus prosthesis is also tried in animals. Implantation of the nucleus pulposus prosthesis in animals resulted in significant restoration of the parameters (ROM, NZ, and NZS) towards the native state; however, fragmentation/herniation of the NPP occured in 47 percent of the cases. Currently, this high rate of failure is a serious disadvantage attributed to such devices.[95] In contrast, some researchers have tested another biomimetic artificial intervertebral discs with reported success. Van der Broek et al. claimed that these devices result in axial behavior closer to the natural disc.[96] McNally et al. found these devices less stiff in axial loading but they reported satisfactory *in vitro* disc height and flexion stiffness after implantation of such devices.[97] Also, annulus sparing intervertebral prosthetic discs are recently introduced, which are reported to produce intact segment biomechanics in terms of range of motion, neutral zone, and stiffness.[98]

The effect of interspinous devices has also been analyzed. They are reported to be effective in stabilizing the unstable segment.[99] Some of the investigators found them biomechanically effective only in extension,[99] while others reported that insertion of such implants can reduce the segmental flexion-extension and lateral bending motions observed after discectomy, without any stabilizing effect on axial rotation.[100]

Recently, the biomechanical properties of lumbar spine after implantation of total facet arthroplasty systems have also been assessed. While complete laminectomy-facetectomy increases range of motion in flexion-extension, lateral bending, and axial rotation, pedicle screw fixation decreases these motions.[101] Total facet arthroplasty systems are reported to maintain these parameters within the normal ranges.[101] Range of motion in the adjacent levels is reported to increase following fusion, whereas implantation of total facet arthroplasty systems can result in near-normal distribution of range of motion at the implanted and remaining lumbar segments.[101]

Posterior lumbar interbody fusion (PLIF) is also considered as a popoular surgical procedure for degenerative lumbar surgeries. It permits large loads to be transmitted through anterior column and restores disc height and lumbar lordosis. Accordingly, it is reported to be biomechanically stronger than posterolateral arthrodesis with posterior spinal instrumentation following discectomies.[102-105] Nonetheless, the exact clinical indications of adding PLIF to conventional approaches of discectomy are still controversial and should be assessed more.

Dynamic stabilization with polyaxial screws and dynamic elastic rod system is also analyzed by some investigators and biomechanical studies have validated it.[106] It is reported to provide enough stability to maintain desirable radiologic improvement over mid-term follow-up.[36] The rate of adjacent level degeneration is also claimed to be low following these surgeries.[36]

## Biomechanics of Traction Devices

Many treatment strategies using external axial distraction have been devised in an attempt to relieve low back pain by affecting the disc and nerve roots. These devices are mainly used to decrease intradiscal pressure in a disc which is assumed to be in danger of prolapse or aggravation of the disc herniation. There is an obvious controversy in the literature regarding the clinical significance of such devices.[57] Nevertheless, from the biomechanical perspective, they are shown to markedly reduce nucleus pressure compared with either simulated standing or lying in cadavers. No difference is reported between distraction with flexion and distraction with extension in regard to posterior annulus compressive stress.[57] The clinical effect of distraction on reduction of the pain and induction of regeneration, however, should be confirmed with further evaluations.

## Conclusion

Understanding the biomechanics of spine is one of the chief prerequisites for successful clinical practice. Biomechanically related anatomy of lumbar spine, biomechanical aspects of lumbar disc degeneration and aging, and biomechanical alterations of different surgical approaches and implants are known to some extent but further work is definitely required to reveal unclear and sometimes controversial aspects of them in future.

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# 8

# Factors Responsible for Symptomatology of Lumbar Disc Herniation

*Alok Agarwal*

## The Origin of Back Pain and Sciatica

### Introduction

Back pain is very common. Equally common is sciatica. The genesis of pain is as interesting as it is difficult.

All the tissues contribute to the symptomatology of back pain and sciatica. The muscles, ligaments, intervertebral discs, intervertebral joints and the bone itself can contribute to the symptoms.

### Early Concepts

In the early days myalgic origin of the pain was very much advocated. This concept has now been largely abandoned. Leriche and Jung (1931)[1] injected local anesthetic in a number of patients with backache and were able to obtain relief from pain. They felt that the pain arose in the ligaments covering the intervertebral disc.

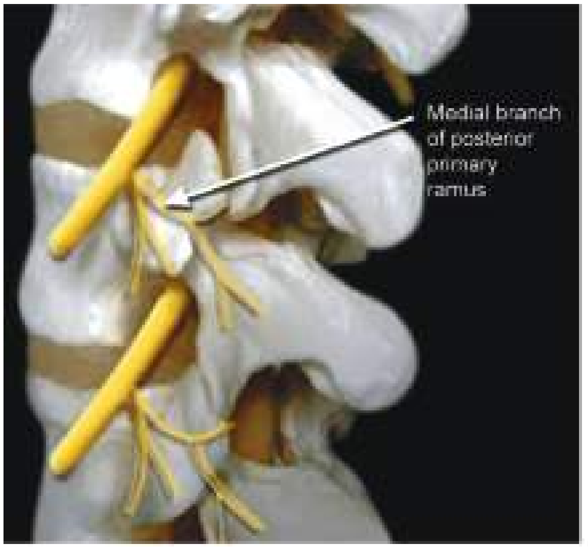
Luschka and Hovelaque in 1925 and Roofe in 1940[1] studied the nerve supply of intervertebral disc. A branch arising distal to the spinal ganglion joined the sympathetic branch and entered the spinal canal (sinuvertebral nerve) (Fig. 8.1). The nerve then supplied the bone, the space between dura and the ligaments and over the intervertebral disc space. The nerve also followed blood vessels. Sinuvertebral nerves are half to one mm thick and its branches run even posteriorly towards ligamentum flavum and the spinous processes.

### The Nerve Supply

Jung and Brunschwing, two of Leriche's students,[2] investigated the nerve supply of intervertebral disc. They felt that the nucleus pulposus and annulus fibrosus did not contain nerve tissue, but there were nerves in the surrounding ligaments. The anterior border of the disc in particular had plentiful of nerve endings more nearer to the attachment of anterior longitudinal ligament to the annulus fibrosus (Fig. 8.2).

It was also felt in those days that degeneration in the disc caused instability and this abnormal motion caused stretching of the ligaments posteriorly giving rise to back pain. The sinuvertebral nerve was first described by von Luschka as early as in 1850. The nerve arises distal to the spinal ganglion, joins the sympathetic branch and passes through the intervertebral foramina into the vertebral canal. It divides into several branches and supply the posterior longitudinal ligament and the annulus fibrosus in the local region. By studying this nerve with special stains it is now established that the outer annulus as well as the posterior longitudinal ligament has a rich nerve supply. The nociceptive fibers are connected to the central nervous system via the sinuvertebral nerve. The branches running posteriorly are not as abundant as in the posterior longitudinal ligament and the outer annulus.

The outer annulus is the tissue of origin of back pain in most cases. The facet synovium does not produce back pain or sciatica. The facet capsule can by its inflammation produce irritation in the nerve root. Muscle, fascia, ligamentum flavum and bone are insensitive. A normal nerve root is insensitive to handling



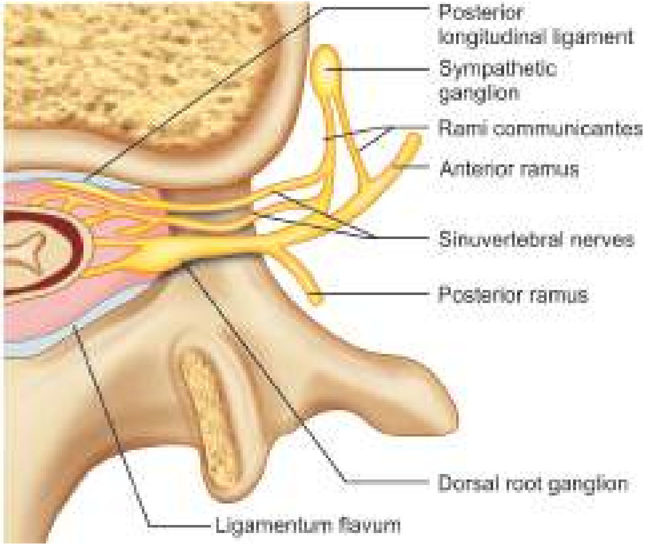



**Fig. 8.1:** Sinuvertebral nerve

or retraction. A nerve root which is inflamed or damaged or distorted is extremely sensitive even to touch and produces typical sciatic pain. Back pain and sciatica does not originate purely from mechanical factors. It can also originate from chemical substances causing local irritation.

## Genesis of Back Pain

It was well known that a patient with acute lumbago for a few days, later gets a true sciatic pain due to prolapsed intervertebral disc. It was natural to look for common explanation of prolapsed lumbar intervertebral disc causing both lumbago and sciatica. It was also felt that rupture of annulus with herniation of nucleus

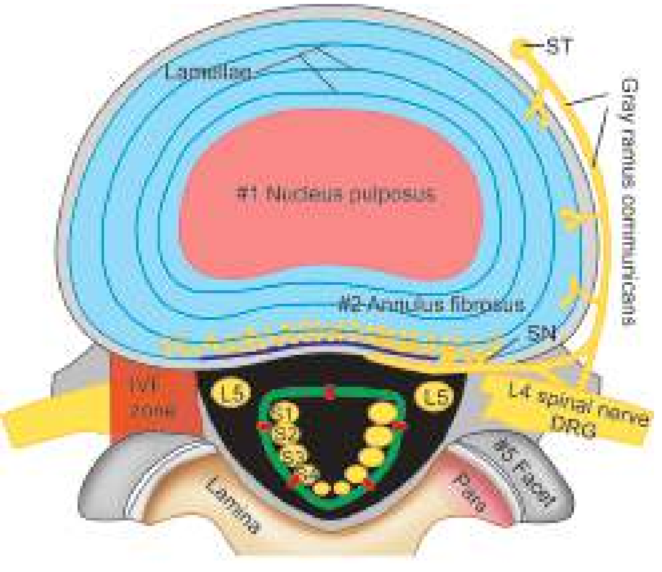



**Fig. 8.2:** Nerve supply to the annulus

brings them in direct contact with the nerves found abundantly in the tissues outside the annulus and this caused lumbago.

The genesis of back pain was found in the ligamentous coverings of the disc. It may be noted here that palpation of the vertebra did not produce pain.

## Pressure on Nerve Root

Like the workers mentioned above Inman and Saunders had conceived that sciatic pain is caused by pressure on the nerve root[3] (Fig. 8.3).

However, there was no experimental evidence to indicate that pressure alone upon the nerve root initiated sciatic pain. Smyth and Wright (1958) carried out experiments to analyse these points. Following surgery for proven cases of prolapsed intervertebral discs a nylon thread was passed round the root and also round the dura. Gentle traction was applied through this thread on the root and the dura for a varying period of time from 1st till 10th postoperative day. Through these experiments it was concluded that the nerve root need only to be touched to produce sciatic pain. The fact that touch alone is sufficient to cause sciatic pain has an important bearing on the operative procedure. Postoperative fractionary fibrosis with a sensitized root from prolonged immobilization or treated conservatively may be sufficient to maintain an acute sciatica.

Continuing operations under local anesthesia Stephen Kuslich (1991)[4] studied the tissue origin of low back pain and sciatica. Sciatica could only be produced by stimulation of a swollen stretched or compressed nerve root. Back pain could be produced by stimulation of several lumbar tissues but by far the most common tissue of origin was the outer layer of the annulus fibrosus and posterior longitudinal ligament. The pattern of referred pain was common. Buttock pain could be produced by stimulation of the annulus and the nerve root (two elements, viz. referred pain and the root pain or sciatica) (Fig. 8.4).

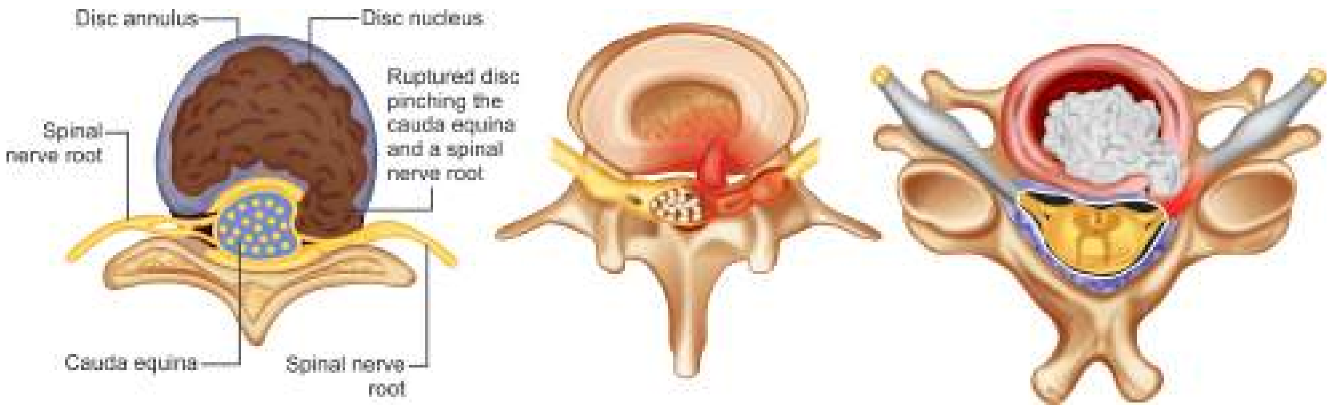



**Fig. 8.3:** Examples of herniated disc causing compression of the nerve root

**Fig. 8.4:** Referred pain in lumbar disc herniation

## Role of Muscles

It is assumed by many that weak and strained muscles are a common source of lumbar pain. But back pain is common in people with strong muscles and it lasts much longer than the muscle sprain which usually disappear after three weeks. In short pathology related to conditions like hematoma or muscle tear are not found in most patients suffering from chronic back pain. Gentle pressure never produced pain. Forceful stretching particularly its attachment to the bone produced a localized low back pain. The pain is sharp and different from the deep seated lumbago pain that the patient suffered. It was concluded that pain was derived from blood vessels and nerves in the muscles rather than from the muscle fibers.

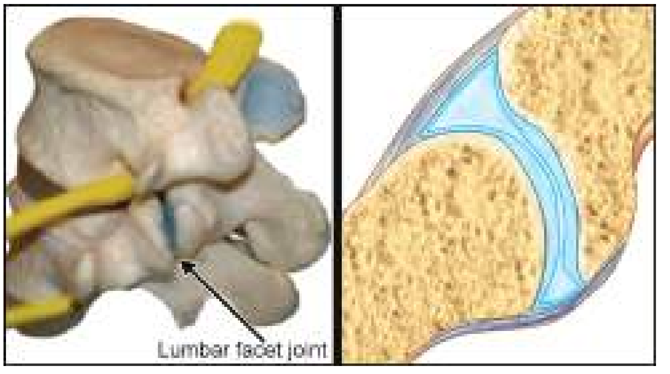



**Fig. 8.5:** Lumbar facet joint (a true synovial joint) with its rich enervation is the common source of pain in the back

## Role of Facet Joint

The facet joint is regarded as a common source of pain by several authors[5] (Fig. 8.5). Procedures like facet injections or RF denervation of facet joints were common at one time. Such procedures were quickly given up. The available clinical and neuroanatomical evidence indicates that there must be some relationship between facet joint syndrome and the process of degeneration in the disc. Hirsch[1] stimulated various lumbar tissues by the use of carefully placed needles in awake patients. He was able to produce back pain by stimulating the posterior portion of the annulus and was able to eliminate pain by injecting a small volume of local anesthetic in that region.

Discography provides valuable information. Most agree that the test is not sufficiently accurate to define all the painful tissues. However, stimulation of the culprit disc induces pain which closely resembles the back pain and or sciatica that the patient suffered.[6]

Falconer (1948) and his associates made similar observations while exploring a clinical prolapsed disc under local anesthesia. Spurling and Granthum (1940) had observed that patients complained of pain in the back during operation with local anesthesia when the annulus fibrosus was manipulated. Wiberg in 1950 observed that firm pressure on the posterior surface of the vertebral body did not cause pain. On the other hand touching the disc itself caused pain in lumbosacral distribution in nearly all the cases.[1,7]

## Clinical Observations[8-14]

Experiments were carried out by using local anesthesia in surgery. Each tissue was localized as dissection progressed into the deeper tissues. Following observations were made.

### *Lumbar Fascia*

In most cases it was possible to touch or cut this fascia without causing pain. However, its junction with the ligament produced some back pain. Similarly touching with cautery the location of blood vessels or nerves piercing the fascia sometimes produced a sharp localized discomfort.

### *Normal Nerve Root*

The normal, uncompressed or unstretched nerve root was completely insensitive to pain. It could be handled and retracted without any anesthesia. Forceful retraction over an extended period of time resulted in mild localized discomfort but never any significant pain.

### *Compressed Nerve Root*

Stimulation or even touching a compressed or stretched nerve root consistently produced the same sciatic distribution pain that the patient had experienced preoperatively. In spite of all that has been written regarding other tissues causing sciatica, the authors were able to reproduce sciatic pain only by stimulating a stretched nerve.

Sciatic pain could be produced by stimulating the nerve at the caudal dura, nerve root sleeve, the ganglion or the nerve distal to the ganglion depending on the site of compression. The ganglion, generally, was a little more tender than the other parts of the nerve root. The pain response was greatest when the nerve root was stimulated close to the compression. The pain could be totally eliminated by injecting 0.5 cc, 1 percent xylocaine under the nerve sleeve with No. 30 needles proximal to the site of compression.

In re-explorations the scar tissue was never tender but the nerve root itself was always tender and produced pain on handling.

### *Posterior Longitudinal Ligament*

Posterior longitudinal ligament was intimately connected with the posterior central portion of the annulus. It was tender and produced central low back pain. Because of its close proximity to the annulus it was not easy to differentiate between these two tissues.

### *Annulus Fibrosus*

Stimulation of the posterior part of the annulus always produced pain that was similar to the pain that the patient suffered. Application of local anesthesia relieved the pain. Application of pressure on the annulus together with pressure on the nerve root produced pain in the buttocks. The production of referred pain depended upon the exact site of the annulus being stimulated. The central annulus and posterior longitudinal ligament produced central back pain. Unilateral stimulation caused unilateral pain. This observation co-relates well with clinical observation of unilateral pain in posterolateral disc prolapse.

### *Vertebral Endplates*

Application of pressure on the vertebral endplate with some instrument did not produce pain. Curretage of the endplate frequently produced deep pain more sharper in quality.

### *Facet Joint*[5]

Tissues around the facet capsule are sensitive to forceful stimulation. The pain was sharp and localized to that region. The capsule was sometimes tender and its pain was referred to the back and to the buttocks. Never did the pain go into the leg. This local pain could be blocked by anesthetic infiltration.

The facet articular cartilage is never tender. In spinal stenosis with very narrow lateral recess the undersurface of superior articular facet comes directly in contact with the nerve root or the posterior surface of the disc (Fig. 8.6). Pressure over the disc at this site produced sciatica type pain. It is possible that the so-called facet syndrome could in fact be pain arising from the annulus itself.

### *Other Tissues*

The ligamentum flavum, epidural fat, posterior dura, nucleus, lamina and spinous processes were insensitive to local mechanical stimulation. Forceful stretch on the supraspinous and interspinous ligaments produced localized low back pain. The spinous process, lamina and the facet could be removed with rongeurs without anesthesia. Clinically, it was not possible to test for deep seated pain and narrow hydrostatic pressure deep in the center of the vertebra.

### *Chemical Factors*[15]

Backache and/or sciatica can also be produced by factors other than mechanical. It is now well-known that chemical factors can cause irritation of the nerve root sheath as well as unmyelinated nerve fibers which are present in the posterior longitudinal ligaments arising from sinuvertebral nerves. Following injury to the tissues, irritating chemical substances like lactic acid, potassium ions, polypeptide kinins, 5-hydroxytryptamine, prostaglandins, histamine, etc. are released. They can irritate normal as well as damaged tissues in the vicinity and cause inflammation. Inflamed tissue produces such substances which in turn can cause further irritation. They can also alter the local pH in the medium and cause irritation by altering the homeostasis. Damaged tissues are more susceptible to the action of such irritant chemicals. They produce backache and sciatica. The sciatica to be produced following such chemical irritation

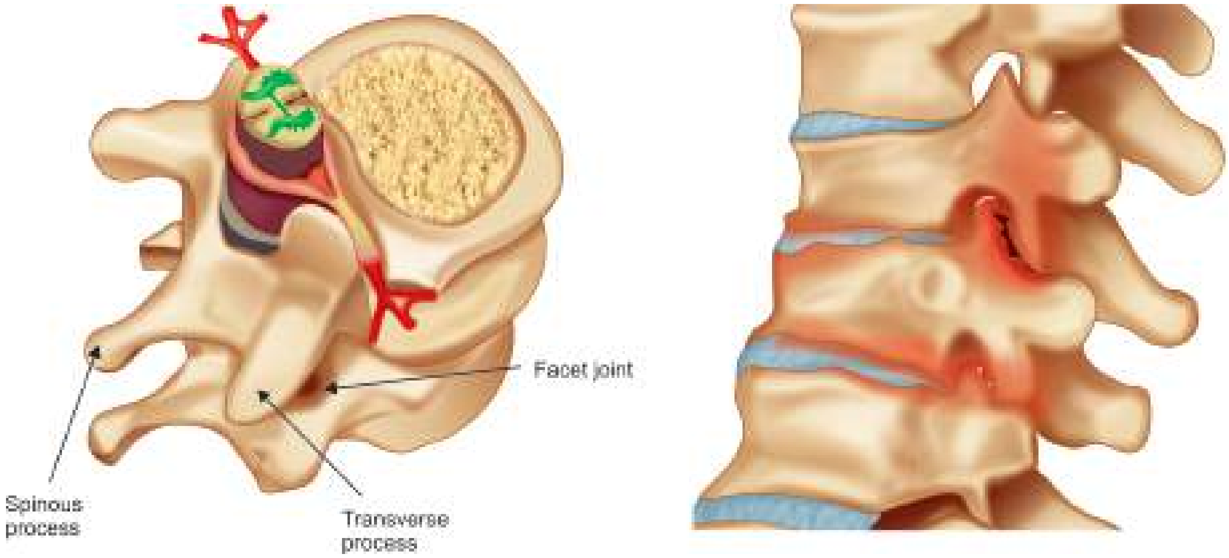



**Fig. 8.6:** In degeneration, the facet joint hypertrophies and the superior facet is migrated upwards with its tip impinging on the nerve root

takes some time and this will explain acute lumbago coming first and sciatic pain following after a day or two. Sciatic pain accompanying disc herniation is due to chemical irritation of the nociceptive receptor system which is then re-enforced by the pressure on the nerve root by the prolapsed disc. The vicious cycle can continue with twisting and tortional forces causing damage to the nerve root.

## Factors Causing Back Pain and Sciatica

### Healthy Spine

The spine with its intricate series of bones, joints, ligaments and muscles is in fact extremely resistant to injuries. Problems start propping up once the muscles supporting the spine become weak or the capsule of facet joints become lax and loose. Its ability to lubricate the joint or when the disc starts degenerating. The spine including lumbar portion is in constant motion. It needs activity to retain motion. But the activity required has to be properly organized. Disciplined exercise schedule done regularly helps to tone the muscles and keep the spine in shape. Regularly conducted exercise activity helps the spine to be non-susceptible very easily to wear and tear not related to age.

Unfortunately many people develop backache because efforts are not made to keep the spine in good shape. It is believed that four out of every five people in a given urban society will experience back pain at some time in their lives. Sedentary life style of the cities is the culprit allowing spine to get out of condition and lay the foundation for back pain.

### Unusual Activity

A person not doing regular exercises and following a sedentary life style in the city suddenly indulges into a spurt of activity. Imagine an executive working through the whole week in his office and lifting nothing more heavier than his smoking pipe suddenly decides to drive himself 100 km away for a weekend relaxation or an office clerk not accustomed to any strenuous activity more than traveling in the local train decides to participate in a two day cricket match. These are the subjects prone to develop sprain in the muscles and ligaments in the back and lay the foundation for chronic back pain.

### Occupational Back Pain

This is a serious problem among working people. It is most common between the ages of thirty and fifty years. Males and females are equally affected. Certain occupations have higher risk of back pain. The garbage collectors have the highest risk. They repeatedly perform the most difficult motion of twisting the spine while throwing a garbage basket into a moving carrier. Next in order are dock workers who strain their spine beyond limits by lifting sheer unusual weights repeatedly. Carrying 100 kg bags on the back is a regular feature. At times the weight lifted is well within the capacity of the person but lifting it inappropriately can create problems.

### Poor Posture

As viewed from the side the spine has a gentle S-shaped curve. This stance gives good posture to the body. If the curvature becomes abnormal the person starts assuming wrong posture resulting in back pain.

Excessive lordosis in the lumbar spine can be congenital. More often it is related to the postural habits of the person. Exaggerated lordosis can be due to protuberant belly or weak abdominal musculature. Lordosis produces stress on the joints hastening the process of degeneration (Fig. 8.7).

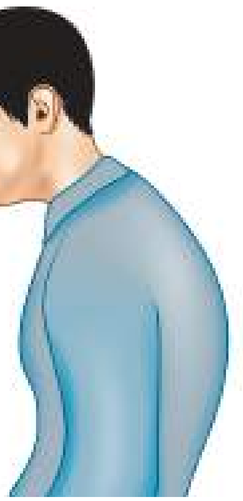


**Fig. 8.7:** Example of poor posture

**Fig. 8.9:** Protruding belly and overweight

## Occupational Poor Posture

Both at work and at home one gets into positions that can trigger back pain. The intradiscal pressure changes with the position of the spine. The pressure is least in lying down position flat on the back. The pressure increases three times on standing. While lifting a 20 kg weight the pressure increases five times. But if the same weight is lifted without bending the knees the pressure is increased to over ten times. Similarly, a weight lifted without warming up can pull ligaments and stretch the muscles abnormally. A computer operator sitting at the desk for hours together actually stresses the back (Fig. 8.8).

## Overweight

It is now common knowledge that a protruding belly causes exaggerated lordosis and stretches the ligaments. The weight bearing axis is disturbed. Biomechanics are deranged. Extra weight anywhere in the body produces additional stress on the spine. Overweight interferes seriously with the regular maintenance of fitness programs.

Overweight or obesity is defined as follows:

If the weight is more than 20 percent of the ideal weight, clinically speaking, one is overweight and should seek out a weight control program (Fig. 8.9).

In normal persons the muscle forces pass through dorso-lumbar region and the weight line of the body passes just in front of the lumbosacral junction (Fig. 8.10). With overweight the

**Fig. 8.8:** Occupational poor posture

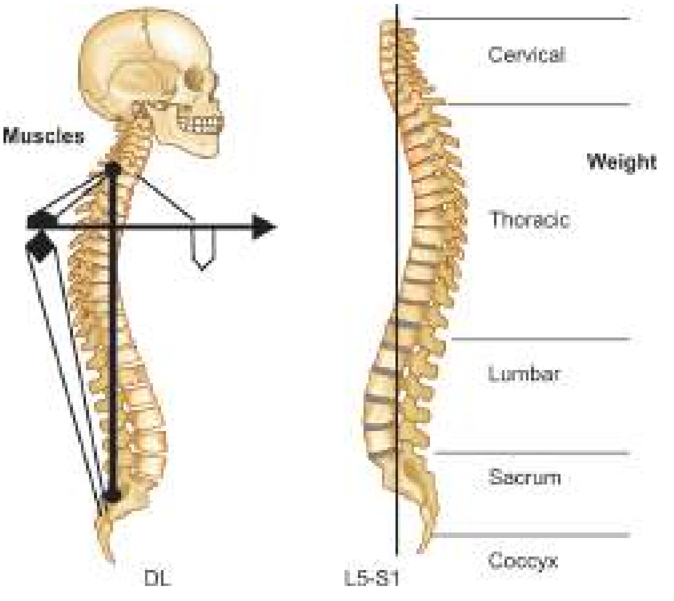



**Fig. 8.10:** Spinal factors: Relation of weight and muscle forces passing through the normal spine

lordotic curvature of the spine is altered giving rise to stress on the muscles and the intervertebral disc.

## Muscle Sprain

Eighty percent of the times the cause for muscle sprain can be pinpointed either to muscles, the intervertebral disc or the joints. Normally the muscles contract and relax in rhythm with the movements in the back. Under abnormal strain the muscles go into spasm tensing up to a point that it becomes hard as lump. Cramps in the muscles can be an expression of fatigue or with associated problems in the facet joints.

## Herniated Lumbar Intervertebral Disc[16-19]

This is the second most common cause of backache and sciatica. It is most common in 4th and 5th lumbar intervertebral discs. Natural process of degeneration starts after the age of thirty in the spine. Wear and tear adds to degeneration. A degenerated disc requires less force to bulge through the annulus. It is not necessary to have severe trauma to cause the intervertebral disc to herniate. Once the disc is degenerated even the morning maneuver of brushing the teeth bending over the sink can produce a herniation specially with a forceful cough.

## The Facet Joints

The facet joints lying in the posterior motion segment must align in rhythm to produce harmonious motion in the spine. Twisting and bending movements are done smoothly by the facet joints. A sudden jerk can cause the capsule of the joint to be pulled causing severe backache arising from the joint. Repeated stresses cause the capsule to be stiff and rough in the first instance and then it loses power to lubricate. The next step is degeneration in the facets with hypertrophy of bony elements and subluxation in the joints leading to laxity in the ligaments. The lax ligaments along with coronal orientation of the facets in a given segment produces disharmony of movement causing back pain. The syndrome of chronic back pain arises in the facet joints.

Given the whole spine, because of its vulnerability, most spinal problems occur in the lumbar region than anywhere else.

## Spinal Stenosis

Since its description by Verbiest in 1954[20-22] the spinal stenosis is now recognized as a definite syndrome causing backache and sciatica (Fig. 8.11). Essentially, it is degenerative process and is more common with advancing age. While treating a given case of herniated lumbar intervertebral disc after the age of 50 years one is obliged to rule out spinal stenosis. Although facet joint arthropathy and spinal stenosis is not synonymous both are interlinked and both are a common cause of chronic back pain. Sciatica is not common with spinal stenosis but this syndrome can be associated with PIVD giving rise to sciatic pain. Surgical alternatives are now available but one has to be cautious in comments about prognosis as the process of degeneration is relentless and can go on adding to discomfort in spite of a successful surgical intervention.

## Less Common Causes

Scoliosis, spondylolysis, spondylolisthesis, trauma, infection, tumors, rheumatic affliction of the joints, collagen disorders, osteoporosis can all give rise to back pain.

## Human Factor: Is Backache Different for Different People?

Different people have different threshold for pain. It can be related to cultural factors, personality traits and social and economic factors. In certain religious cults pain in fact can be an ecstasy.

A person with back pain cannot go to work. It upsets his state of mind. He starts worrying about a million life problems and then depression sets in. Even after a successful treatment a depressed person finds it difficult to appreciate the fact that he is relieved of back pain.

Back pain is intriguing and difficult to be measured. Chronic back pain patients are known to have become drug dependant. The doctor intensely desires to help the patient but he becomes frustrated when he is not able to achieve it. It is not surprising that many doctors refuse to see patients with chronic back pain.

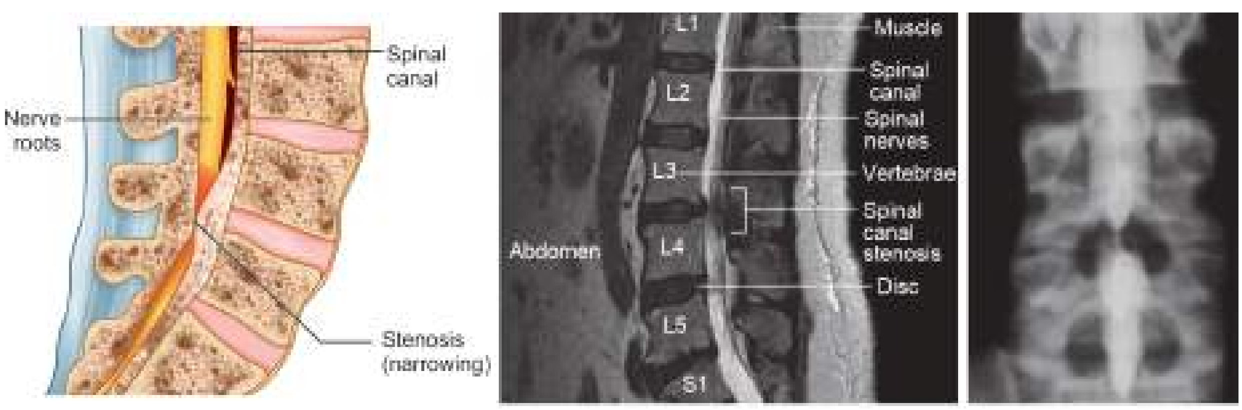
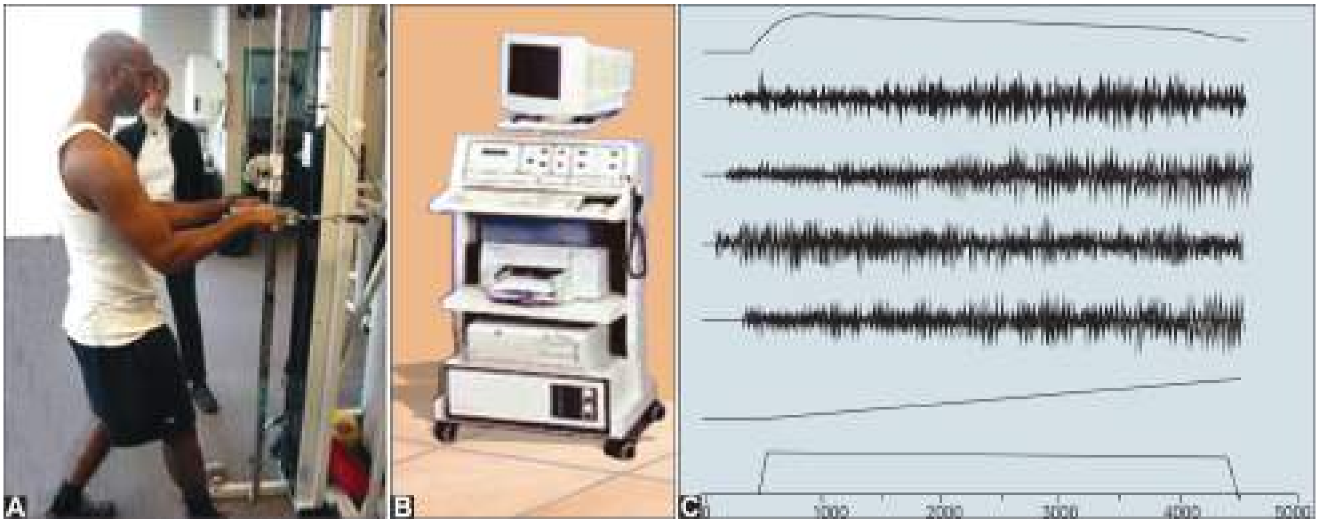



**Fig. 8.11:** Spinal stenosis: Essentially a degenerative process is more common with advancing age




**Figs 8.12A to C:** Computerized isokinetic testing to know the muscle strength and to predict future occurrence of back pain. (A) Isokinetic testing in progress; (B) Isokinetic testing machine; (C) Charting muscle power

## Can Backache be Predicted?

This is a new concept in the understanding of back pain and susceptibility of certain persons to it. It is now possible to determine a person's individual risk of sustaining injury to the back.

## Computerized Isokinetic Testing (CIT)

Through this procedure the strength of person's back can be measured. In sitting position the person extends backwards and forwards. The resistance is in direct proportion to the amount of torque created by the person (Figs 8.12A to C). The stronger the back, more is the resistance and more is the torque registered by the computer. The strength of the abdominal and spinal muscles is measured and compared with the readily available average figures. It must match with the body weight. Normally, the ratio between the back extensors and the abdominal muscles should be at least 3:2. The extensors alone should be able to produce a torque equivalent to the body weight. However, mine workers, fisherfolk, long distance runners and athletes can produce torque of up to 200 percent of their body weight. Peons, stenos, office clerks and office superintendents can hardly reach up to 70 percent of their body weight. Executives indulging in recreational activities like golf, swimming, playing tennis, etc. can almost reach the target.

If the torque as registered by the computer is only 70 percent then one has to do exercise regularly and at the same time follow certain precautions like warming up before doing exercises, not to feel fatigued at the end of the day and not to lift weights that he is not normally accustomed to.

If the torque falls below 70 percent then there is a definite risk of getting back pain.

## Ergonomics

This word is now used more frequently. Ergonomics involves fitting a given job to a given person. Most of our chairs are meant for average sized persons. Ergonomics are well utilized while making seats of the car. But if a woman is short she has to draw the seat in the front to reach the accelerator only to realize that the steering wheel almost touches her chest. Ergonomics play an important role in maintaining alignment of the spine and reducing the fatigue. The principle of ergonomics can be easily applied all the time for example if the cupboard is high, standing on a chair is easier that trying to approach the top otherwise. A worker doing his job bending forwards is quite comfortable when he rests one leg on a foot stool. The principle of ergonomics when applied judiciously can go a long way in preventing several cases of back pain with or without sciatica.

## Back Pain Arising from the Sacroiliac Joint[23]

Sacroiliac joint is a very stable joint. It is not vulnerable to minor trauma. It is a bucket handle type of joint and true pain in the sacroiliac joint must also be felt over pubic symphisis anteriorly. Violent trauma causing direct impact over the joint can produce damage to the joint causing true sacroiliac joint pain. But it is rare. True sacroiliac joint pain is more common in young ladies following deliveries in quick succession. During the later months of pregnancy the supporting ligaments become relaxed. During delivery the joints are susceptible to minor trauma. Following delivery the patient complains of pain over the sacroiliac joint area. The pain then radiates around the greater trochanter and then anteriorly over the anterior part of the groin. On examination clinically only tension signs are present and there are no objective findings.

**Fig. 8.13:** Backward extension of the leg producing pain can be due to three causes: (1) Sacroiliac joint pain; (2) Upper lumbar disc prolapse; and (3) Pathology in the hip joint. Other clinical parameters are essential for differentiation

The most reliable tension signs is manual compression of the pelvis in lateral position producing stress over the sacroiliac joint. The pain produced by resisted abduction of the hip from contraction of the gluteus medius can be due to sacroiliac joint or the hip joint itself but hyperextention of the hip giving pain can only be due to sacroiliac joint pain, or hip joint pain or pain from 3rd lumbar disc prolapse (Fig. 8.13) causing compression of the 4th lumbar root. This pain is usually felt anteriorly.

True sacroiliac joint sprain, subsides within a few days of rest along with analgesics and anti-inflammatory drugs. Very rarely intra-articular steroids give dramatic relief when pain persists.

### *Infection in the Sacroiliac Joint*

This was common at one time but now it is rare. In the past tuberculous infection in adults and pyogenic infection in the young was common. Both these infections are now rare in the sacroiliac joint.

At times the joint is affected by the Ewing's sarcoma of pelvic bone. Ewing's sarcoma has a special predilection for pelvic bone.

### *Iatrogenic Sacroiliac Joint Pain*

It is very common to remove bone grafts from the posterosuperior iliac spine. If one does not confine oneself to removing the bone within the gluteal lines the iliolumbar ligament may be divided causing pelvic instability and sacroiliac joint pain.

Among the inflammatory lesion ankylosing spondylitis involving the sacroiliac joint is still common showing haziness of the iliac joint. Less common causes of inflammatory sacroiliac spondylitis is Psoriasis and Reiter's syndrome.

## Ankylosing Spondylitis

Ankylosing spondylitis is not spinal rheumatoid arthritis. It is more common in males. The latex fixation test is usually negative. The disease is more common among relatives of the patient due to genetic involvement. HLA B27 antigen is present in 90 percent of the cases. The pathology first starts in the sacroiliac joint. But when it spreads diffusely into the spine it goes beyond the confines of back pain.

The joint space in oblique views is widened due to inflammatory destruction of subarticular bone. Then there is subchondral sclerosis obliterating the joint space and causing fuzziness.

In the early stages the patient present with stiff back and on examination the flexion movement is restricted. Only ESR is slightly elevated.

Once the disease spreads to the vertebral column the pathology becomes self evident.

There is no specific treatment to cure the disease. Awareness of the presence of disease must be in the mind of the doctor. The exercise is evolved towards amelioration of the symptoms of the patient. Usually, the patient has to take anti-inflammatory drugs for a long time along with judicious exercises to keep the spine as mobile as is possible.

### *Psoriasis*

Like in ankylosing spondylitis almost identical radiological changes can be seen in the sacroiliac joint in patients with psoriasis. HLA B27 antigen is present in 90 percent of the patients. The presentation is also with pain in the sacroiliac joint with stiffness in the back and limited flexion. Psoriasis patient can also develop mechanical backache like any one else and in all cases of backache psoriasis should not be considered as the causative factor. Sacroiliac joint arthritis can also be produced in seronegative peripheral arthritis with bowel disease and in Reiter's syndrome. Reiter's disease is nonbacterial urethritis, conjunctivitis and arthritis which is common in the sacroiliac joint. Its frequency in persons engaged in extramarital sex suggests infectious origin to the problem.

Although affections of the sacroiliac joint can present as backache it must be remembered that the sacroiliac joint because of its in built stability is immune to the day-to-day minor sprains.

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# 9

# Clinical Presentation of Lumbar Disc Herniation

*Sudhendoo Babhulkar, Sumeet Pawar*

## Introduction

Ninety percent of the population at some time or another get back pain to warrant medical attention. Most of the times the pain is musculofascial and the incidence is highest in the middle age. In most of them the pain resolves insiduously. Specific injury is only found in few cases.

In others an episode of lifting, bending or twisting brings on the pain. Discogenic pain is a dull ache usually deep seated and located asymmetrically.[1-4] Pain referred from the sacroiliac joint is also similar and like discogenic pain is at times referred to buttock and thigh. Muscle spasm although protective is so disabling that patient cannot bend forwards to brush teeth or put on shoes. The lumbosacral angle is straightened. Further persistence of pain depends on the development of instability. As disc degenerates instability is created and local pain persists. As the instability worsens the spinal roots may get stretched and one can then get true sciatic pain in absence of protrusion.

The production of sciatic pain depends not only on disc protrusion[5,6] but also on the size of the bony lumbar canal. If the canal is broad even a moderate sized disc prolapse may not produce sciatic pain but on the other hand even a small disc prolapse in a patient with narrow canal may produce severe symptoms.[7,8] Sciatic pain suggests stretching of the spinal nerve by the prolapsed disc. At times severe discogenic pain can simulate sciatica but it can never reproduce true sciatic pain. Hence the importance of sciatica in accurate clinical localization of the diseased disc cannot be underestimated. Danforth and Wilson (1925) [9] were the first to believe that sciatica was the result of compression of a spinal root. Since the paper of Mixter and Barr the etiology of sciatica is no more contested.

Coughing and sneezing increases intraspinal pressure and aggravates sciatica. Valsalva maneuver also aggravates sciatica. The shooting pain arises deep in the buttock and goes down the back of thigh into the posterior or posterolateral compartment of leg. From then on the 5th lumbar root pain may be felt on the dorsum of the foot or rarely in the great toe. Numbness rather than pain is felt more often in the great toe. The first sacral root pain stops at the ankle joint. Besides straightening of the lumbosacral angle sciatica produces scoliosis. In most people the posterolateral protrusion shifts the root medially and to prevent irritation, the patient bend away from the side of pain. (Convexity of scoliosis on the side of pain). If the disc protrudes in the axilla displacing the root laterally then the scoliosis is in the opposite direction to make the root loose. Percussion or firm palpation of the midline spine almost invariably aggravates sciatica. When the nerve is traumatized tenderness can be felt along the sciatic nerve. Ninety percent of the disc prolapses arise in the 4th and 5th lumbar discs involving primarily the 5th lumbar and 1st sacral roots within the distribution of sciatic nerve. The nerve root of each vertebra enters the foramen below the pedicle, the disc being below the pedicle it compresses the next lower root. The disc between L4/5 compresses the 5th lumbar root and the disc between L5/S1 compresses the first sacral sacroiliac (SI) root.

When a nerve root is displaced by the disc it is stretched and is under tension. Normally the roots of cauda equina are slack and wavy and movements of the spine or legs can accommodate for lengthening of roots without producing pain or discomfort.

In a case of disc prolapse when the root is tense any movement which stretches the nerve further produces sciatic pain.

## Neurogenic Claudication

Claudication means to limp and be lame. The term was used to describe condition of limbs in vascular occlusive diseases. For example, originally it was realized that trotting carriage horses would limp then stop and after a while would start trotting again. In 1858 charcot applied the term to describe the vascular occlusive condition in human beings. Dejerine (1911) introduced the term to describe spinal intermittent claudication. He described three cases in which activity was followed by limb weakness and appearance of pyramidal signs. Symptoms and signs disappeared with rest. The mechanism was thought to be exercise related spinal ischemia resulting in weakness. Bergmark (1950) had occasion to study histopathology of the spinal cord of one of his patients who had died. He showed destruction of anterior horn cells and demyelination of anterior pyramidal fibers, thus conclusively proving the existence of this entity in the spinal cord. Blau and Logue (1961) introduced the term further to describe intermittent claudication of the cauda equina. Henk Verbiest can rightly be described as the father of neurogenic claudication. He established relationship between lumbar spondylosis and neurogenic signs and symptoms in the legs. In 1949 he described three cases of lumbar canal stenosis who were relieved by decompressive laminectomy. He then (1954) described congenital narrow lumbar canal and devised calipers to measure the canal at operation. As a result of this work most spinal surgeons now imply neurogenic claudication as spinal stenosis. Ehni (1975) contributed important observations on neurogenic claudication.[10-19]

Based on this fact it can be assumed that sciatica is produced either by root ischemia or mechanical compression as described above.

## Blood Supply

The blood supply of the spinal cord comes from anterior spinal artery and its recognized radicular contribution. In the lumbar region four segmental arteries arise from the aorta and fifth one arises often from middle sacral artery. The radicular branches of these vessels enter the spinal canal to supply the roots, and cauda equina. Blau and Logue inferred that temporary and recurring disturbance of the blood supply to parts of the cauda equina was responsible for neurogenic syndrome.[5,6]

## Back Pain

Severe back pain is not common with neurogenic claudication. It is primarily radicular in nature and radiated down the affected limb. At times people have complained of pain going up the affected limb. Usually it starts in the buttock, goes along the back of thigh to much below the knee joint. Walking aggravates the pain and standing does not relieve the pain. Either sitting or bending forwards produces relief effectively. When symptoms are severe lying in supine position (extension of spine) causes pain which is described as restless legs. Tingling in the toes is common and may progress to numbness. Saddle pain in perineum and genitalia is common. Crouched up position gives relief during night.

## Sensory Dysfunction

There is sensory dysfunction at the height of pain which is described by the patients as poor circulation, cold feet, tingling, burning, etc. Sharp pain may also bring on hyperesthesia in the area of the involved root. With intense saddle pain genital hypoesthesia is common. Eighty-five percent of the discs involve L5 and S1 roots, But neurogenic claudication does seem to be more common with L4 root giving rise to weakness in knee extension. This results in sudden falls particularly if both limbs are affected. Intermittent sphincter weakness is known to occur in claudication pain. Lying prone for half an hour for myelography can cause temporary difficulty in passing urine and sexual potency can become less.

## Sciatic Pain

Classical lumbar root signs associated with disc are absent with neurogenic claudication. Back pain although present in more than 50 percent of the cases does not play an important role. Back pain in neurogenic claudication is posture related being brought on by extension of the spine and relieved by flexion.

The femoral nerve traction test is more indicative of neurogenic claudication involving L3 and L4 roots rather than straight leg raising test involving L5 and SI roots.

### Clinical Presentation of the Patient[4,20-22]

The great majority of the disc prolapses requiring operation occur during early middle age. Two thirds of the 500 cases reviewed by O’Conell (1951) were aged between 20 and 40 years. The incidence was more common in males in the proposition of two to one attributed mainly to more arduous nature of the man’s work. This fact has recently been confirmed by the author (Ramani 1983). In his series of 200 cases 140 were males. An accurate and detailed history is essential. Correct diagnosis can often be based upon it. Mode of onset, previous episodes, relation to effort or rest and nature of employment of the patient are important factors.

### Precipitating Factor

History of injury immediately or shortly before the onset of symptoms is elicited in not more than half the patients. The nature of injury may be a fall on the buttock or in the lumbar region of back or indirect like abrupt hyperextension of the spine. Commonly it is associated with muscular effort like lifting weight in flexed position. Recurrent episodes may follow minor episodes like sudden twisting and bending movements.

### Low Back Pain (LBP)

The onset of back pain or lumbago may be sudden after lifting a heavy weight or more insidious with slow progress after twisting injury to the back. Often the backache to start with is mild and is aggravated by exertion and relieved with rest. The pain is felt widely throughout the lumbar spine and the sacrum, usually bilaterally and feels deep. It spreads to sacro iliac joints and deep in the gluteal regions. At times the pain is felt over the iliac crest and in the groin. The spine becomes stiff due to muscle spasm and movements become painful with the result patient turns in bed cautiously. He tries to move the whole body as a block rather than perform a movement. If muscle spasm is bilateral then normal lordosis is obliterated and if it is unilateral then scoliosis and list of the spine is produced. Rest relieves pain. Between episodes of acute pain dull ache may persist in the back and tender spots can be elicited. Patients have often complained of feeling of insecurity in the spine at the level of disc prolapse. Back pain is usually the first symptom. Sciatica follows several days or weeks later.

## Sciatica

The most common symptoms of acute prolapsed disc are back pain and sciatica. Since 85 to 90 percent of the prolapses occur in the lowest two discs they involve primarily the fifth lumbar and first sacral roots. The sciatica is in the distribution of these two roots. It starts proximally and takes days or weeks to reach the periphery. It starts as continuing pain in the buttock and the back of the thigh, and then involves posterior of posterolateral part of the calf. Heel, sole or the dorsum of the foot may be affected. The pain is deep in the muscles and the bone. Movements of the spine and maneuvers like coughing, sneezing aggravates the pain and it becomes increasingly intense, shooting like electric shock down the leg. Patient walks with limp keeping knee flexed, pelvis tilted and exaggerated lordosis. He states that sitting is less comfortable than standing and he is prepared to have his meal standing. This may be because in sitting (i) the muscles of the back already in spasm feels more tense, (ii) in standing the abdominal muscles may provide additional support by increasing abdominal pressure and (iii) tenderness over the buttocks may make sitting difficult. The distribution of pain will naturally be different if the disc prolapse is at a higher level.

An important feature of the pain is intermittent exacerbation and remission. In some rare cases the sciatic pain may suddenly disappear leaving behind motor deficit or numbness due to ischemia or acute compression of the nerve.

### Paresthesiae

This is a subjective disturbance of cutaneous sensibility. It is fairly common if proper enquiry is made. It includes tingling, pins and needles and numbness. The skin over the area of distribution of nerve is unusually sensitive to light touch and pin prick. Paresthesiae is usually felt peripherally over the foot or posterior calf often aggravated by pain.

### Muscle Weakness

Slight degree of weakness usually evident on examination is usually not noticed by the patient. Foot drop is commonly observed by the patient as difficulty in clearing the ground while walking or climbing. Sudden fall may be due to knee giving way because of quadriceps weakness.

### Disturbance of Sphincters

Inability to pass urine as a sole symptom of disc prolapse has been described. However, it is rare for the patient to present in this way. More often they have other associated symptoms of cauda equina compression including loss of sexual potency.

### Cauda Equina Syndrome

In this syndrome, the severe pain is centered around the low back and the perianal region. Radicular symptoms may be masked. Difficulty in micturation or even frequency or rentetion with overflow may develop early. History of recent impotence may be elicited in males. Pain in the legs or sciatica is usually followed by numbness in feet and difficulty in walking. This syndrome is produced by large disc prolapse in the midline. It then compresses several nerve roots of the cauda equina.[15,16,23] The centrally placed visceral fibers to the lower abdominal organs are most affected. Perianal numbness and loss of anal reflex characterize advanced cauda equina syndrome. This syndrome does not respond to the conservative line of treatment. It does require an operation and once the syndrome is diagnosed the operation should be done expeditiously to avoid bladder complications.

### Intermittent Neurogenic Claudication

In this syndrome the symptoms are suggestive of vascular insufficiency in the lower extremities. Patients complain of pain the posterior aspect of both thighs and calves. The pain is made worse on walking or with exertion. The subjective complaints are similar to those associated with occlusive arteriosclerosis of aortic and femoral vessels. Physical examination reveals normal pulsations, normal temperature of skin and no evidence of ischemic changes. In prolapsed disc the symptoms of claudication are produced by stenotic configuration of the spinal canal, further aggravated by disc prolapse. In these cases myelogram sometimes show complete block and the lesion is most common at the level of L4/5 or at L3/4.

### Syndrome of Facet Hypertrophy and Tropism

The syndrome is not well understood by many. The author had described this in 1983.

It forms and important cause of backache. It is usually common in males and particularly those who are engaged in heavy labor. They have usually suffered from chronic backache for several years. They have degeneration in the disc followed by instability in the motion segment. This leads to chronic degenerative changes in the facet joints which become hypertrophied and coronally oriented.[1,21] The ligamentum flavum is buckled under the hypertrophied facet and resultant lateral spinal stenosis compresses on the cauda equina and the roots.[24] Instability in the motion segment is the hallmark of this syndrome. They usually complain of morning stiffness and have difficulty in getting out of bed. There is pain deep seated in the lumbar region. The pain in both legs is not true sciatic type but vague. Walking for a while seems to loosen the back with diminution in the intensity of pain. Climbing becomes difficult and standing and sitting is painful. On examination, the back is found to be stiff. Lordosis is obliterated. There is no scoliosis. Spinal movements are painful and restricted. SLR and femoral stretch tests are negative. There is no wasting or weakness in the muscles. Localizing signs are often absent and X-rays along with myelography clinch the diagnosis. Inspite of significant defect seen on the myelogram prolapsed disc is usually absent.

## Physical Signs

### Stance and Gait

The pelvis of the patient is tilted usually to one side with the result there is slight flexion of hip and knee joints and correction causes pain. The spine is tilted and there is scoliosis. Normal lumbar curve of the spine is usually obliterated. Spinal movements are greatly restricted particularly the flexion. There is hardly any rotational movement in the lumbar spine but attempts at rotation in the higher spine causes pain. The paravertebral muscles are prominent due to spasm and the buttock on the affected side has lost its shape due to wasting. Standing tip-toe on the affected side is not possible due to pain and weakness of plantar flexion. Movements are slow. Trunk dips to the affected side and patient turns to one side as a whole like a block of wood rather than twisting.

### Involvement of the Muscles

Tenderness over muscles in common in acute disc prolapse. It can be elicited usually over paraverteberal, gluteal, hamstrings and calf muscles. It is interesting to note that tenderness is pathognomonic of disc prolapse. It is not found in root compression from other causes. Hence, diminution of tenderness is a sign of relief from symptoms of disc prolapse, weakness in the muscles usually sets in after a week or so and continues even after recovery from pain. In long standing cases it is not unusual to find the whole leg to be wasted from disuse. Significant wasting is usually noted in the calf or quadriceps muscles. Fasciculation is not seen. Plantar flexion and inversion of foot is affected if SI root is involved. Dorsi flexion and eversion of foot is affected if L5 root is involved and extension of knee is weak if L4 root is involved.

### Sensations

Surprisingly in many patients with disc prolapse impairment of sensations cannot be satisfactorily demonstrated. All the same presence of hypoesthesia conforming with pattern of root distribution confirms the presence of organic lesion involving the nerve root. Gross impairment of sensations should raise the possibility of leprosy rather than disc prolapse. With involvement of one nerve root vibration and position sense is not usually affected.

### Reflexes

The plantar response is usually normal. Presence or absence of ankle or knee jerks is of great importance. In compression of SI root the ankle jerk is absent. The knee jerk is diminished or absent if L3 and L4 roots are involved. When L5 root is involved jerks are present. Anomalous reflexes may be due to multiple disc prolapses or to a previous healed disc lesion. It has been observed that an absent ankle jerk in prolapsed disc syndrome remains absent following surgical treatment of the prolapse disc.

### Tension Signs

This term was introduced by O'Connel in 1951[25] to describe those tests which aggravated root pain by increasing stretch or tension in them. Two tests which are important will be described here.

#### *Straight Leg Raising (SLR or Lasegue's Test)*

This is performed with patient lying supine and is well relaxed (Fig. 9.1). The leg is slowly raised with knee remaining extended. The leg is raised by the examiner by placing his hand under the heel. In young children, the leg can be raised to beyond 90 degrees. In young adults, it can be raised up to 90 degrees and in elderly patients up to about 75 degrees. In cases of prolapse of 4th or 5th lumbar disc elevation of leg produces pain. Limitation of straight leg raising correlates with severity of the disc prolapse and SLR improves as acuity of disc pain becomes less. The test should be performed slowly with the confidence of the patient. The test can be refined by raising the leg to just short of causing pain and then passively flexing the head or dorsiflexing the foot. Both these maneuvers will bring on the pain.

**Fig. 9.1:** Straight leg raising test is an important physical sign in backache and sciatica. The leg must be raised slowly with the knee extended

**Fig. 9.2:** The lumbar spine must be held rigid, if necessary, by flexing the lower hip. The upper hip is extended. A rotary strain is produced on the pelvis. The sacroiliac joint produces pain. In case of higher lumbar disc prolapse the pain is felt anteriorly on the thigh

**Fig. 9.3:** Compression applied manually over the pelvis while the patient is lying on his side can stress the sacroiliac joint and produce pain

*Femoral Stretch Test*

This test applies tension to the upper lumbar roots and is useful in neurogenic claudication. The patient lies in the lateral position with affected side facing above with knee and hip slightly flexed. It has two components. The hip is first extended thus creating tension in the iliopsoas and hence traction on the upper lumbar nerve roots (Fig. 9.2). The knee is then progressively flexed to increase the tension in the femoral nerve. The pain is felt in front of the thigh. In a small percentage (about 3%) but extremely important group of cases the protrusion is large and acute enough to cause severe compression of the cauda equina.

Diagnosis is difficult and the operation which otherwise should have been an emergency is delayed. Long standing or permanent disability results from paralysis of sphincters and distal muscles particularly foot drop. Compression develops suddenly and progresses very rapidly. Another feature of this syndrome is slight degree of pain and in some patients the cessation of pain with the onset of paralysis. Urinary retention and defective bowel control are the compelling symptoms over a background of chronic backache. Urgent treatment involving surgery is absolutely essential in such cases.

The most common roots to be involved in lumbar disc prolapse are L5 and SI, almost equally. Far out lateral disc protrusions are common in higher lumbar discs than lower ones.[1] In view of their position backache is not a common feature of far out lat. disc. He may complain of pain in the flank, gluteal region or in the groin. Pain may be very severe and episodic bringing tears in the eyes of the sufferer and is disproportionate to the neurological deficit.[26]

## Typical Presentation of 4th Lumbar Disc Prolapse

The L5 root is involved. The back is stiff and sore. There is scoliosis and obliteration of lumbar lordosis. Twisting movements and forward flexion is painful. The pain from the back is felt in the gluteal region around the greater trochanter, posterolaterally into the thigh, posterolaterally into the leg and at times on the dorsum of foot. Numbness is usually felt in the great toe and with weakness in extensor hallucis longus. There is difficulty in putting on the slipper or the slipper slips out from the foot. On examination the SLR is restricted even in chronic cases. There may be weakness in tibialis anterior and extensor hallucis longus muscles. There is no obvious muscle wasting and the sensory loss is difficult to be mapped. Ankle and knee jerks are usually normal.

## Typical Presentation of 5th Lumbar Disc Prolapse

The sacroiliac root is involved. With backache the lumbar lordosis is obliterated. Scoliosis is not pronounced. Forward flexion is very much diminished but twisting movements are not so painful as in 4th lumbar disc prolapse. The pain from the back is felt in the sacroiliac joint and from there into the back of buttock and in the fold at the inferior border of buttock. It travels along the back of thigh to the back of calf muscle and stops at the ankle joint. The pain is never felt over the foot. Paresthesias or numbness with feeling of pins and needles on the lateral side of foot including the lateral two small toes is common and sensory loss can be charted on the lateral side of foot although it is not appreciably noticed on the toes. Ankle jerk is absent or diminished and there is wasting in the calf muscles. Vibration sense may be diminished on the outer malleolus.

From the clinical history and presentation, it is not difficult clinically to different between the 4th and the 5th lumbar disc prolapse.

It is possible to elicit sacroiliac joint pain by applying manually pressure over the pelvis while the patient is lying on his side. The pressure can stress the sacroiliac joint and produce pain (Fig. 9.3).

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# Section 3

# Investigations

## Section Outline

# 10

# Role of CT in Diagnosis of Lumbar Disc Herniation

*Manoj Deshmukh, Jay Kotecha*

## Introduction

Before the advent of magnetic resonance imaging (MRI), computed tomography (CT) was considered to be the method of choice for diagnosis of lumbar disc herniation. However, at present MRI has largely replaced CT for the purpose of diagnosis of lumbar disc herniation, mainly because of its better soft tissue resolution and nonionizing nature. However, there are certain conditions where MRI is contraindicated (e.g. cardiac pacemaker, cochlear implant) or provides limited information (e.g. extensive metal implants in the spine). In such conditions, CT along with myelography is still considered the best imaging modality to diagnose disc herniation.

## Indications for CT Myelogram

Indications of CT scan for lumbar disc herniation in the modern era are conditions where MRI is contraindicated or where MRI provides limited information like in case of metallic implants (Figs 10.1A to C).

Contraindications to MRI include pacemakers, defibrillators, cochlear implants, neurostimulator, metallic foreign body in eye, programmable drug infusion pump, programmable hydrocephalus shunt, aneurysmal clips, ocular implants, and claustrophobia.

The advantages of CT myelography over MRI are low cost, easy availability, can be used in cases where MRI is contraindicated, better resolution than conventional imaging, artifacts due to metallic implants less compared to MRI, images obtained can be viewed with multiplanar reconstruction, and often yields better information about the bony structures than does MRI.

Ancillary findings like vacuum phenomenon and Schmorl's nodes are often depict better on CT (Figs 10.2 and 10.3).

The disadvantages of CT myelography over MRI are soft tissue resolution is inferior to MRI, exposure to ionizing radiation, CT myelography requires lumbar puncture.

## Technique of CT Myelogram

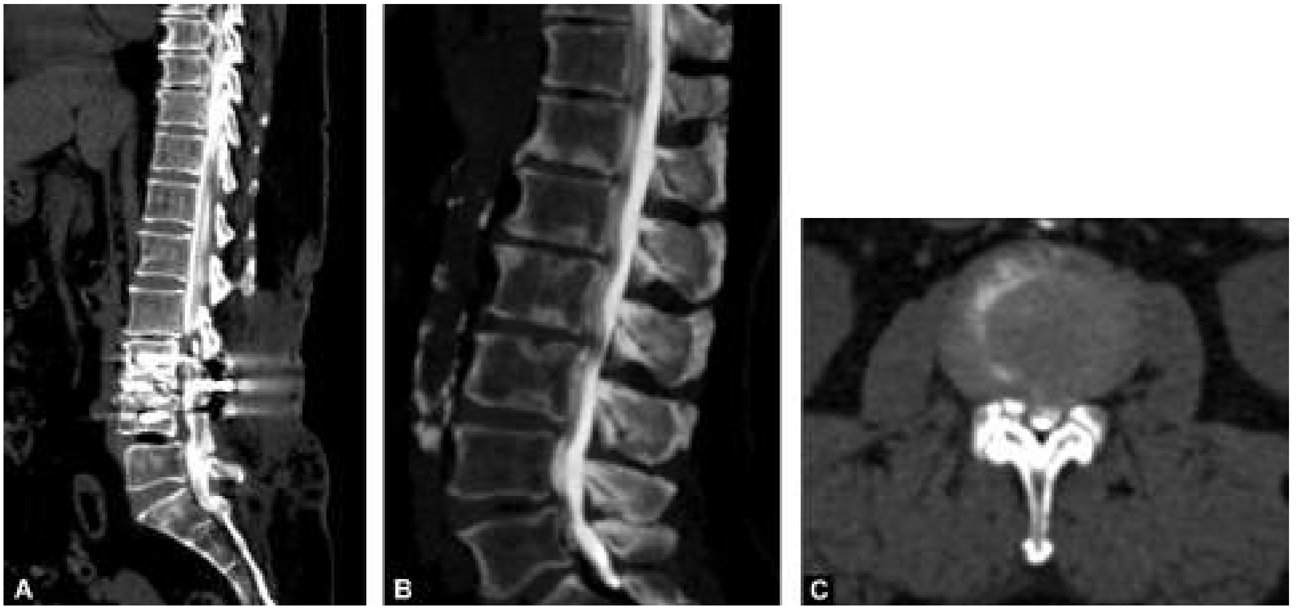
Before the advent of multidetector CT, it was required to tilt the gantry to obtain axial images in the plane of the intervertebral disc. But with the use of multidetector CT volumetric data is obtained which can be reconstructed in any plane, including the plane of the intervertebral disc.

Computed tomography myelography involves injection of nonionic contrast (6–8 mL) into the spinal subarachnoid space under fluoroscopic guidance and then obtaining thin section images of the spine.

Plain CT scans do not show the intrathecal component of nerve roots and the spinal cord is visualized clearly only where the subarachnoid space is wide. By injecting a low concentration of nonionic water-soluble contrast medium in the subarachnoid space, these structures can be visualized.

Computed tomography myelogram accurately depicts the extradural mass caused by herniated disc and clearly delineates its relationship to the cord and proximal nerve roots.

In postoperative cases, epidural fibrosis when extensive can completely obliterate epidural fat. In these cases CT myelography can outline the thecal sac or nerve root within the canal adjacent to the fibrous tissue.




**Figs 10.1A to C:** Sagittal and axial CT myelogram images in a patient with a pacemaker

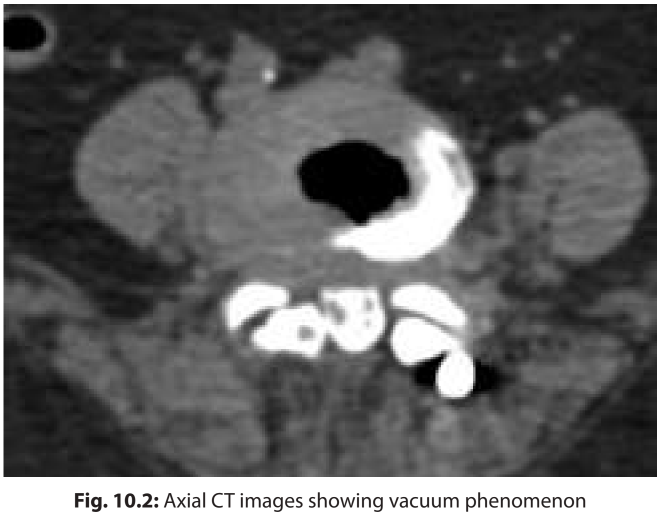


**Fig. 10.2:** Axial CT images showing vacuum phenomenon

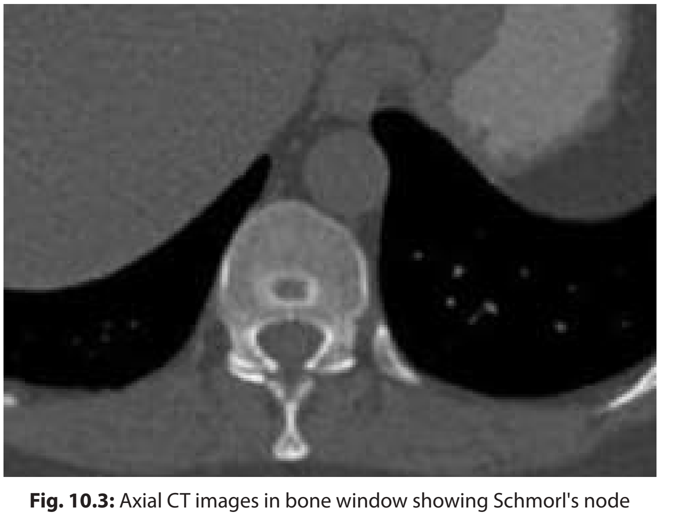


**Fig. 10.3:** Axial CT images in bone window showing Schmorl's node

With the advent of multidetector computed tomography (MDCT), multiplanar reconstruction (MPR) and volume rendering techniques (VRT) reconstruction is possible which gives 3 dimensional images, and further helps in reaching the diagnosis and demonstrating the lesion (Figs 10.4A and B).

The advantages of this technique over plain CT include:

- Better delineation of the herniated lumbar disc, can detect pathologies which are not recognizable on plain CT.

The disadvantages include:

- Invasive procedure requiring lumbar puncture, may give rise to postprocedural headache as a result of CSF leak.

## Anatomy and Physiology

The bony components of the spine include the body, pedicles, lamina and spinous, transverse and articular processes.

In the lumbar region, vertebrae have a transverse diameter which is more than its anteroposterior diameter. It is composed of peripheral dense cortical bone, which appears as a dense white line on a CT section, and central cancellous bone which has a lesser attenuation due to the marrow within. The cortex is discontinuous posteriorly at the midline where the basivertebral vein passes to anastomose with the anterior internal vertebral


**Figs 10.4A and B:** Volume rendered images showing a L4-5 disc herniation

veins. On CT, these appear as lucent lines coursing through the mid body and should not be mistaken for fractures.

The pedicles arise from the posterolateral aspect of the body and connect the lamina with the body. The transverse process in the lumbar area extends laterally and posteriorly.

The canal through which lumbar nerve courses is called "spinal nerve canal". The lateral end of this canal is referred to as the "intervertebral foramen".

Apophyseal joints are articulations between the superior and inferior articular processes of two adjacent vertebrae. These are true synovial joints. In the lumbar spine, the joints are oriented in a parasagittal plane in the upper lumbar area with an oblique orientation in the lower lumbar area.

Ligamentum flavum bridges the interlaminar space, being attached to anterior surface of the lamina above and posterior surface of the lamina below. Anterior and posterior longitudinal ligaments are not visualized on CT.

The lumbar intervertebral discs are larger and thicker than discs and the rest of the spine. They have CT attenuation values of 50 to 100 Hounsfield units and appear as soft tissue density structures. It is not possible to distinguish between the nucleus pulposus and annulus fibrosus on CT scan. The posterior margin of the lumbar discs has a slight concavity or appears flat. The lumbosacral disc in contrast to the lumbar discs has a linear or slightly posteriorly convex dorsal margin in healthy adults (Fig. 10.5).

The total adult CSF volume is about 150 mL (50% intracranial, 50% spinal). About 500 to 750 mL of CSF is produced each day (0.4 mL/min, 20–30 mL/hr). Adult opening pressure is normally 7 to 15 cm fluid, >18 is abnormal (although for young adults, can be slightly higher with normal <18–20 cm).

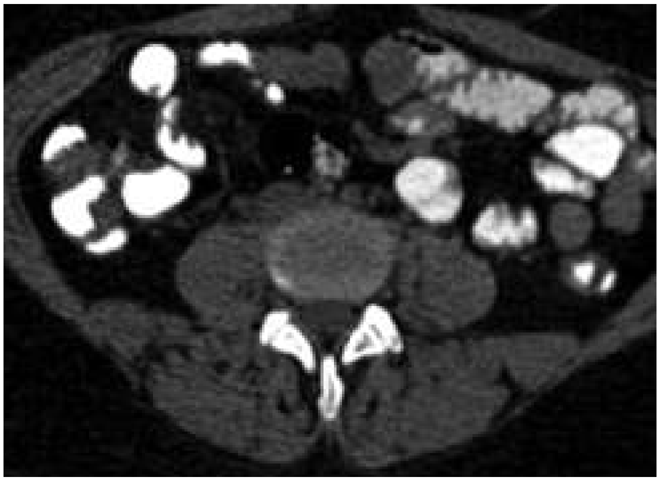


**Fig. 10.5:** The epidural space contains fat, vessels and neural elements. The nerve roots of the cauda equina are usually seen as isodense punctate structures within the thecal sac

## Pathology

The spectrum of lumbar disc herniation can vary from disc buldging, disc herniation in form of protrusion, extrusion or disc migration.

*Disc bulging:* The diagnosis of disc bulging is made when there is smooth circular extension of the annulus beyond the vertebral endplate (Fig. 10.6). Disc bulge can occur along the entire circumference or it can be focal.

*Disc herniation (protrusion):* This occurs when there is localized weakening or partial disruption of the annular fibers (Fig. 10.7). The herniated disc can be posterolateral (paracentral, 60%), directly posterior (central, 30%) and lateral (foraminal, 10%).

*Disc herniation (extrusion):* This occurs when there is complete tear of the annulus along with extrusion of the nucleus pulposus.

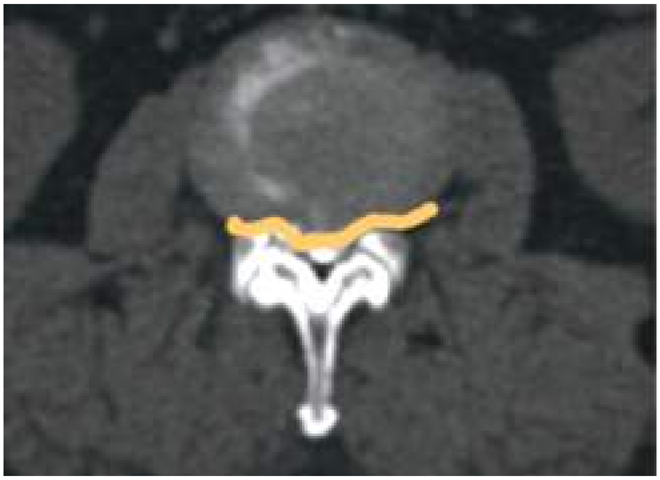


**Fig. 10.6:** CT image showing smooth circular extension of the annulus beyond the vertebral endplate suggestive of a disc bulge

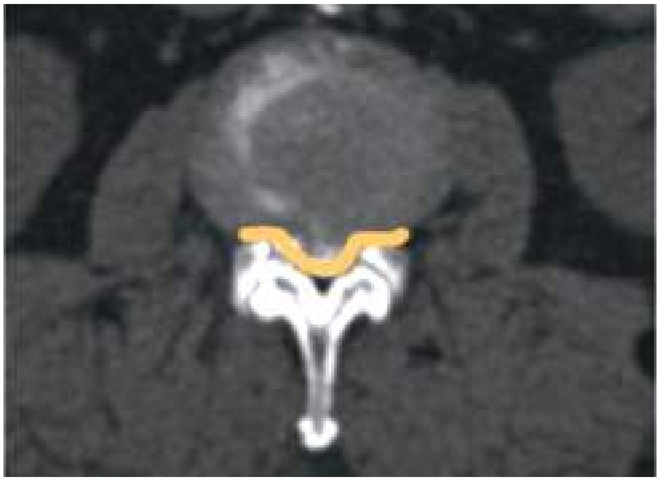
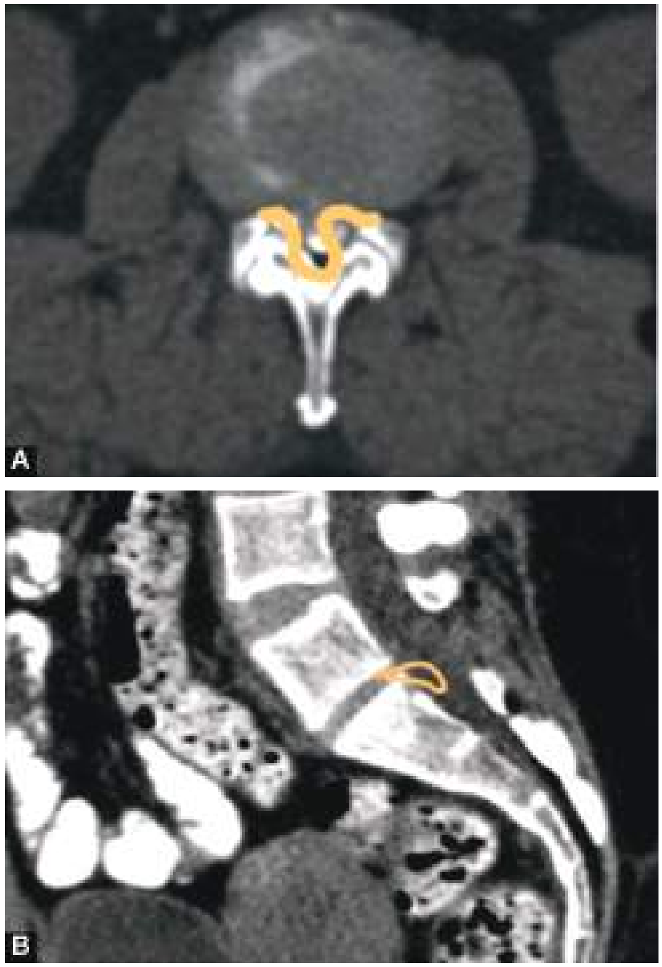


**Fig. 10.7:** Disc protrusion in axial CT image




**Figs 10.8A and B:** Disc herniation in axial CT image

In case of extrusion, the herniated nucleus pulposus is still in contact with in the disc of origin (Figs 10.8A and B).

*Disc sequestration:* This occurs when the extruded nucleus pulposus looses its contact with the disc of origin and migrates upwards or downwards in the extradural space (Fig. 10.9).

The diagnosis of herniated disc on CT is based on differential density of disc from the spinal dura, nerve roots and epidural fat. Generally, the disc is hyperdense compared to these structures.

Identification of herniated disc may be difficult in the following conditions:

- *Calcified herniated nucleus pulposus:* Herniated disc may undergo calcification which may be speckled or dense and homogeneous.
- Such all lesion may be indistinguishable from a bony spur.
- *Sequestrated disc:* Recognition may be relatively easy when the fragment is large. Small fragment may lead to erroneous interpretation.
- *Recurrent herniated nucleus pulposus:* In an operated patient, it may be difficult to distinguish herniated disc from postoperative fibrosis or scaring as both of them have got similar HU.

## Possible Complications

The most common complications occur due to meningeal reactions, spinal headache, vomiting, vertigo, and neck pain. This is often due to CSF loss due to dural injury from the puncture. This can be minimized by using a small needle. It is also useful to direct the bevel of the needle parallel to the longitudinal fibers of the thecal sac during puncture. The limiting factor for needle gauge is the viscosity of the contrast material.

Other complications include nerve root damage, meningitis, epidural abscess, contrast reaction, CSF leak, or hemorrhage.

Unusual complications include damage to the spinal cord, due to a low conus or tethered cord with a lumbar approach.

**Fig. 10.9:** Complete disc sequestration

If there is inadvertent injection into the subdural space it is usually best to discontinue the study and reschedule it two weeks later. This is because the enlarged (contrast containing) subdural space fills the region of the canal that previously contained subarachnoid space. It is thus difficult to reposition the needle tip into the subarachnoid space.

If a small subdural injection is discovered early, it may be possible to reposition the needle and continue with the study.

## Conclusion

Presently, MRI is the investigation of choice for diagnosis of lumbar disc herniation. However, certain conditions where MRI is contraindicated or where information obtained by MRI is limited due to artifacts, CT myelography is used. CT myelography is more sensitive compared to plain CT for the diagnosis of lumbar disc herniation.

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# MRI in Diagnosis of Herniated Lumbar Intervertebral Discs

*Makarand Kulkarni, Palak Popat*

## Introduction

In the history of medicine, it seems like yesterday when magnetic resonance imaging (MRI) was first introduced as a diagnostic tool in clinical medicine.[1] Also, among its diversified applications that we see today, its birth was heralded with imaging of the brain and spine, with even the lowest field strength magnet of 0.2 Tesla adequately image the same. What we want to point out to, is the fact that spine imaging by MRI is well studied and well documented with good accuracy. And as the ball has set rolling, since the advent of MRI, there have been lightening speed advances in the strength of magnet going up to 3 Tesla (with 7 Tesla magnets under trial) newer and faster sequences and newer techniques, all of which have now made a spine MRI easily available, with faster imaging and with better soft tissue characterization.

In this chapter, we give you an overview about reading the MRI, specially dedicated to the nonradiologist clinician to review his case.

An MRI for lumbar spine for the disc may be advised in a variety of situations[2,3] such as:

- Uncertain diagnosis
- To narrow the list of differential diagnosis
- To assess the severity of the diseased disc
- Complications due to the primary pathology
- Decide upon medical versus surgical management
- Assess the postoperative spine for road to recovery and failed back syndrome
- Imaging the pediatric spine.

## Relevant Anatomy

The vertebrae have a cortex and a central medulla which may be predominantly fatty or hematopoietic, with the imaging appearances depending on its constitution. The calcified cortex appears dark on all sequences. So the bones have a dark cortex on all sequences. The fatty marrow appears relatively hyperintense on T1W and T2W sequences with suppressed signal (i.e. dark) on fat saturated sequences such as STIR. Whereas hematopoietic marrow appears isointense and hyperintense on T1W and T2W sequences respectively. Often there is a heterogeneous appearance to the signal intensities as seen in physiological conversion, marrow reconversion processes and hematologic malignancies. Infective and neoplastic conditions have an iso to hypointense signal appearance on T1W and hyperintense on T2W sequences.

The ligaments such as anterior and posterior longitudinal ligaments are dark on all sequences, and so are the blood vessels as they are seen as a signal void.

The spinal cord is isointense on all sequences bathed in CSF which appears dark and bright respectively on T1W and T2W sequences.

The rest of the tissues portray a signal based on certain tissue properties such as extent of inflammation, hence edema reflecting its water content. Properties also depend on the cellularity of a given tissue.

## MRI Anatomy of the Disc

The height of the disc may indirectly reflect its healthy versus pathological state.

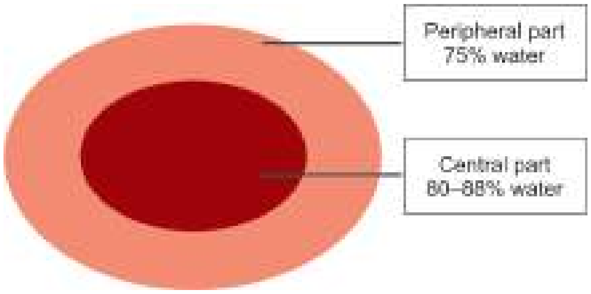



**Fig. 11.1:** An illustration showing the relative composition of water in the first two decades. With aging, both nearly contain about 70% water

The normal disc has a slight central concavity posteriorly except for the L5-S1 disc which may be uniformly of ovoid shape.

A disc has a central part which comprises of gelatinous nucleus pulposus which is normally hydrated, and the inner fibrocartilaginous annulus (Fig. 11.1), the two together inseparably appearing hypointense on T1W and hyperintense on T2W sequences respectively.

The fibrocartilaginous peripheral annulus fibrosus component alongwith the outermost Sharpey's fibers appear hypointense on all sequences.

The intervertebral disc in an infant shows a high signal intensity on T2W images except for a central low signal intensity area representing notochord remnants.

After childhood, a fibrous intranuclear cleft noted as a normal aging process on T2W sequences.

## The Pathological Disc

There are stages of a disc involvement, the earliest being disc dehydration. At the molecular level, this occurs as a result of decrease in water binding capacity, disintegration of proteoglycans and increase in the collagen content.

Here the disc loses its peripheral and central differentiation, beginning along the dorsal and ventral margins gradually proceeding towards the center with eventually by around the third to fourth decade, the disc homogeneously appears dark.

A disc degeneration begins with a tear in the annular fibers which have been classified into three types of annular tear:

1. Type I: Concentric (Fig. 11.2)
2. Type II: Radial (Fig. 11.3)
3. Type III: Transverse (Fig. 11.4)

Type I and II may be incidental findings and may occur as a part of normal aging, however, Type III radial tears are often associated with degenerative discs.

On imaging, tears appear as hyperintense on T2W as well as fat saturated sequences and may occasionally enhance on post-gadolinium fat sat T1W images.

### Disc Degeneration

Defined on MRI as loss of disc height with decreased signal intensity on T2W images.

**Fig. 11.2:** A result of concentric delamination of the longitudinal fibers of annulus fibrosus

**Fig. 11.3:** A result of tear in a direction perpendicular to the longitudinal fiber orientation involving all layers of the annulus

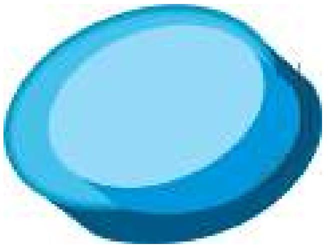


**Fig. 11.4:** A tear involving the Sharpey's fibers at its insertion with ring apophysis

May be associated with Kummel's disease (intradiscal gas due to vacuum phenomenon).

### Disc Bulge

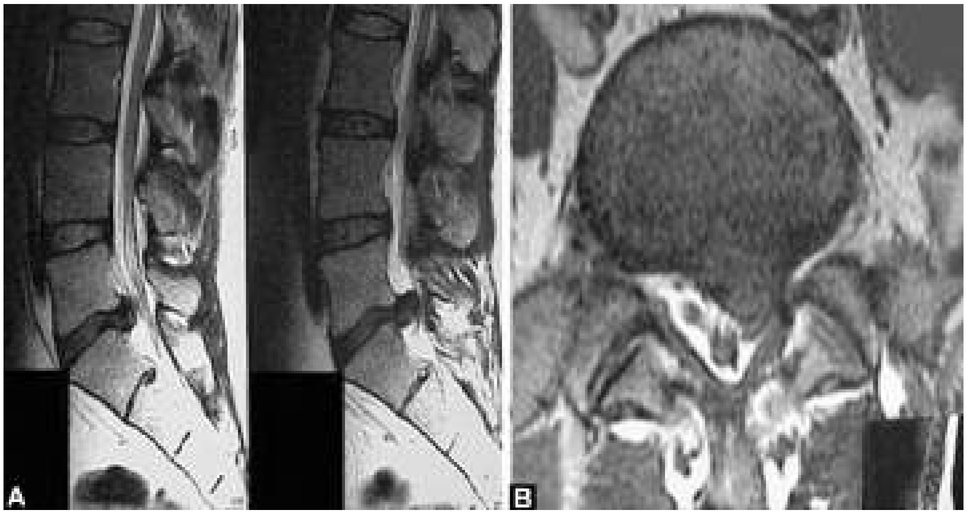
It refers to the bulge of the disc outwards beyond its vertebral margins due to loss of elasticity of nucleus pulposus. Mild bulges are often seen in asymptomatic population over 20 years of age seen as a loss of its posterior concavity.

Moderate bulges are seen as diffuse, nonfocal, circumferential and symmetric.

May be associated with annular tears and can still be asymptomatic.

### Disc Herniation (Herniated Nucleus Pulposus: HNP) (Figs 11.5A and B)

It refers to the focal protrusion of disc material beyond its vertebral margin through an annular tear (Fig. 11.6). A third of patients with this finding may still be asymptomatic. Ninety percent of lumbar disc herniation occur at L4-L5 level, of which 93 percent are intraspinal, 3 percent intraforaminal and 4 percent are extraforaminal or far lateral.




**Figs 11.5A and B:** MRI showing large disc at L5-S1 level

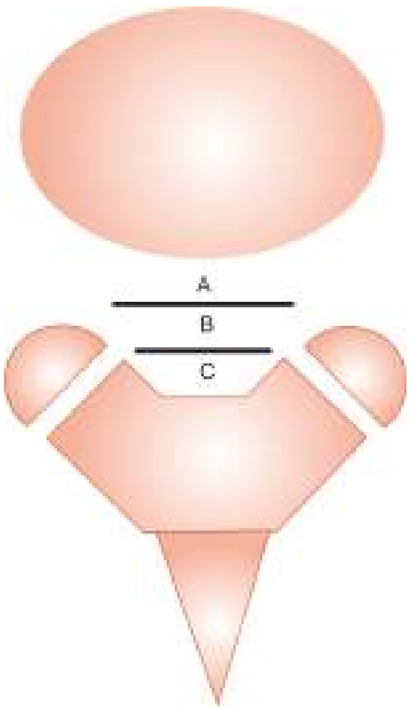



**Fig. 11.6:** Represents the extent of disc herniation with canal compromise (A: Mild, B: Moderate, C: Severe)

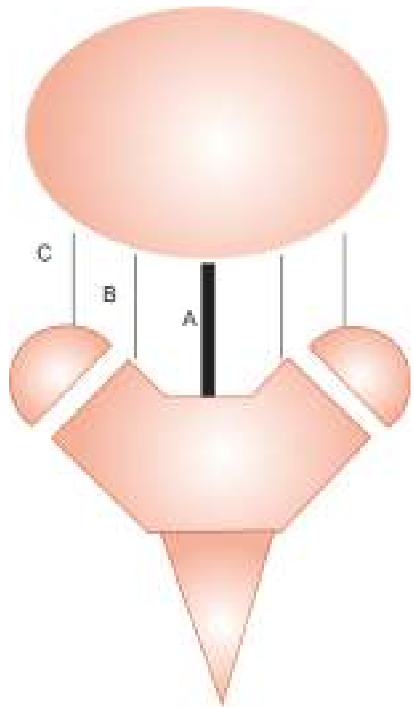



**Fig. 11.7:** Represents the location of the disc with the midline position as central, A: As paracentral, B: As lateral or foraminal and C: As far lateral or extraforaminal

The position of the disc can be very well appreciated on MRI. Central disc herniations beneath the posterior longitudinal ligament are uncommon, and when present, have poorer outcomes postdiscectomy.

Paracentral herniation, the most common that we see compress the traversing nerve root with resulting radiculopathy (Fig. 11.7). We would like to remind you that at the level of a disc, it is the superior level nerve root that traverses, while the inferior nerve root level that exits.

Foraminal herniations and extraforaminal herniations too are uncommon and may compress the dorsal root ganglia with severe radiculopathy and the sympathetic chain with symptoms of reflex sympathetic dystrophy respectively.

## Fallacies of MRI

Often a patient presents with severe discogenic pain but on MRI, it is a miniscule bulge and symptoms do not correlate. You are then possibly dealing with a high grade or full thickness radial tear which allows the pulposus to herniate out and impinge upon the sinuvertebral nerve plexus that lies in the outer third of annulus causing severe pain.

On MRI, the high signal of the annular tear is often associated with the fibrosed low intensity protruded disc.

Atypical herniated discs may show high signal on either or on both T1W and T2W images.

They may show ring enhancement on contrast administration if it contains vascularized fragments.

Differentials may include normal variants such as conjoined nerve root, dilated root sleeve, and perineural cyst.

### Disc Migration

It refers to the migration of the herniated fragment either cephalad or caudad with reference to the parent disc level, best appreciated on sagittal sections. The disc however maintains continuity with its parent disc.

### Disc Sequestration

It refers to the separation of the herniated disc from its parent disc. It may atypically lie posterior to the thecal sac, may migrate down a root sleeve and may penetrate the posterior longitudinal ligament. When vascularized, it may intensely enhance, and in the given setting, its importance lies in differentiating it from a neurogenic tumor or ependymoma.

## Ancillary Features of an Overall Degenerative Process: The Mimics of a Discogenic Pain

### Vertebral Degeneration

Type I with hypointense and hyperintense marrow due to fissuring and vascularized fibrous tissue.

Type II with fatty marrow replacement appearing isointense to hyperintense on both T1W and T2W sequences.

Type III marrow with dark signal on both T1W and T2W sequences subjacent to severely degenerated discs.

### Facetal Arthrosis

Refers to the osteoarthritis of the synovial lined articulation of the articular processes in the form of fibrillation, erosion, denudation of the articular cartilage in that order and with new bone formation.

### Synovial Cysts

A cyst adjacent to a degenerated facet joint, may contain clear fluid, gel like substance, a fluid-fluid level, hemosiderin or air. The solid component and the cyst wall may enhance on contrast administration.[4]

### Spondylosis

Refers to various combinations of osteophyte formation arising from the site of insertion of the Sharpey's fibers (i.e. few mm away from the discovertebral junction initially aligned horizontally and then vertically) and Schmorl's nodes which are intravertebral disc herniation and endplate sclerosis.

### Spinal Stenosis

May be congenital, acquired or a combination of the two.

Acquired causes are mostly a result of disc pathologies, with other causes being facetal arthropathy and ligamentum flavum laxity or hypertrophy.

## The Postoperative Spine

Imaging of these cases must always be performed with a contrast enhanced fat sat scan.[2,3]

The expected postoperative changes can be categorized as osseous and soft tissue changes.

### Soft Tissue Changes

*Epidural fibrosis:* Occurs in most patients, with enhancing soft tissue replacing the epidural fat. Early and intense enhancement is often noted in the initial year of surgery, and may be persistent for years after surgery.

*Nerve roots:* Intrathecally, the dorsal root ganglia and extraforaminal nerve roots may all enhance pre- and postoperatively due to lack of blood-nerve barrier.[3]

*Discs:* Enhancement of the posterior annulus is noted in almost 80 percent patients after discectomy with central part enhancing in less than 20 percent patients.

*Endplates:* Marrow enhancement may occur only in complicated discectomy or in discitis.

## Failed Back Surgery Syndrome

This entity is coined for that spectrum of operated spine cases who either had persistent symptoms, relieved but soon present with recurrent symptoms, or worsening symptoms bearing an incidence of about 10 to 40 percent. Special light is thrown on this topic due to the challenges faced by the radiologist in determining one of the myriad causes for this entity as well as for the neurosurgeon for whom the goal is achieved suboptimally, so also to assess cases who can gain relief by an added procedure or revised surgery.

### Causes

#### *Surgical Causes*

*Very common*

- Recurrent/persistent HNP at same or another site.

- Epidural fibrosis
- Facet arthrosis/spinal stenosis.

*Common:*

- Neuritis-persistent enhancement beyond 6 to 8 months of surgery.
- Referred pain from another site.

*Uncommon:*

- Discitis
- Osteomyelitis
- Arachnoiditis
- Epidural abscess/hematoma
- CSF fistula.

*Nonsurgical Causes*

- Common
  Associated spondylolysis and spondylolisthesis
  Facetal arthrosis
- Uncommon
  Spinal stenosis
  Spinal, meningeal, nerve root inflammation
  Tumors, cysts, sacral meningocele.

### Imaging of the Failed Back Surgery Syndrome

Immediate postoperative status is a difficult period for differentiation of the etiologies, since most of them appear as an enhancing extradural soft tissue.

It is crucial to correctly differentiate between an epidural scar versus residual/recurrent HNP in the subacute and chronic postoperative status for the neurosurgeon since a revised surgery for the disc can alleviate the symptoms.

The scar appears as an intensely early enhancing soft tissue whereas disc fragment shows no enhancement or occasionally shows delayed rim enhancement.

Arachnoiditis may be well identified with the 'naked sac sign' (empty sac), intradural fibrosis, nerve root clumping, loculation, sacculation, root retraction and adhesions.[1]

### The Pediatric Spine

Low back ache has a different spectrum of etiologies compared to adults, with congenital being the most common cause.

Due to the lack of radiation in MRI, apart from its greater soft tissue characterization, MRI is the modality of choice in pediatric population.

Disc herniation *per se* is an uncommon cause for back pain, and for the few cases, it is mostly post-traumatic due to sudden stress rather than a degenerative cause. The incidence for disc herniation is however increasing in the adolescent population.

## Conclusion

With the help of MRI, we exactly know with documental proof, the extent of the disease, we are given an insight into which patient may benefit medical versus surgical management, prognosticate the postoperative relief of symptoms as well as have a look into the spine of the not so fortunate cases with failed back syndrome.

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# Image Diagnosis of Lumbar Disc Herniation

*Kyeong-Sik Ryu, Chun-Kun Park*

## Introduction

Lumbar disc herniation (LDH) is defined as focal displacement of nuclear, annular, or endplate material beyond the normal peripheral margins of the disc delimited by the margins of the vertebral body endplates.[1]

In most of LDH cases, it is essential to take a medical history and carry out a physical examination in their diagnosis. Generally, the patients present with dull or sharp low back pain intensified by bending, coughing, or sneezing. The pain, so called 'sciatica', usually radiates from the buttock into the leg or foot, and it can combine with burning, tingling, and numbness.[2-6] In the serious cases, weakness, sensory dysfunction of lower extremities, or sphincter dysfunction may appear.

A variety of imaging methods have been applied to determine the characteristics of LDH. Nowadays, magnetic resonance imaging (MRI) is the most popular imaging tool and a study of choice for LDH. Computed tomography (CT) is an alternative imaging modality, which can be performed quick and painless. These days, myelography has been almost abandoned in diagnosis of LDH because of its invasiveness and lack of clinical usefulness, however when this procedure is combined with CT (myelography-CT: myelo-CT), it may become one of the best diagnostic procedure to assess the severity of nerve root compression caused by various pathology. This chapter introduces the imaging procedures in the diagnosis of LDH, and defines their clinical usefulness.

## Plain Radiography

Plain radiograph is an imaging modality used in the first place as a primary procedure to observe changes of bony structure in the lumbar spine. It is cheap and universally available, but impossible to directly visualize the soft tissues such as disc, neural structure, and muscles or ligaments. Plain radiographs for lumbar spine consist of anteroposterior (AP), both side oblique and lateral views. In plain views, age-related spinal degeneration including osteophyte, bony spur, endplate sclerosis, vacuum in the disc space, narrowing of the disc height and/or ligament calcification can be demonstrated.

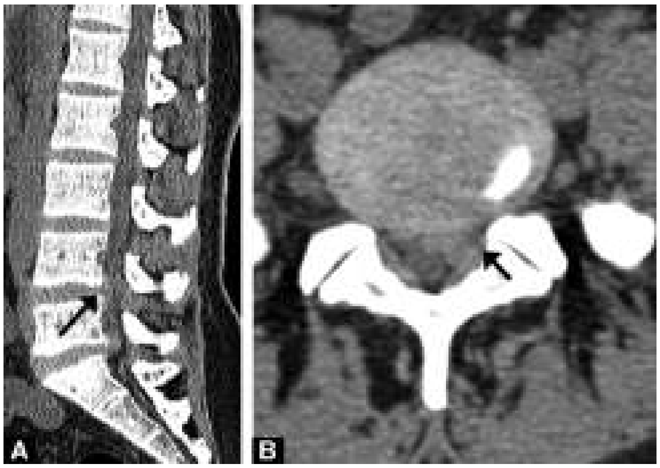
In lumbar disc herniation, diagnostic information from plain radiographs is a few compared to the other imaging studies. Narrowing intervertebral disc height may be one of a few detectable signs suggesting a possible presence of a disc herniation. Infrequently, a calcified rim outlining the herniated disc fragment can be found. In chronic disc herniation, osteophytes in the posterior vertebral body or foramen can be presented.

Scoliotic posture on AP view is more frequently found in coincidence with LDH than others, which is considered as a compensatory attempt of the body to relieve nerve irritation.[7-9] Loss of lordosis can be found due to paraspinal muscle spasm (Figs 12.1A and B).

## Computed Tomography

A computed tomography (CT) scanner takes a series of cross-sectional images from many different directions and creates

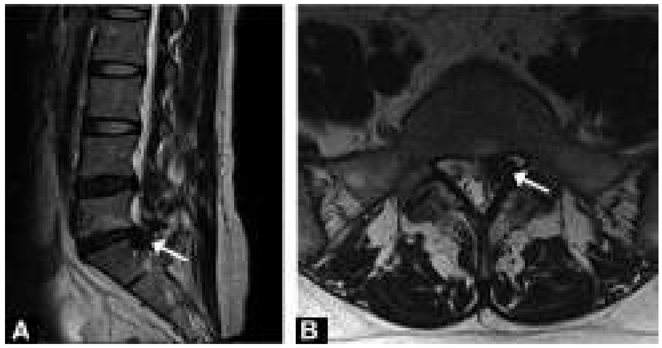
**Figs 12.1A and B:** Plain anteroposterior X-ray. (A) Compensatory scoliosis posture in coincidence with lumbar disc herniation; (B) Loss of lordosis on lateral film can be found due to paraspinal muscle spasm



**Figs 12.2A and B:** Computed tomography (CT); sagittal reconstruction image (A) showing herniation of disc into spinal canal at L4-5 (black arrow). Axial image (B) showing a paracentral disc herniation to left side (black arrow). But its delineation is obscure

three-dimensional images of the spinal column.[10-12] CT has the distinct advantage of being noninvasive and provides direct anatomic information. CT can provide precise information of bony condition. Calcified disc, limbus fracture, herniated disc combing with osteophyte can be easily detected observing CT images. The presence of gas around the herniated disc can be also discovered.

Because its delineation of soft tissues on CT images is somewhat obscure, very small herniation can be missed (Figs 12.2A and B). In such case, addition of contrast material into the thecal sac (myelo-CT) can remarkably improve the accuracy to define obscure the herniated disc on CT.



**Figs 12.3A and B:** Magnetic resonance imaging (MRI); T2-weighted sagittal reconstruction image (A) showing disc herniation into the spinal canal at L5-S1 (white arrow). T2-weighted axial image (B) showing a paracentral disc herniation to left side (white arrow)

## Magnetic Resonance Imaging

Magnetic resonance imaging (MRI) is a noninvasive procedure, and the best among the imaging tools to visualize the soft tissues of the spine including disc, joints, neural structures, muscles, ligaments, and blood vessels. MRI is a study of choice to identify a location of the herniated disc and affected nerve roots.

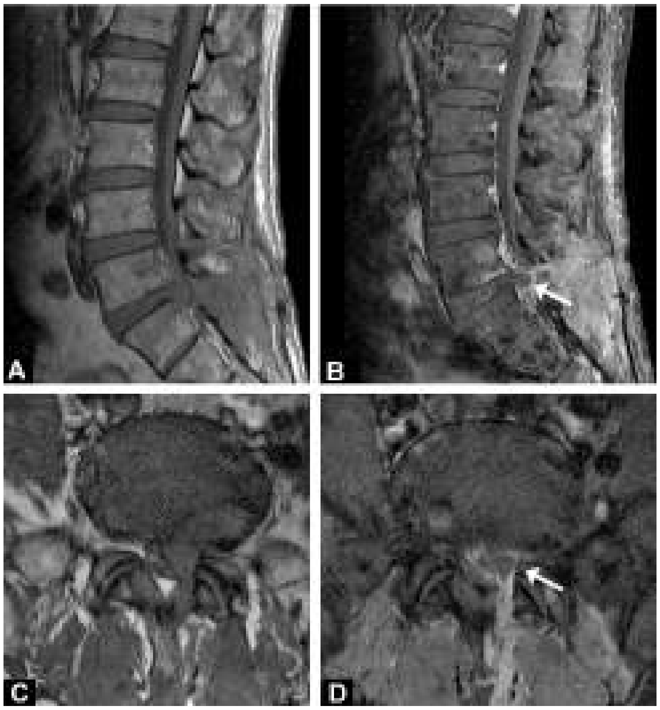
Many clinical studies have recommended MRI as the first choice in the diagnosis of LDH.[13-16] The symmetric bulging, protrusion, extrusion, and sequestration of free fragment of herniated disc can be differentiated, and the migration of free disc fragment to superior or inferior also can be observed. Even the location of herniated disc, central, paracentral, foraminal, or extraforaminal is readily defined (Figs 12.3A and B). The degenerative condition of the disc can be seen, and its degree can be assessed by observing the alterations of signal intensity in the central or peripheral disc on T2-weighted images.

In a patient who has a history of lumbar surgery, MRI following intravenous injection of contrast material (Gadolinium) is useful to demonstrate the specific anatomical features, especially postoperative changes around previous surgical area.[17,18] A recurrent disc herniation is readily differentiated from postoperative epidural fibrosis (Figs 12.4A to D).[14,19,20] Frequently, dorsal root ganglion can be enhanced after Gadolinium injection, but its clinical significance has been not proven.

Recently, dynamic MRI has emerged and is in the center of attention. The influence of postures, flexion and extension on the discs and the related changes in images of the soft structures can be studied and clinically applied. In flexion and extension MRI, a hidden disc herniation can be identified which cannot be seen in MRI on neutral supine position. MRI-compatible axial-loading device mimicking MRI in the standing position can provide information of position-dependent lumbar disc herniation.

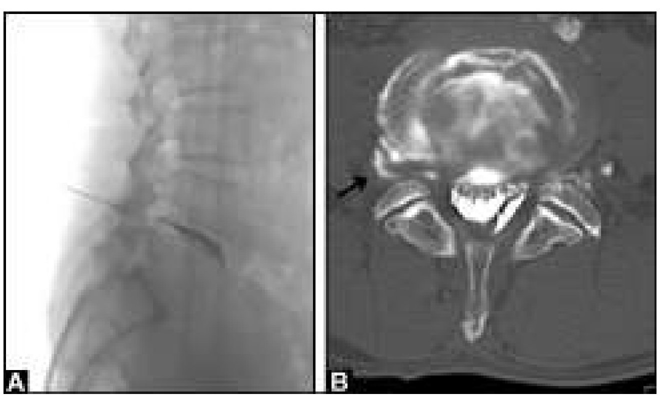
## Discography and CT Discography

Discography involves the injection of contrast material into the discs (Figs 12.5A and B). Although the diagnostic value in the assessment of discogenic pain in internal disc disruption (IDD) is still on debate, the one in the determination of specific disc

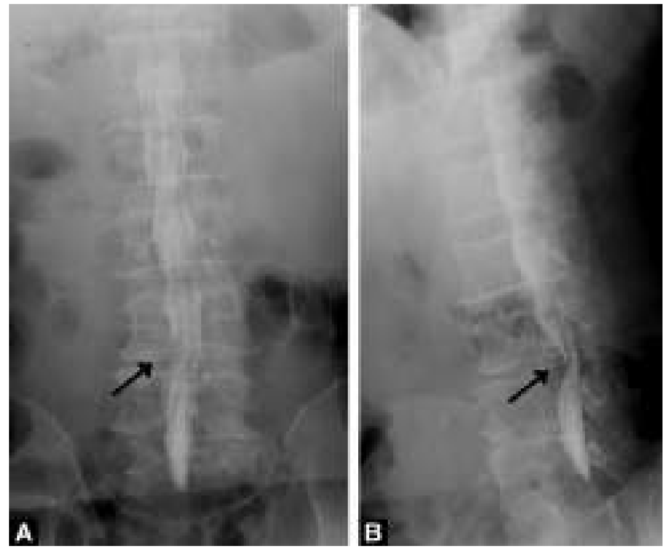



**Figs 12.4A to D:** Gadolinium-enhanced MRI; pre-enhanced T1 MR images (A and C) showing poorly delineated mass in the spinal canal. Gadolinium-enhanced T1 MR images (B and D) showing rim-enhancing mass indicating herniated disc fragment (white arrows)

herniation is well recognized. For instance, CT discography is considered as one of the best imaging modalities to determine a foraminal or extraforaminal disc herniation.[23-25] On lateral X-ray view, indirect diagnosis of disc herniation can be made by defining the outlines of the abnormal dye in posterior margin of the disc and the provocation of concordant back or leg pain,[21,22] and, when a disc herniation is diagnosed by other imaging procedures, discography provides information whether herniation is contained or noncontained. Combining with CT (CT




**Figs 12.5A and B:** Discography (A) demonstrating the injection of contrast material into the L4-5 disc. CT discography (B) showing an extraforaminal disc herniation (black arrow)




**Figs 12.6A and B:** Myelogram showing a filling defect of nerve root sleeve (black arrows)

discography) can show the presence, location, and degree of annular degeneration including annular tear in axial section.

## Myelogram

Myelography involves intrathecal injection of a radiopaque contrast and the taking X-rays. Myelography used to be a choice of the imaging modality in the diagnosis of LDH before the advent of CT or MRI. Currently, its use is limited because of invasiveness and the related complications. By defining the deformed outline of thecal sac and a filling defect of nerve root sleeve, disc herniation can be indirectly demonstrated (Figs 12.6A and B).[12,23,24] But, differentiation with other causes of neural compression including spinal stenosis, tumor, or abscess is not easy. And foraminal and extraforaminal disc herniation cannot be diagnosed only by simple myelography. Myelography followed by CT (myelo-CT) highly enhances the accuracy in the diagnosis of LDH.

## Myelo-CT

Myelo-CT combines the advantages of both imaging modalities. Comparison studies of myelo-CT with MRI in the diagnostic accuracy of LDH have shown equivocal: less,[25,26] higher[27,28] or equivalent (Figs 12.7A and B).[29] The authors have studied the accuracy of myelo-CT in detection of nerve root compression by various kinds of spinal pathology, and have found out the superiority of myelo-CT to MRI in determination of existence and/or severity of root compression.

## Summary

MRI is currently the most accurate noninvasive imaging modality to diagnose LDH and to determine its exact location. CT can provide some information related to a calcified disc, limbus


**Figs 12.7A and B:** MRI showing a herniated disc fragments just contacting with a root but not showing its severity (A), but Myelo-CT showing complete obliteration of the identical root and demonstrating the degree of compression indirectly (B)

fracture, or herniated disc combing with osteophyte. Myelo-CT is useful to define the clinical significance of mild LDH by determining its severity in the degree of nerve root compression. A foraminal or extraforaminal disc herniation can be detected by MRI but readily confirmed by CT discography, known as the best diagnostic tool in this disease entity.

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# Section 4

# Surgical Techniques

## Section Outline

- **Minimally Invasive Surgical Management of Lumbar Disc Herniation by Anterior Epidural Endoscopy: Epiduroscopy**
  *Marcos Masini, Aldo Calaça*
- **Lumbar Microendoscopic Discectomy**
  *Mehmet Zileli, Vehbi Gülmen*
- **Minimally Invasive Lumbar Microdiscectomy**
  *Richard Kim, Pulak Ray, Christopher M Loftus, Bong-Soo Kim*
- **Tubular Microsurgical Discectomy for the Treatment of Lumbar Disc Herniation**
  *Marcos Masini, Wellingson Silva Paiva, Rogério Safatle Barros*
- **Endoscopic Spine Surgery as Treatment for Lumbar Disc Herniation and Foraminal Stenosis**
  *Enrique Osorio-Fonseca, Jorge Felipe Ramírez, José Gabriel Rugeles, Gabriel Oswaldo Alonso*
- **Minimally Invasive Technique for Lumbar Disc Herniation**
  *A Bambang Darwono*
- **Laser Assisted Percutaneous and Endoscopic Lumbar Discectomy**
  *Martin TN Knight*
- **Thermodiscoplasty and Percutaneous 360 degree Rhizolysis as a Treatment for Herniated Disc or Facet Lumbar Pain**
  *Enrique Osorio-Fonseca, Jorge Felipe Ramírez, José Gabriel Rugeles, Gabriel Oswaldo Alonso*
- **Lumbar Discs Herniation Treated by Ozone Therapy**
  *Marcos Masini, João Flávio G Madureira*
- **Use of Robots in the Surgical Management of Lumbar Disc Herniation: Dream or Reality**
  *PS Ramani*

# 13

# Lumbar Laminectomy

*PS Ramani*

## Introduction

Today the most common condition for which a standard laminectomy which includes excision of spinous process and laminae on both sides is done is lumbar canal stenosis where neural elements are compressed giving rise to neurogenic claudication. In fact, the latter is the sign of lumbar canal stenosis. However, in many parts of the world some surgeons still indulge in doing laminectomy for a given case of lumbar disc herniation.[1-6] Hence, this chapter is included in this book to outline steps of laminectomy in lumbar spine.

When the lumbar spine is exposed for any surgical procedure at least some portion of bone has to be removed depending on the surgical need for example in a case of prolapsed lumbar intervertebral disc at L4/5 the junction between lamina and the spinous process has to be nibbled away to gain access to the prolapsed disc. More radical bilateral exposures are necessary for burst fractures for correction of instability.

Laminectomy is just the entry point. In lateral recess stenosis facetectomy has to be performed and in nerve root compression at the exit, foraminotomy is to be done. The prolapsed disc needs to be excised.[6-14]

## Factors Contributing to Lumbar Canal Stenosis

Several factors contribute to crowding the neural elements in the neural canal giving rise to lumbar canal stenosis and neurogenic claudication:

1. Congenital narrow lumbar canal
2. Congenital short pedicles
3. Degeneration and facet joints hypertrophy and tropism
4. Settlement of disc space
5. Upwards migration of superior facet
6. Prolapsed lumbar intervertebral disc
7. Buckling of the ligamentum flavum
8. Chronic calcified disc
9. Osteophytes along disc margins
10. Formation of synovial cyst
11. Degenerative spondylolisthesis

### Advantages

1. Spinal surgery for lumbar disc herniation took birth with this approach.
2. Laminectomy is the oldest surgical procedure.
3. Most familiar surgical procedure.
4. Simple procedure. Easy to be familiar.
5. Several pathologies in the lumbar spine can be handled by this approach.
6. Each spinal surgeon must be, at first, familiar with this approach.

### Disadvantages

1. It is a morbid procedure.
2. Needs longer convalescence.
3. Chance of infection is high.
4. Iatrogenic instability can occur.

## Surgical Technique

The procedure is done under general anesthesia in prone position on a Wilson's frame. It is extremely important that the patient is positioned such that the abdomen hangs free. Pressure on the abdomen will increase pressure within the epidural venous plexus and may lead to annoying and unwanted bleeding during the procedure.

A midline incision is marked with the help of image intensifier (Fig. 13.1) that is in the center of pathology to be addressed by laminectomy. The incision should not be unnecessarily long (Fig. 13.2). Following preparation, draping and infiltration of the incision marked with a mixture of xylocaine with adrenaline if not contraindicate in the proportion of 50:50 of 1 percent xylocaine and 1:2,00,000 adrenaline.

The skin is incised with help of No. 15 blade (Fig. 13.3) and the edges skin are held apart with subcutaneous sutures rather than metal retractor (Fig. 13.4).

The lumbosacral fascia is identified. The fascia is opened in the midline with electrocautery (Fig. 13.5). The paraspinal muscles are composed of two layers. The superficial layer consists of spinalis, longissimus and erector spinalis muscles from medial to lateral side. The deep layer consists of multifidus, rotators and intertransversalis muscles. The two layers are subperiosteally seperated from spinous processes and laminae with electrocautery. The lateral extent of dissection will depend on the indication for laminectomy. The facet joints should be exposed partly. It is not necessary to expose the transverse processes. Spinal retractors or Dr Ramani's microretractors (Figs 13.6 and 13.7) are used to retract the muscles. The posterior view of the spine is exposed (Fig. 13.8). In lumbar region the spinous processes point directly backwards. Important ligaments in this region are supraspinous, interspinous, ligamentum flavum, facet capsule and intertransverse ligaments.

*Removal of the spinous process:* This can be done with Horsley's bone cutter (Figs 13.9 and 13.10) or it can be excised with Northfield bone rongeur.

**Fig. 13.1:** C-arm marking of the correct level is very important

**Fig. 13.2:** Marking the incision in midline centered on the laminectomy to be performed. The incision should not be unnecessarily long

**Fig. 13.3:** The skin is incised using No. 15 blade

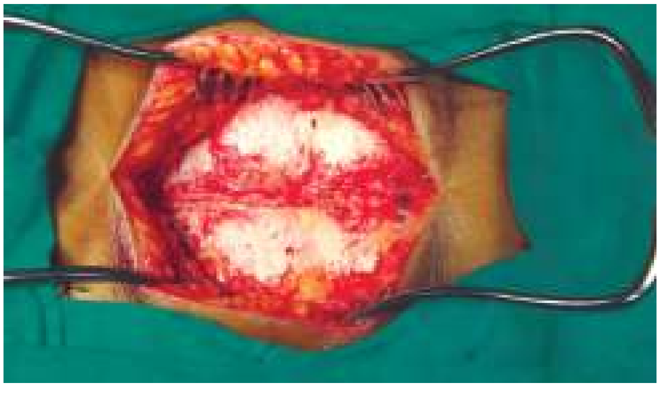


**Fig. 13.4:** The paraspinal lumbosacral fascia is exposed

Chipping too deep must be avoided. Once can easily enter the spinal canal and damage the dural sac. Taking Adsons's dissector or Cushing's No. 4 dissector the ligamentum flavum is separated from under surface of the lamina.

**Fig. 13.5:** The paraspinal muscles are subperiosteally separated with electrocautery

**Fig. 13.8:** Exposure of posterior part of the spine. In the lumbar region the spinous processes are directed backwards

**Fig. 13.6:** The Cloward spinal retractor

**Fig. 13.9:** Cutting the spinous processes with Horsley's bone cutter

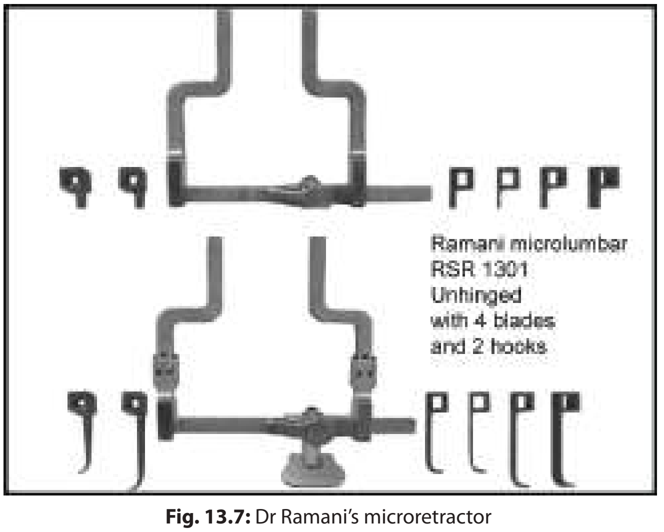



**Fig. 13.7:** Dr Ramani's microretractor

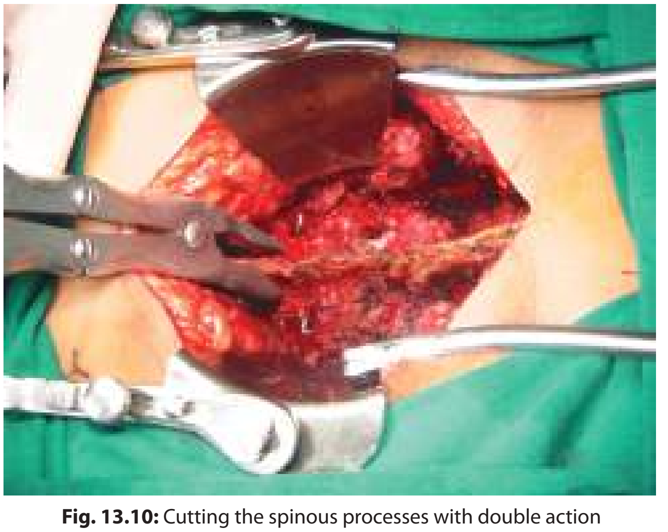
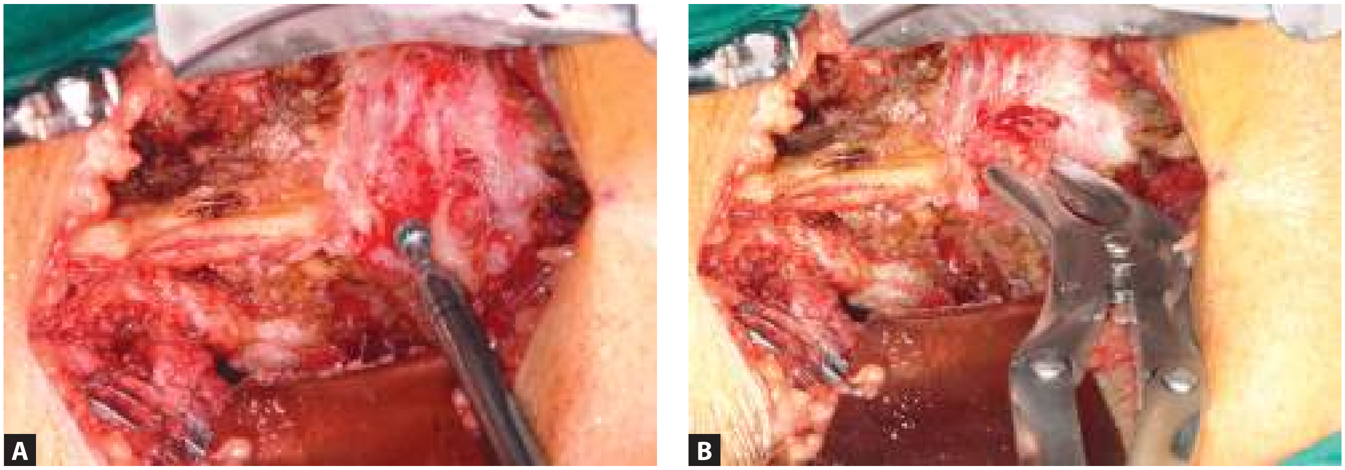


**Fig. 13.10:** Cutting the spinous processes with double action Leksell bone rongeur




**Figs 13.11A and B:** The thick laminae can be drilled to make it thin with high speed drill and then nibbled away with double action oblique Lekcell rongeur

The laminae are then nibbled away with Leksell double action oblique bone rongeur (Fig. 13.11B). The lower blade of the rongeur should be inserted under the lamina to an angle of 45 degrees. This will prevent insertion of instrument too deep in the canal.

If the laminae are too thick then they can be thinned out by using high speed drill (Fig. 13.11A). With experience one can use the cutting drill but if one feels apprehensive, diamond drill can be used from the beginning. Once the lamina is thinned out Leksell rongeur can be used more effectively. Added security can be achieved by inserting a cotton patty flat under the lamina and then safely working over the cotton patty. As such the lamina always gets thicker laterally towards the facet. Alternatively, the thinned out lamina can be removed with 3 mm 45 degree forward Aesculap rongeurs (Fig. 13.12).

To do the laminectomy at first the laminae are thinned out with high speed drill and then the major part is excised with double action rongeur.

The laminae are excised first on one side and then on the other side.

The ligamentum flavum now covers the dura. It should be very carefully separated from the dura before it is excised using 3 mm 45 degree forward rongeur.

To remove the lateral portions of the ligamentum flavum, it is at first separated from the dura with a wet cotton patty and then the ligamentum is nibbled away meticulously until the lateral portion of the dura is exposed very clearly (Fig. 13.13).

However narrow the canal may be, the dural sac has to lie medial to the medial surface of the pedicle. To this extent the dura must be exposed and the medial surface of the pedicle felt with Cushing No.4 dissector.

This part of the procedure exposes the dura but necessity always arises for more dissection for example in lumbar canal stenosis the lateral recesses are narrow and they need to be widened. This can be done by undercutting the facet.

It can be done in three ways:

1. As Cloward did the facet can be undercut with 3 or 4 mm osteotome protecting the dura with wet cotton patty. In this

**Fig. 13.12:** The thinned laminae are excised with 45 degrees forward cutting 3 and 4 mm Kerrison or Aesculap punches

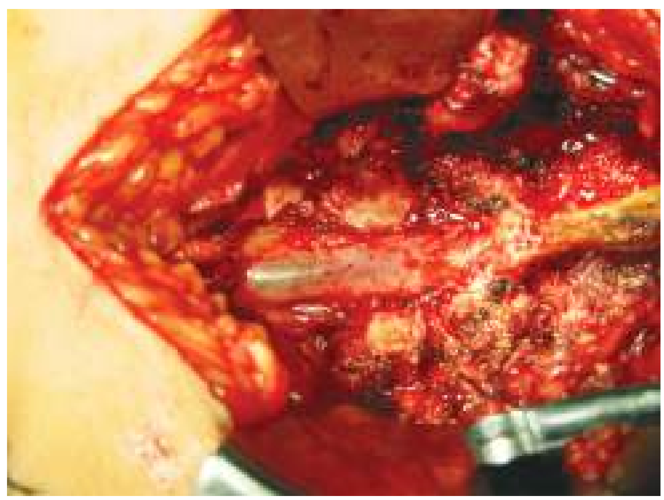


**Fig. 13.13:** The procedure of laminectomy being complete the dura is exposed

part of the procedure the dura must be well protected as in narrow lumbar canal usually there is paucity of fat and there is real danger of damaging the dura and causing CSF leak or damage the nerve root. The foot plate of the rougeur should be inserted very carefully under the tissues. Today this procedure can be performed with ultrasound bone scalpel very safely.
2. In the second method the part of the facet impinging into the canal (medial facetectomy-partial) can be excised using 2 and 3 mm Kerrison rongeurs. Everytime the dura should be seen to be protected.
3. The medial part of facet is first thinned out by using high speed drill and then excising the remaining part with 3 mm rongeur.

   Any epidural bleeding should be carefully controlled with bipolar coagulation under magnified vision of the microscope. The microscope should always be handy during any spinal procedure.

   Alternatively hemostasis can be achieved with a piece of gelfoam over cotton patty or surgical of thrombin and gentle pressure.

## Laminoplasty Instead of Laminectomy

Particularly in children this is a better option to prevent post-operative scoliosis with the growth in the bone. Instead of excising the bone the laminae are cut at its junction with facets with fine tip cutting high speed drill and inserting a foot plate under the lamina to protect the dura. By this way the lamina can be removed en bloc and then sutured back in place after completing the operative procedure.

Experience with high speed drill is absolutely essential and practice on cadavers is mandatory.

## The Closure

- Self retaining retractors are removed.
- Meticulous hemostasis is achieved.
- With meticulous hemostasis although the drain can be avoided, the author always prefers to keep adrain for 24 to 48 hours to keep the wound supple and clean.
- The paraspinal muscles are approximated in two layers with interrupted sutures of 0 or 1 Vicryl. The deeper layer has inverted sutures and all the sutures are tied later after taking all sutures whereas outer layer has standard interrupted sutures with surgical knot.
- The lumbodorsal fascia is sutured meticulously with same absorbable suture.
- The subcutaneous tissue is sutured with interrupted 3/0 absorbable sutures.
- The skin is closed with either black silk interrupted sutures, nylon continuous running sutures, a running subcuticular stitch or surgical staples.

## Complications

**There can be several complications.**

1. In view of exposure which is formidable infection has to be watched for.
2. Dural tear, CSF leak or neural element damage is a distinct possibility. Whether one likes it or not dural tears occur in 15 percent of cases. It is not always possible to close the rent with sutures. Sometimes it is very difficult.

   Covering the rent with a piece of fascia and sealing it with tissue glue is the only answer. If the rent is small but cannot be sutures it can be covered with a piece of muscle which is flattened by pressing it with hammer is useful.

   Gelfoam *per se* does not close the defect.

   When in difficulty a lumbar drain for four days diverts the CSF and helps to close the defect.
3. *Iatrogenic postlaminectomy instability:* There is a distinct possibility. The incidence in literature varies from 4 to 15 percent.

**The causes are:**

1. Number of levels operated.
2. Extent of wide decompression.
3. Facetectomy. Unilateral complete facetectomy does not produce instability.
4. Inadvertent cutting of pars.
5. Presence of joint mobility preoperatively.

Older patients with extensive degenerative spondylosis usually do not develop instability.[14-19]

## Conclusion

Laminectomy is a relatively safe procedure provided meticulous care in surgical technique is followed.

One has to be attentive and gentle in handling the instruments.

Although, long-term follow-up has shown fibrosis in muscles separated from the spinous processes and laminae, in more practical terms it has not produced disability.

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# 14

# Microlumbar Decompression for Lumbar Disc Disease

*Abdul Hafid Bajamal, Muhammad Faris, Eko Agus Subagio*

## Introduction

Williams, Yasargil and Caspar have popularized the microsurgery in the lumbar disectomy.[1-3] The use of the microscope, micro instruments and doing by a well trained surgeon in the microsurgery will provide several benefits in many surgical spinal decompressions. By using a microscope, the nervous structures can be seen clearly through magnification and can be mobilized gently and safely.

Microlumbar decompression is one of the surgeries of the spine that is often done the most by the neurosurgeon.[4,5] Disc herniation is often followed by other degenerative changes such as osteophyte formation, thickening of the ligamentum flavum, facet hypertrophy, foramen stenosis and canal stenosis.[6,7] A single or multiple degenerative changes can produce irritation or compression of the nerve root. To treat those abnormalities, a decompression should be done.

Through a small skin incision, discectomy and all of the decompression procedures in those cases can be done well. Although there are neurosurgeons who can conduct the bilateral decompression through the one side, good experiences are needed here to do it optimally with minimal risk.

## Indication for Surgery

A selection of the appropriate patients based on clinical examination and high quality imaging will give the optimal result of the operation.

### Clinical Evaluation

The main indication of microlumbar decompression is primarily a way to perform microdiscectomy to excise a prolapsed disc which also causes sciatic pain. In general, the cause of pain is a disc herniation at one level. The back pain that is followed by the pain on the leg can be caused by different abnormalities inside and outside the spine. The clinical findings that are related to the imaging are required to determine the pathology which is supposed to be operated. A continuous radicular pain which does not get better through conservative therapy and a progressive neurological deficit are indications for implementing the decompression. The cauda syndrome is an indication for emergency surgical decompression because of the large disc herniation which is followed by "saddle back" anesthesia, bladder and bowel involvement.

### Imaging Evaluation

Besides the routine evaluation of bone structure and mobility to see if there is a listhesis on the X-ray examination of lumbosacral spine, magnetic resonance imaging (MRI) 1.5 Tesla is an appropriate choice to obtain a good imaging quality of various spine soft tissue structure. We can see the detailed changes on the structures of bones, ligaments, discs, facet joints, nerve roots, involvement of epidural spaces or intradural spaces.[5,8]

When in the imaging is found more than one disc problems, it must be specified by the clinical observation, what actually the causes of the sciatic pain. Discectomy on more than one level should be based on a very serious consideration. The patient

Fig. 14.1: An upward migration of sequestered disc fragment


Fig. 14.2: Downward migration of sequestered disc fragment

with the typical pain, who is observed through the high quality imaging but the abnormality still cannot be found, is more profitable to use nonsurgical treatment.[8]

The pain of the patient depends on the magnitude of the pressure disc fragment, on the other hands, the location of the fragment also determines the pain. For instance, a small disc fragment that presses near the foramen is able to give a very deep pain.

On the imaging, disc herniation can be seen in several variations. In addition to the different locations such as median and paramedian, it can also be found lateral and far lateral herniation.

Herniated disc can is still inside a thin layer of a torn annulus, but some are already out of the annulus and located on the subligament of posterior longitudinal ligament and even there is also a disc fragment that has been migrated in the epidural space which is known as a sequestered disc (Figs 14.1 and 14.2).

## Operative Techniques

### Position

The patient is positioned after general anesthesia. There are many variations in positioning the patient.The standard one is prone position with a pillow on the chest and inguinal with the goal that the abdomen is relax.[9,10] Then the back can be made slightly to be more flexion by bending the table. This position can help to open out interlaminar space.

Another position is the knee-chest prone position or the prone position using the Wilson frame. Intra-abdominal pressure does not differ between prone position and the knee-chest position. Both positions provide good conditions for lumbar microdiscectomy.[10]

### Level of Identification

After the disinfection and draping are done, marking using a spinal needle is introduced into the interspinous ligament to ensure the level and location of skin incision.

### Skin and Soft Tissue Opening

Adrenaline-Lidocain solution 1/100,000 or 1/200,000 is injected subcutaneously and a long the spinous process. Skin incision 2 to 5.4 cm in length and about 1 to 1.5 cm lateral from the midline is proceeded deeper into the subcutaneous fat. Fascia incision 2 cm from the midline and the fascia reflects medially. Sharply using cutting diathermy or sharp periosteal elevator, the paravertebral muscle layer is separated from the spinous process to lamina, until interlaminar space can be seen clearly then retractor can be just inserted. There are choice of retractors, Scoville retractor, Caspar retractors, modified hemilaminectomy retractor.

Then, the surface of the lamina and ligamentum flavum are cleaned up.

### Bone Opening

Before further exploration, identification level with X-ray should be done and checked with imaging of MRI. On the level of the interlaminar space L5-S1,which is usually quite large, is often unnecessary to open the bone for discectomy. The opening is large enough to do microsurgery exploration with micro-instrument (Fig. 14.3A). But at the interspace L4-5 and more to the rostral, which are often too narrow. Laminotomy should be conducted to open some of the superior and lateral lamina in order to provide enough space for a further and deeper exploration (Fig. 14.3B)

**Fig. 14.3A:** Axial CT imaging of unilateral bone opening after microdiscectomy

**Fig. 14.3B:** Narrow interlaminar space of L4-5 and above level. Red dots is laminotomy for microdiscectomy approach

The presurgical plan should evaluate the presence of stenosis. It is mandatory to decompress widely prior to manipulating the dural sac or root to facilitate discectomy. Laminotomy and widening of the canal or the lateral portion of the bony protruded resulting from hypertrophied facet joint preferably with a high speed drill. If that is not available, Kerrison rongeur No. 2 and 3 can be used. This bone can be safely removed, as the undersurface is still protected by the ligamentum flavum. This bony resection removes the lateral recess stenosis and allows exposure of the lateral disc space.[8,9]

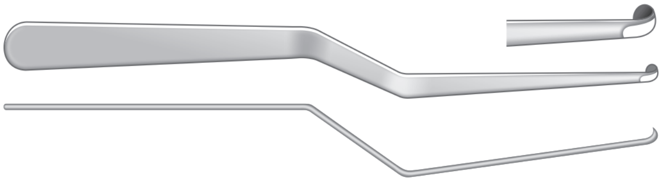


**Fig. 14.4:** Love nerve hook

## Ligamentum Flavum Opening

At the level of L5-S1, ligamentum flavum should be incised from the lateral using blade No. 15. Then set it aside at the medial and fix it with the suture. There are many modification to preserve ligamentum flavum.[5,8,11] At a time before closing the wound, this ligament should be placed where it firstly is without sewing. If it is hypertrophy, just make it thin. Preserving the ligamentum flavum and epidural fat is thought to minimize postoperative epidural fibrosis.[12]

## Discectomy

The blunt dissectors are then used to palpate gently, beginning within the almost rostral of the lateral recess of the spinal canal. The dissectors move caudally slowly as caudal as a possible. By doing this, the surgeon can determine the compression, how big the protrusion is. The lateral disc space can be identified. The nerve root and dura are mobilized by using Love nerve hook (Fig. 14.4).

This maneuver allows excellent exposure of the disc herniation. Retraction on the nerve root must be gentle all the time and avoid continual retraction. Preservation of the epidural fat is important to prevent direct pressure to the nerve roots from postoperative formation of cicatrix tissue. In some patient there is thick epidural fat tissue, this can be retracted by cottonoid to the medial, or some time we have to excised amount of fat in order to get a good visualization.[9,12]

If there is no disc herniation, the surgeon should think about wrong level. X-ray should be taken for evaluation. The problem of the wrong level in spinal surgery must be included in the framework of the operating theater's daily activity.[13] The root can be displaced posterior or laterally by herniated disc material. After the nerve root gently retracted medially over the dome of the herniation then epidural veins coming in the way were gently coagulated by bipolar forcep and cut then exposing of the disc prolapse can be accomplished.

Sometimes it is necessary to open the posterior longitudinal ligament and the annular ligament to entrance into the disc space by using No. 15 blade. A limited disc material should be removed from the disc space. All fragmented, loose fragment or "pappy" material should be removed. It is not desirable to remove all disc materials.

No correlation between the amount of the removed disc and the long-term outcome, recurrence rate, or postoperative instability.[4] It is important to remove all of the disc fragments pathology by disc forceps and not miss any migrated disc fragments.

**Fig. 14.5:** Facet hypertrophy and neural foramen stenosis

**Fig. 14.6:** Multiple lumbar disc prolapse

To avoid overlooking of migrated fragment, one should explore gentle by ball ended dissector or blunt angled dissector to surround epidural space and press the surface of posterior longitudinal ligament to push migrated fragment to come in the epidural space. Lateral and intraforaminal herniation should also be identified from the imaging.

The main purpose of the surgery is the root decompression. As long as the root is decompressed, the symptoms will be relieved. All structures which can cause the pressure on the root should be relieved. Such as disc fragment, osteophyte, thickening of ligamentum flavum or foramen stenosis. Prominence osteophyte which compresses the nerve root should be trimmed or impacted down.

## Lateral Recess Stenosis

Axial MRI can be helpful in evaluating the lateral recess, but during surgery this location must be determined for possible stenosis due to the hypertrophy of the facet or thickening of ligament (Fig. 14.5).

## Foramen Decompression

After disc protrusion and fragments are excised then one should explore the foramen by using a probe or angle nerve hook to make sure that there is no compression of the nerve root in the foramen,[6] (Fig. 14.5). Then if indicated, foramen decompression can be done by removal some of overlying bone and ligamentum flavum.

## Multiple Disc Prolapse

The procedure can be carried out at two levels on one side, at same level on both sides or at the different levels on either side. In case of two levels on one side, the incision is extended a little. In case of same level on either side the incision, one inch long is taken in the midline. In case of different levels on two sides, two separate paramedic incisions are taken. One has to think very carefully before doing two or more levels because the cause of pain is usually only from one location[5,8,14] (Fig. 14.6).

## Wound Closing

After completed, the retractor is removed and bleeding were treated, restored muscle to normal position without stitches, fascia sealed with a few stitches.[5,9,15] The wound is sutured in layers. The skin was suture by subcuticular fashion. In general, the installation of vacuum drain is only done when there is a strong indication. Mobilization of the patient may be done on the next day, the patient may sit and walk.

Back muscle function is often impaired in patients awaiting surgery for prolapsed intervertebral disc. Surgery does not correct back muscle dysfunction and may make it worse. The results showed that a 4-week postoperative exercise program improved pain, disability, and spinal function in patients after microdiscectomy.[16]

## Special Situation

### Spondylolisthesis

Spondylolisthesis should be diagnosed preoperatively by lateral view of lumbosacral spine X-ray with the patient in standing position and move to flexion and extension position. If there is instability then stabilization procedure should be done after the discectomy.

**Fig. 14.7:** Posterolateral approach for far lateral disc prolapse through intertransverse. Red color is bone opening

### Spinal Stenosis

Spinal stenosis can be known by imaging before the surgery. During surgery especially after discectomy, one should evaluate the canal, lateral recess and the foramen to detect stenosis. If it is found, there must be a decompression to handle it.

### Far Lateral Disc Herniation

Extraforaminal or far lateral or extreme lateral disc herniation is very rare and estimated only 10 percent of all symptomatic disc herniation. The imaging is usually helpful in showing the relationship between the disc, nerve root and the pars lateral interarticularis. For this kind of herniation, the approach should be through extraforaminal or parasagittal approach with paramedic muscle splitting. The incision is about the groove between the multifidus and the longissimus muscles, descending from intertransverse process to neuroforamen through the lateral orientation (Fig. 14.7). The disadvantages are deeper dissection and it also potentially causes an injury to the nerve. The surgeon should maximally try not to open the facet. It is important not to displace the nerve root aggressively because the dorsal ganglion within is very sensitive to be manipulated.[8,17,18]

## Complication

### Dural Tear

Dural tear is very rare. The chance of the tear is increased in the elderly, severe facet hypertrophy and in case of resurgery with scar formation. It usually occurs during the course of the bone removal, the dura can fold over the foot of a punch. That is why in every course of bone removal, the dura should be protected. There is no occasion for blind removal. If dura was torn then the surgeon should suture it gently by 5-0 nylon suture and pack with small piece of thin muscle.[5,8,9,19,20]

### Bleeding

Venous bleeding can occur because of injury in the vena during manipulation of epidural space. There is usually a large chronic congestion vena due to chronic disc prolapse. Bipolar coagulation should be done. In case of oozing, that will be helped by putting "surgicel" overlying and press with small cotton for few minutes.

### Discitis

Antibiotic prophylactic is still used to prevent the risk of the infection. It is also important to prevent from using curette to the disc plate. The infection source is usually coming from outside during surgery. Minimally invasive spinal surgery techniques may reduce postoperative wound infections as much as 10-fold compared with other large, modern series of open spinal surgery published in the literature.[21-23]

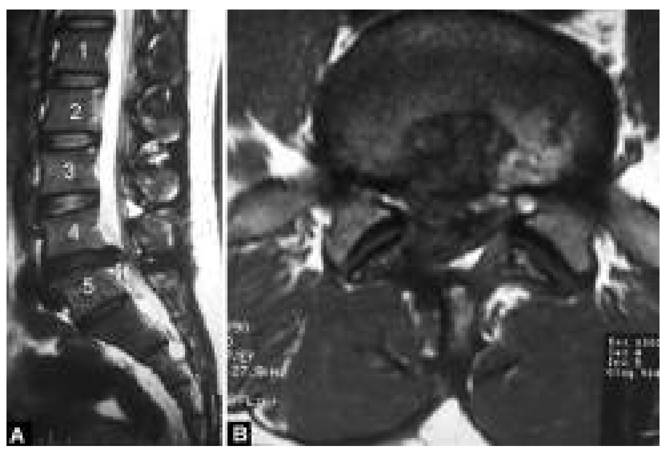
### Scar Formation

Prevention of perineural scar formation has been challenging for many decades. The sensitivity of each patient is absolutely different. According to the author's experiences, the important thing is a gentle manipulation, no hematoma, treat any point of the bleeding gently, preserve epidural fat, do not leave any material in the operative field.[8,9,12,19,20] If there is still oozing and it cannot be controlled, a small diameter of low vacuum drain should be inserted for 24 hours.

### Reoperation

Recurrence disc herniation of same level and same side in 5 to 10 percent (Figs 14.8A and B). For diagnostic of recurrence case the imaging can be more difficult to diagnose. If the finding on contrast enhanced imaging MRI and clinical condition are clear then resurgery is indicated.

Disc extrusion can easily be differentiated with the scar formation by using contrast injection during MRI procedure. Scar will be enhanced by contrast injection but the disc fragment is not. The cicatrix tissue cannot be totally excised, during surgery we can only propose for partial excision in order to decompress the nerve.[8,9,12,19,20]




**Figs 14.8A and B:** Recurrence of disc herniation at the same level and same side

**Table 14.1:** Results after more than one year follow-up Macnab criteria

| Criteria | No. of patients | Percentage of the result |
|---|---|---|
| Excellent | 85 | 70% |
| Good | 17 | 14% |
| Fair | 10 | 8% |
| Poor | 10 | 8% |

**Table 14.2:** Recurrence of backache 122 patient, follow-up time 5 years

| Level of the recurrence | No. of patients | Percentage |
|---|---|---|
| Same level same side | 7 | 5.7% |
| Same level other side | 5 | 4% |
| Adjacent level | 10 | 8% |
| Other level | 6 | 4.9% |
| Total | 28 | 23% |

Obesity was a strong and independent predictor of recurrent HNP after lumbar microdiscectomy. Surgeons should incorporate weight loss counseling into their preoperative discussions with patients.

*There are lots of factors for recurrence:*
- Inadequate decompression at the lateral recess
- Migrated disc materials may have been overlooked
- Inadequate resection of disc materials
- Missing the correct level
- Scar tissue/fibrosis.

Repeating discectomy will increase the risk of injury of dura and nerve root and decrease chances of a successful clinical outcome.[8,19,20]

## Results

From my own experience, 122 patients after follow-up more than one year, the result according to Macnab criteria (Tables 14.1 and 14.2).[24]

## Conclusion

At present, the safest, simplest, and most reliable technique is still microlumbar decompression. Through the small incision, with minimal and gentle dissection, the patients will hospitalize shortly with the excellent result and very minimal complications. These factors make microlumbar decompression as a procedure of choice for a lot of selected cases.

Key point is that a minimal access may minimize the “invasiveness” of surgery, but only correct diagnosis and successful neural decompression can give a successful long-term result.

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15

# Lumbar Microdiscectomy with Preserving of Ligamentum Flavum and Fat Tissue

*R Kemal Koc*

Although several surgical interventions for the treatment of lumbar disc herniation have been described up to now, there is not a standard method that everyone accepts. The reason of this is the lack of a satisfactory prognosis.

## Prognosis in Patients Undergoing Lumbar Disc Surgery

- 5 to 10 percent of them are permanently symptomatic and cannot work
- 25 percent of them cannot return to the original work
- 40 to 50 percent of them have DTR altered and show sensory deficit.

## Surgical Procedures for Lumbar Disc Herniation Up to Now

- Discectomy, Mixter and Barr, 1934
- Chemonucleolysis, Lyman Smith, 1964
- Percutaneous nucleotomy, Hijikata, 1975
- Microdiscectomy, Yasargil, 1968
- Otomotized percutaneous lumbar discectomy, Onik, 1984
- Laser discectomy, Ascher and Choy, 1987
- Endoscopic discectomy, Schreiber and Suezawa, 1986 and was developed by Mayer, Brock, and Mathews
- Microendoscopic discectomy, Smith and Foley, 1995
- Microdiscectomy with preserving ligamentum flavum, Delamarter, 1997
- Intradiscal electrothermy, Saal and Saal, 2000[1]

## Terminology

*Lumbar microdiscectomy with preserving the ligamentum flavum and fat tissue:* The removal of herniated lumbar intervertebral disc via posterior approach with the help of surgical microscope and microsurgical instruments, and preservation anterior part of ligamentum flavum and epidural fat tissue.

The ligamentum flavum is the anatomic plane between the epidural and laminar-extralaminar spaces, which should be meticulously preserved for a possible reoperation. Preservation of the ligamentum flavum together with other epidural anatomic structures, such as epidural fat tissue and venous plexuses, and limited removal of the lamina are important components in preventing epidural fibrosis that may be the cause of failed back surgery syndrome.

## Surgical Microscope

### Advantages

- Desired magnification
- Three-dimensional image
- Better visibility
- Same image with assistant surgeon
- A smaller incision.

### Disadvantages

- Adjustment process to microscope
- Narrow study area
- Pathology may be overlooked[2]

## Indications for Surgical Treatment of Lumbar Disc Herniation

- Cauda equina syndrome
- Sudden or progressive loss of strength
- *Failure of medical treatment:* Severe pain despite medical therapy during 3 weeks or those who are in agonizing pain.
  Significant pain despite medical therapy during 4 to 6 weeks. Recurrent pain after three months
- Frequent episodes of recurrent disc herniation.

## Patient Selection Criteria [American Academy of Neurological Surgeons (AANS), American Academy of Orthopedic Surgeons (AAOS)]

- Failure of conservative treatment
- Showed symptomatic nerve root compression and/or segmental instability at neuroimaging
- Suitability of radicular pain at physiological, dermatomal or sclerotomal distribution
- Change in the motor, sensory and DTR, and that one or more at affected segment.

## Preoperative Planning

- Magnetic resonance (MR)
- Lumbosacral radiographs
- Patient information and consent form.

## Anesthesia

- *General anesthesia:* Frequently used. Risk: 1/10,000
- *Spinal anesthesia:* Short duration of anesthesia, less potential of forming nausea and vomiting less urinary retention, less need for antiemetic and analgesic use, shorter duration of hospital stay.[3]

## Preparation of the Patient and Position

- *Antibiotic prophylaxis*
  *Cefazolin sodium* 1 g IV
- *The patient's position*
  *The knee-chest position:* Superior in overweight patients
  *Prone positioning (flexion giving the table):* Superior if stenosis is accompanied
- *Localization:* Intraoperative C-arm; an injector needle is placed vertically at possible level. Lateral X-ray is obtained.

## Skin: Interlaminar Approach

The 1.5 to 2.0 cm long skin incision is made in the midline. Dorsolumbar fascia is opened at 5 mm lateral of midline. Paravertebral muscles are dissected by periostial elevator bluntly without deattaching to spinous process, then retracted laterally. Meyerding retractor or the like is placed. Microscope is taken in the surgical field. Interlaminar distance is exposed. Partial hemilaminotomy is performed by high-speed drill.

Paravertebral muscles stripping must not exceed the lateral facet and facet capsules should be protected. If stripping of the paravertebral muscles exceeds the lateral facet, it may cause denervation and devascularization and ultimately cause low back pain. The size of the incision is directly proportional to the prevalence of denervation.

## Preserving of Ligamentum Flavum

It can be done in three ways:

1. One-sided flap technique
2. Two-sided flap technique
3. Three-sided flap technique.

It is more accurate to start with one-sided flap technique, if necessary, to proceed with two- or three-sided flap technique. Sometimes all ligamentum flavum may be removed. Epidural fat tissue should be protected, even when all the ligamentum flavum is excised.[4]

## Approach to the Spinal Canal with One-sided Flap Technique while Maintaining the Ligamentum Flavum

The 2/3rd outer layer of the ligamentum flavum attached upper surface of the lower lamina, 1/3rd inner layer attached lower surface of them. The outer layer is easily separated. Peeled outer layer in horizontal direction is removed. Facet capsule should not be traumatized. The fibrous capsule between the medial portion of the facet capsule and lateral portion of ligamentum flavum is cut by the monopolar. So, it is not traumatized. Lateral of flavum is opened by dissector in cranial-caudal direction. Lateral part of flavum is partially resected. Adequate exposure provided by retraction of the flavum. Adipose tissue is preserved. Epidural veins are preserved if possible. Ligamentum flavum returns to its original position, when retraction of the ligament is released.

Park et al.[5] had operated 377 cases with microdiscectomy preserving the ligamentum flavum. Follow-up time was 4.2 years (mean 2–6.5 years). Satisfactory results; 93.9 percent at 6 months, 84.1 percent at 30 months. Recurrent disc herniation; 4.8 percent. Complications; 1.3 percent. They reported that reoperation was easier and safer, epidural scar tissue were seen less, when ligamentum flavum protected.

Aydin et al.[6] reported that the ligamentum flavum preserving technique was useful in achieving a favorable long-term outcome, and if necessary, reoperation was easier and safer (Table 15.1).

Ozer et al.[7] suggested that the group with preserved ligamentum flavum showed significantly less local fibrosis at 6 months postoperatively. The authors speculated that this surgical technique provided a physical protective barrier that could reduce or even eliminate fibrosis-related complications after lumbar disc surgery (Table 15.2).

**Table 15.1:** Aydin and colleagues study comparing standard microdiscectomy and microdiscectomy with protected the ligamentum flavum

| | Ligamentum flavum protected | Standard discectomy |
|---|---|---|
| Clinical outcome in postoperative 4 weeks | 96.75 % | 81.5% |
| Reoperation | 4.5% | 9 % |
| Recurrence | 1.7% | 4.5 % |
| Recurrence at other levels | 2.5% | 3.5 % |
| Fibrosis | 18% | 37 % |
| Symptoms due to fibrosis | 0 % | 1 % |
| Complications | 2.25% | 9.5% |
| Day of hospital stay | 0.9 days | 2.25 days |

**Table 15.2:** Ozer and colleagues study comparing conventional microdiscectomy and microdiscectomy with preserving ligamentum flavum

| | Conventional microdiscectomy | | Microdiscectomy with preserving of ligamentum flavum | |
|---|---|---|---|---|
| | Preoperative | Postoperative | Preoperative | Postoperative |
| Visual analog scale (VAS) | 9.2 | 3.2 | 9.2 | 2.6 |
| Oswestry scale | 88 | 28.2 | 85.2 | 22.2 |
| Straight leg raising test | 29° | 63° | 26° | 71° |
| Scar grade | | 1.8 | | 1 |

## Advantages of Preserving of Ligamentum Flavum

- Acts as a barrier over the dura
- Epidural fibrosis is prevented
- Reoperation is easier.

## Identification of Nerve Root

If there is a facet hypertrophy, then the medial of superior facet is excised. The medial of inferior pedicle is palpated with nerve hook, nerve root is exposed up to exit foramen. Isthmus must be protected.

## Identification of Disc Herniation

Nerve root is distracted medially. Axilla may be exposed, if necessary. Avoid continuous distraction of nerve root (710 ± 21.3 g, 39.5 ± 21 sec, no problem).[8] The size and distribution of disc herniation is identified. First, the free fragments are removed.

## Removal of Disc Herniation

It can be done in three ways:

1. *Total discectomy:* All disc contents with cartilage endplate are removed.
2. *Subtotal discectomy:* All disc contents without cartilage endplate are removed.
3. *Limited discectomy:* Only the parts of responsible compression and the parts coming loosely from disc space are removed.

Total discectomy was used in the past. In the recent years, the limited discectomy was recommended. Lumbar microdiscectomy with limited disc excision is a safe, effective, and reliable method for treating selected patients with herniated lumbar discs.[9]

## Discectomy

There is a direct relation with the width of herniated disc removal and instability development.[10] For this reason, discectomy should be restricted as much as possible and it must be avoided from aggressive discectomy (Figs 15.1 and 15.2).

Thomé, et al.[11] reported that the surgical time is shorter and postoperatively significantly less back and leg pain in sequestrectomy.

*Thomé et al. suggestions:*

If there is sequestered disc herniation:

- Removal of the fragment
- If annular tear is seen, discectomy from torn annulus
- If annular tear is not seen, no discectomy to be done.

If there is extruded disc herniation:

- Removal of the herniated portion
- Discectomy from the perforated sections.

If there is a protruded disc herniation:

- The opening of the PLL and annulus with a transverse incision parallel to the disc and discectomy.

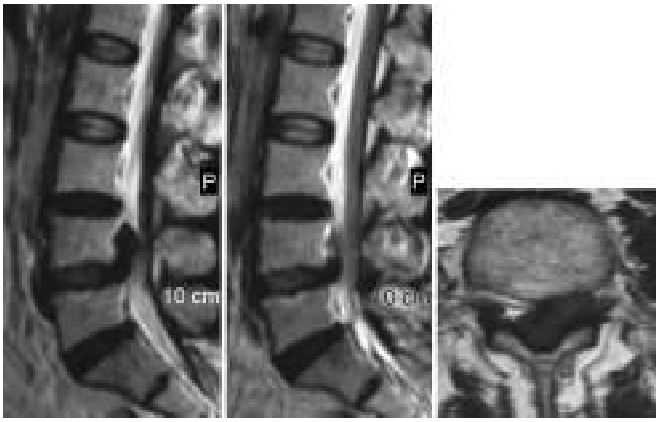


**Fig. 15.1:** MRI showing L4-L5 disc herniation which had caused footdrop

After discectomy, ligamentum flavum returns to its original state after the release of flavum dissection. Surgical field is irrigated with normal saline. If flavum have to be resected and there is no adequate fat graft in epidural area, a pediculated fat graft was used to cover the root and dura at the end.

Barth et al.[12] suggested that there is a direct relationship between low back pain and Modic changes, they said that, there was better clinical results in sequestrectomy. Chin et al.[13] also reported a worse prognosis in Modic type 1 and 2.

*There are three types of Modic changes:*[14,15]

*Type 1: Modic changes:* inflammatory, hypervascular period. Sign microinstability.

*Type 2: Modic changes:* fatty degeneration. More stable.

*Type 3: Modic changes:* stable period.

Type 1—Modic changes is more unstable. So, It is useful to make additional instrumentation to microdiscectomy.

Carragee et al. found that recurrent pain, recurrent disc herniation and a reoperation rates changed significantly according to the type of disc herniation (Table 15.3).[16]

## Closing

- Lumbodorsal fascia is sutured with 2/0 absorbable suture
- Subcutaneous tissue is sutured with absorbable 4/0 suture
- Skin is sutured subcutaneously with absorbable 4/0 suture
- For postoperative analgesia: 1 g paracetamol IV is given 45 minutes before the conclusion of surgery.

## Postoperative Care

- PO 6 hours; the patient is mobilized.
- PO 2 days; incision site is dressed. PO 3 days; incision site is opened.
- PO 4 days; daily shower is allowed.
- Postoperatively asked to lie at rest, walking is allowed increasing gradually.
- PO 2 to 3 weeks; the removal of the lumbosacral belt is requested.
- The patient is motivated to lumbar extensor muscle stretching exercise on the early postoperative period and to do back exercises after one month.

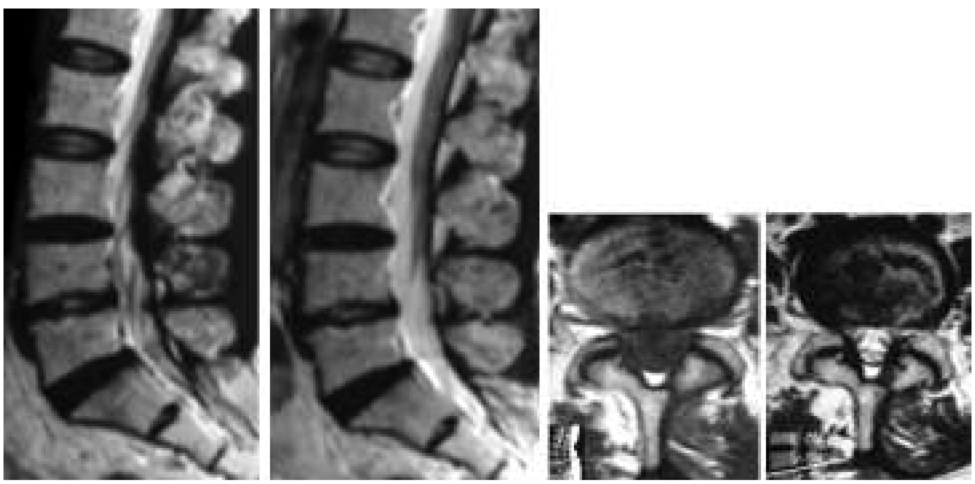

**Fig. 15.2:** Postoperative MRI after excision of disc

**Table 15.3:** Relationship between type of disc herniation and recurrence

| Type of hernia | Recurrent pain % | Recurrent disc % | Reoperation % |
|---|---|---|---|
| Fissure-fragment | 1.1 | 1.1 | 1.1 |
| Defect-fragment | 27.3 | 27.3 | 21.2 |
| Contained-fragment | 11.9 | 9.5 | 4.8 |
| Contained-no fragment | 37.5 | 12.5 | 6.3 |

- PO 1 week; the patient may enter into sexual relations in passive condition.
- The patients may return to their original work in 2 to 3 weeks for lighter work and in 1.5 to 3 months for heavy work.

## Complications

- Epidural fibrosis; 1 to 3 percent
- Superficial wound infection; 2 percent
- The disc space infections; <1 percent
- Dural tear; 1 percent
- Overlooked pathology; <1 percent
- Nerve root injury; <1 percent
- Lesions due to the position <1 percent
- Postoperative segmental instability; 3 percent.

## Preoperative Poor Prognostic Factors

- *Symptom duration:*
  - More than 3 months in those with leg pain; a higher risk of developing failed back surgery syndrome (FBSS).[17]
  - Longer than 8 months for those with leg pain; a less satisfaction rate of return to work.[18]
- *Low back or leg pain:* If low back pain is dominant, successful rate is less. If patients with leg pain are young and active, the success rate is higher.[19]
- *The disc level:* L5-S1 level is better than L4-5 level.[19]
- *Type of herniation:* Sequestered and extruded disc is better than the protruded disc.[19]
- Employee compensation status and job dissatisfaction may cause low success rate.
- *Patient's age:* Advanced age decreases the success rate.[20]
- *Diabetes mellitus:* A lower success rate.
- *Obesity:* Obese patients are with a low success rate. However, small incisions with the method of minimally invasive discectomy does not make a difference in the results shown in other individuals.[21]

## Conclusion

- There is a direct relationship between the development of instability and the width of discectomy.
- The parts of the nucleus pulposus which is not degenerated must be protected as much as possible.
- Lumbar microdiscectomy is safe. It provides short duration of hospital stay and short return time to work. It is an easy and short learning process technique.
- In lumbar microdiscectomy with preserving of ligamentum flavum and fat tissue, epidural fibrosis is less and reoperation is more secure and easier.

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# Annular Repair in Lumbar Discectomy

*Ben Roitberg, Michael Cui, Javed Khader Eliyas*

## Introduction

Since Mixter and Barr first described lumbar discectomy as a treatment for herniated intervertebral discs, spine surgeons have performed in numerous discectomies with good results – ranging between 80 percent and 98 percent.[1-4] Although initial outcome is usually very good, reherniation after discectomy can be as high as 15 percent and the procedure can expedite further disc degeneration.[5-7] Jansson et al. observed that 27 percent of reherniations either required or underwent a second operation within 10 years.[8] In a prospective cohort study almost a quarter of patients after discectomy had recurrent herniation at the same site by 2 years, about half of which were symptomatic.[9] Current discectomy techniques focus on decompressing the involved nerve root. Also there is no consensus on the amount of disc to be removed; procedures can range from taking out just the herniated material ("sequestrectomy") to extensive extirpation with intent to limit reherniation.[6,10-12] Many of the drawbacks of discectomy, such as progression of degeneration, depend on the amount of nucleus pulposus (NP) removed and damage to the posterior vertebral structures.[13] Disc removal has been shown to lead to facet joint degeneration.[13,14] Reherniation may be more frequent if the annular opening is more than 6 mm.[6,15] Back pain can persist after discectomy, which can negatively impact quality of life.[16-18] As discectomy is performed mostly on employed individuals in their productive years, socioeconomic implications are expected.[19]

Annular repair aims to close the annular opening, either one that is identified at surgery, or made at the time of the operation, in order to prevent recurrent herniation, stabilize further disc degeneration by maintaining intradiscal pressure, and negate other ill-effects of removal or loss of healthy disc.[15]

## Annulus Fibrosus: Structural and Molecular Composition

The intervertebral disc (IVD) is a remnant of embryological notochord, is sandwiched between adjoining cartilaginous endplates at all subaxial intervertebral segments until the sacrum.[20] It consists of central NP and the surrounding annulus fibrosus (AF).[5] Both AF and NP change considerably chemically and biomechanically throughout life.[21] The AF is made up of water (60–90%), collagen (50–70% dry weight), proteoglycans (10–20% dry weight) and noncollagenous proteins like elastin.[22] While the total collagen content decreases from the outer layer to the inner, the proportion of the type II collagen fibers increases in the same direction.[23] Type II collagen fibers are arranged into lamellae and resist potential crack propagation. The lamellae prevent one crack or tear expanding through the entire disc hence multiple cracks or tears are needed before failure occurs.[24]

In addition to type II collagen fibers, type 1 collagen, fibers can be found throughout the annulus.[25] Type I collagen fibers are arranged in 15 to 25 concentric layers to form a laminated structure.[26] The annulus collagen fibers are parallel and tilted with respect to the axis of the disc by about 65°.[27] Despite taking up only 2 percent of the dry weight of the AF, elastin is essential in giving the AF its recoil properties. These elastin fibers are arranged parallel to each other and in the same direction as collagen bundles within the lamellae.[28] Lastly, at the periphery there is what is known as Sharpey's fibers providing strength to the IVD by passing through the endplates to penetrate the bone of the vertebral body where they attach.[29]

The annulus is often thought of as one structure but due to cellular and structural differences, the AF functions as two distinct zones. The inner AF acts as a transition zone between the highly organized collagenous structure of outer AF and the highly hydrated NP.[25] As a result of its location, the inner AF experiences higher hydrostatic pressure from the NP and less tensile force than the outer AF.[30] The inner layers with more type II collagen, in semblance to articular cartilage, help withstanding compression generated during loading. Compressive forces may also induce type II collagen formation while type I collagen found in the disc provides more tensile strength.[23] The end result is collagen fibers cross-linking into a network that provides tensile strength and distributes load over large parts of the AF. Diminished functional cross bridging leads to loss of mechanical properties of the collagen network, impairing the ability of the AF to resist forces delivered by compression of the disc.[31,5]

### Facet Joints

The two adjacent facet joints play an integral role in the biomechanics of the IVD. Postdiscectomy, significant changes were observed in the load bearing behavior of facet joints in cadaver lumbar spines.[32] There seems to be a cause and effect relationship between narrowing of the IVD space and facet joint degeneration, which is quite often identified in clinical scenarios. The degeneration has been noted to be reversible if the disc height is restored.[13] Disc space narrowing can lead to facet joint degeneration by chronically increasing facet joint peak pressure.[33]

## Physiology of the Intervertebral Disc

Each day a large amount of strain is placed on the vertebral body. The intervertebral disc (IVD) oppose these forces in three directions, compression, torsion, and shear (Fig. 16.1).[23] The composition and organization of the AF play a critical role in how the IVD reacts to these differing forces.[34]

### Compression

The IVD is capable of acting as a shock absorber for compression.[23] The ability to resist compression lies in the soft fluid like NP and elastic tissue of the AF. The fluid like NP will deform but overall volume will remain constant.[35] The outward wall of the AF will expand, leading to radial stress,[36] and absorb the compression.[37,38] Additionally, the posterior apophyseal joints limit displacement as well as load bearing.[39] The end result is decrease in disc height and associated disc bulging.[40]

The expansion of the AF is facilitated by the collagen fibers in the lamella organized in circular, longitudinal, and oblique fashion. The arrangement allows the collagen fibers to slide and rotate other collagen fibers in adjacent lamella, expanding the AF. Elastin fibers may also play a role in this expansion.[23] The elasticity of the NP is related to its water binding capacity, which

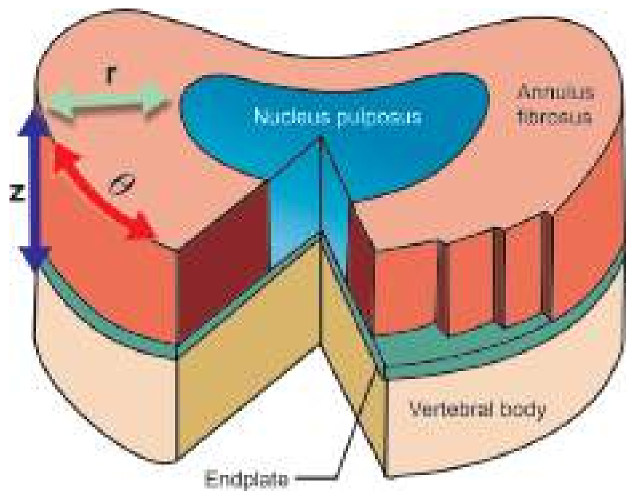



**Fig. 16.1:** Different strains/forces experienced by the annulus: movement in the radial (r) direction accommodates the expansion of the NP during compression, decrease/increase in the height (z) of the AF can occur during compression and flexion respectively while θ parallels the lamellae due to torsion

can be lost through minute tears in the AF, disrupting the ability of the annulus to act as a semipermeable membrane.[41] The importance of the AF is further highlighted in experiments where the IVD was capable of resisting compression at near normal levels after NP alone was completely removed. This indicates that the AF may be the primary load bearing structure.[35] The AF has properties similar to many elastic or semi-elastic systems. As a result, damage can occur if an annulus statically loaded to approach elastic limits is exposed to dynamic stress.[23]

### Bending/Tension

Most of the tensile strength of the vertebral column comes from the AF. The tensile strength of the AF ranges between 15 and 50 kg/cm$^2$ compared to only 8 to 10 kg/cm$^2$ of the vertebral body.[42] Stretching and tensing one half of the AF compresses the other half.[43] Compression occurs due to the movement of vertically and obliquely oriented collagen fibers in the lamellae and the outward expansion of similarly arranged elastic fiber in response to outward thrust. The tensing forces are facilitated by the movement of vertically and arranged collagen fibers in contiguous lamellae and the stretching of similarly arranged concomitant elastic fibers.[43] The recovery characteristics of the discs are due to extension and contraction of annular fibers and not due to fluid flow. Recovery is due to energy stored in annular fibers.[44]

Collagen provides tensile reinforcement as long as they are stretched by the stress applied[45] which in turn is dependent on the water content of the annulus.[46] Increased amount of collagen in the outer AF helps in resisting bending and torsional forces. If the IVD only acted as a pressure vessel, then the collagen content would be higher in the inner lamellae.[36] However, this is not the case since a high collagen level is found in the outer lamellae as well to resist tensile forces.[23]

### Torsion/Shear

The AF experiences shear stress during torsion and bending of the spine.[40] During shear stress, the AF is both anisotropic and vasoelastic.[47-49] Torsion of spine produces prominent shearing of the AF in the radial plane.[40] When torsion is applied to a disc, only half of the annular fibers—those in the direction of the applied torque; are tilted to withstand the resulting stress.[50]

As with any structure, there are different ways the AF can be damaged. Most of the damage comes in the form of changes to the components that make up the AF or the organization of the components. Injury from excessive loads on the AF can result in disorganization of cellular architecture as well as degradation of extracellular matrix (ECM).[51] While other factors such as dehydration prevents the normal recruitment of tensile support.[52] As a person ages, issues similar to dehydration arise in the AF in addition to structural damage such as a decrease in the number of distinct layers of the AF.[53]

## Annular Healing

The annulus has very limited healing potential. After making a transverse cut in rabbit model, Smith et al. categorized annular healing into three different phases.[54] The early, middle and late phases deal with healing of the outer annulus, inner annulus and NP respectively.

Immediately after annulotomy, NP material is seen to protrude into the incision as a tongue like process. The material contains notochordal cells embedded in mucoid material. The fibrous element of the nucleus, consisting of fine collagenous fibers and a few fibroblasts and cartilage cells remain *in situ*.[54] The superficial outer AF heals through active fibrous tissue proliferation leading to changes in the fibrocartilaginous tissue immediately surrounding the incision. The healing progresses from lateral to medial in the wound and becomes well established by 10 days post incision.[54] After a few weeks, the inner annular fibers begin healing next, starting laterally and progressing centripetally, taking up to a year to heal.[54]

Late stage healing involves the NP material that has protruded into the AF. At 6 months the fibroblast and cartilage cells begin to proliferate. By the second year collagenous tissue increases and becomes increasingly dense while both cartilage and fibroblast decrease in number.[54] Similar findings were found in sheep and dog studies.[55,56] It is important to note that while there appears to be healing in the outer annulus, the wound could still be open in ventral fibers due to their inertness.[54]

## Annular Healing Influenced by Surgical Technique

A study done by Key and Ford compared annular healing capacity of three different types of posterior annular incisions: a square annular window, a transverse incision, and puncture with a 20-gauge needle.[57] At follow-up, bone, blood, fibrin, and cartilage debris initially filled the annular window and transverse incisions. A thin layer of fibrous tissue gradually replaced the debris. Slow progressive disc protrusion was observed at some levels in the square window and transverse incision groups. The needle puncture site revealed nothing abnormal and the site could not be identified after 22 weeks.[57] Despite no apparent visible abnormality, recent rabbit models show that the needle puncture has immediate and progressive biomechanical and biological consequences that may lead to degenerative remodeling of the IVD.[58]

A study by Ahlgren et al. looked at similar features after different annulotomy repair techniques.[59] Pressure/volume testing done after a box type incision with muscle graft and slit and cruciate incisions with simple sutures showed no difference in mean intradiscal pressure.[59] Interestingly, box type incisions had only 40 to 50 percent strength of slit or cruciate incisions in the early healing phase. No significant difference was seen in rate of strengthening after 2 weeks across all types of repairs. Surprisingly Hampton et al. after performing a similar experiment, concluded that the 3 × 5 mm box incision had the greatest amount of healing.[55] After healing, there was a large mass of fibrous tissue that filled the box type incision whereas there was only a small cap of fibrous tissue at the periphery of the slit incision. The author concluded that the slit incision healed poorly and could provide a pathway of escape for nuclear fluids.[55] However, no pressure recordings was performed in this study.

## Need for Repair

The limited healing ability of the AF by itself makes a compelling case for annular repair. There are a few theories as to why the annulus has difficulty healing. Some point to the avascular nature of the AF resulting in a low metabolic rate and reliance of diffusion for nutrients.[54] This theory stems from the comparatively better healing ability of the outer annulus, assumed to be due to slightly increased vascularity.[54] The case for annular repair is further supported by the potential consequences of not repairing the AF. Post-annulotomy, annular tone is reduced resulting in failure to transfer compressive load from the NP. The end result is the AF coming under axial compression.[5] If the AF is not repaired, end result could be loss of disc height, over loading of facet joints, and accelerated disc and facet degeneration.[60] Though removing the extruded or sequestrated disc alone can be argued as less damaging to the remaining annulus, just sequestrectomy has been associated with higher incidence of recurrences.[61,62] Hence, the need to do adequate discectomy followed by possible annular repair.

## Techniques of Repair

After the patient undergoes regular lumbar discectomy, the surgeon is left with the choice of performing a primary annular closure. The biggest technical requisite to perform annular closure is availability of sufficient space around the annulotomy to suture manually or deploy annular closure systems without causing durotomy or injuring traversing nerve root. This might sometimes result in a larger laminotomy, generous facetectomy and extensive ligamentectomy. Otherwise the procedure is quite unremarkable from a regular discectomy performed through either open minimally invasive or endoscopic method.

## Sutures

Yasargil was the first to report on clinical outcome of annular repair following lumbar discectomy using direct suture repair and Later Lehmann et al. presented their results in 1997, both of which showed significant reduction in reoperations when annulus was repaired.[63,64] Also Cauthen performed annular closures after discectomy with different techniques including fascia grafts with promising results.[65] Following a few clinical studies with mixed results, some authors designed animal studies to look at strength of annular repair. Ahlgren et al. studied if suturing the annular defect in sheep model led to stronger healing. They found that while sutured discs had a tendency towards stronger healing, it was not statistically significant.[59] The authors might not have found a huge difference due to the small number of study animals and difference between most animals being quadripedal unlike humans.

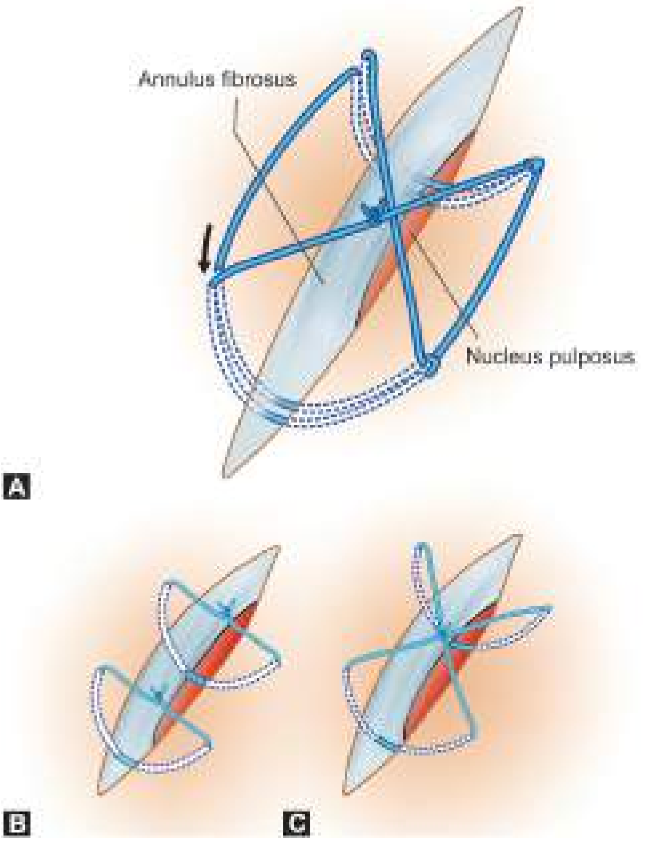
In order for the AF to remain intact, appositional forces (contact pressure) between the annulotomy surfaces must exceed the intradiscal pressure generated. Otherwise the annulotomy may open and leak nucleus, causing recurrences. A similar concept is found in general surgery where closing a defect in a hollow organ is performed using the "purse string suture".[15] This concept has been applied to annular repair resulting in a variety of repair techniques.

## Modified Purse String Sutures

Chiang et al. describe a modified purse string suture (MPSS) where two horizontal mattress sutures are used which act as 2 anchor loops on one side of a rectangle while the origin and the end of the suture are on the other (Figs 16.2A to C). The four corners of the rectangle are connected in a cruciate fashion and then contracted to close the center of the rectangle.[15] This technique generated 18 percent more contact pressure than the simple suture, employing two vertical simple sutures, and 25 percent more contact pressure than a continuous crossed suture. Additionally, the MPSS had the highest average leakage pressure. The data seems to suggest MPSS to be a superior suture technique, however, further tests need to be performed before the technique can be utilized in humans.[15]

## Devices

In addition to sutures there are currently commercial devices such as Xclose tissue repair system (Anulex Technologies, Minnetonka MN, United States) and INclose Surgical Mesh System (Anulex Technologies, Minnetonka MN, United States) utilized for annular repair (Fig. 16.3). These modified sutures with anchors focus on containing the NP and do not compensate for the loss of annulus material or reverse biomechanical changes that have occurred in the damaged AF.[65,66] Preliminary results from a multicentric randomized control study (RCT) looking at annular repair with Xclose system shows at least 40 percent reduction in risk of second surgery for recurrent herniation.[67]




**Figs 16.2A to C:** The three suturing technique described by Chiang et al: (A) CYF Modified purse string suture; (B) CYF Simple suture; (C) CYF Crossed suture. Out of all the sutures the modified purse string suture had the highest contact pressure and average leakage pressure

The Barricaid (Intrinsic Therapeutics, Inc., Woburn, MA) implant is capable of fully bridging the defect in the AF by forming a mechanical barrier. The implant consists of a woven mesh with titanium bone anchor that is placed between the AF and NP. The result is a device that reinforces the complete posterior annulus and would prevent contralateral herniation.[68]

The Disc Annular Repair Technology (Magellan Spine Technologies, Inc., Irvine, CA) or DART is a recently developed implant that provides closure of the AF. When the DART is implanted, it is placed along the posterior edge of the vertebral body close to the central axis of rotation. The device is then aligned with the load column of the vertebral body and secured in place at the apophyseal ring.[69] The Anova device (Anova Corp, Summit NJ, United States) consists of an inner polyester mesh and an outer ePTFE barrier. The device is secured to the spine by welding sutures and intraosseous sutures. The device is applied over the annulotomy defect.[70]

Out of all these devices, the Xclose system is the only FDA approved system available for use. The Barricaid and DART are being tested in Europe while the Anova device has only been tested in animals. The Xclose system was used in a prospective, single-blinded, randomized, controlled clinical trial.

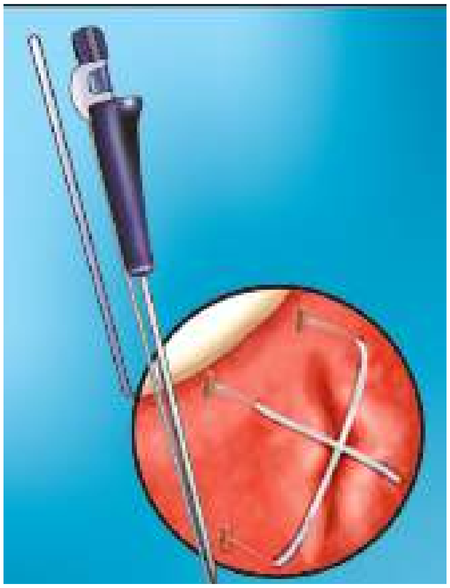


**Fig. 16.3:** Xclose tissue repair system (Anulex Technologies, Minnetonka MN, USA). The device is on the left and the end result appears very similar to sutures with anchor arranged in a cruciate fashion

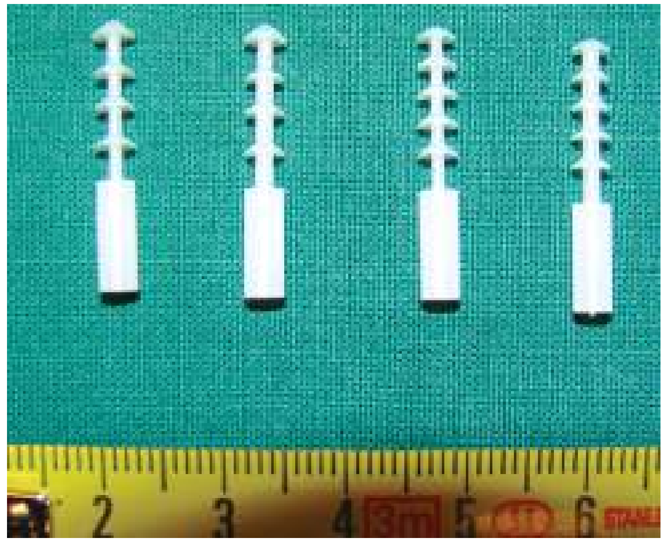


**Fig. 16.4:** Annular closure devices (ACDs) currently being studied in goats. The two on the left have 4 barbs while the two on the right have 5 barbs. Being plastic, this has been noted to incite immense inflammatory response

The researchers found that patients that have undergone annular repair had a 50 percent reduction in the risk of needing a second surgery for recurrent herniation.[67] Similar results were found using the Barricaid system as well.[71]

Often in clinical practice suturing or using an anchoring device could be challenging due to restrictions in space. Some difficulties are indeed locations that are inconvenient, tears that are too big, inflamed tissue that does not hold and often operator inexperience. In the previously highlighted RCT reduction in risk of second surgery for re-herniation rose to 50 percent in experienced hands.[67] Industrial developments such as a new "Versa-Close" system (Anulex Technologies, Minnetonka MN, USA), which can anchor to neighboring bone, works towards mitigating these technical hurdles.

### Annular Closure Devices

These devices are currently being studied in goat intervertebral discs. The annular closure devices (ACD) have either four or five barbs and are meant to close a standardized 3 mm circular defect in the AF (Fig. 16.4). All of the tested devices were able to withstand axial compression forces of over 1000 N.[72] The ACD are inserted into the AF until all barbs of the rings are inside the defect. The back end of the ACD is used to hold implants during implantation.[72] The study noted that 4-barbed ACD performed better than 5-barbed ACD. The former was able to withstand on average 4000 N where as the latter could withstand 1000 N only. Even though these devices did not significantly reduce lateral flexion, a tendency towards a small restriction can be observed. The decrease in diameter of both defect and barbed rings may help reduce contact with endplate and is preferred from a biomechanical viewpoint.[72] However, after 6 weeks all ACDs revealed signs of severe plastic deformation, especially in the barbs. Additionally out of the 10 goats in the study, 7 closure devices were partially displaced and 7 were fully displaced. Further testing and modifications are needed before these are even considered viable in humans.

## Newer Research in Regenerative Techniques

Current repair techniques focus on closing the annular wound but do little to stimulate the healing of the AF. Tissue engineering,[67] cell therapy, and synthetic scaffolding offer methods to aid in the restoration of the disc.[73]

### Cell and Gene Therapy

Herniated disc cells, due to their availability, have been used but have an increased rate of senescence.[74] Using mesenchymal stem cells may prevent the problem regarding senescence, limited supply, and culturing of AF cells.[75] AF cells, derived from inner AF, must be cultured in three-dimensional environments such as alginate, agarose or collagen hydrogels to prevent loss of phenotype.[76-78] Hydrostatic pressure influences AF cells by enhancing type II collagen production and promoting Extracellular matrix (ECM) elaboration and organization.[79] There has also been some research into utilizing gene therapy for annular repair. Studies have shown that rabbit AF cells continuously stimulated by osteogenic protein-1 (OP-1) were able to repair the ECM, increase collagen content, and produced a more pronounced effect on proteoglycan synthesis.[80,81] Bone morphogenetic protein (BMP) and Sox-9, when overexpressed, were observed to enhance collagen synthesis *in vitro*.[82] Gene therapy and cell therapy might not be mutually exclusive but rather interdependent and overlapping. In the AF, direct mechanical strength and a certain volume to patch the defect appears to be required in order to contain the NP.[83]

### Scaffolds

The purpose of a scaffold is to provide both direct mechanical stability and allow formation of native tissue in the long-term, hence often needed for the newer tissue growth. General principles like immunogenicity, biocompatibility, biodegradability, and method of graft delivery are universally considered.[84] All scaffolds should be able to fill/repair the AF and contain the NP, allow AF cells to survive, and maintain/restore the mechanical properties of the spinal motion segment.[5] There are many different scaffolds being developed. An oriented electrospun-nanofiber is the only scaffold that mirrored the anisotropy and nonlinearity of the lamella while also allowing the AF cells to attach and deposit necessary IVD components.[85] The poly 1,8-octanediol malate (POM) scaffold is a 3D scaffold, which simulates the deformability of the AF and has good biocompatibility.[86] A biphasic scaffold has been developed which simulates the type 1 collagen-rich outer AF and an inner biomaterial based on poly-poly-caprolactone triol malate (PPCLM) which has biomechanical properties similar to the inner AF.[87] The scaffold can be made in sheets that resemble the concentric layer like in native AF.[88] While these scaffolds appear promising, most of the studies find that there is production of type II collagen and aggrecan instead of collagen type I, which is the most common ECM component of the AF.[89] Type II collagen is an insufficient bridge to repair because it does not bundle or form fibrillated structures.[5] Research has also shown that some tissues found in scaffolds do not resemble native AF tissue.[90] while others have been histologically comparable.[91] Scaffolds are an exciting possibility and further research needs to be done before they are viable.

## Challenges in Research

Currently, during research, AF lesions are generally made at the anterolateral region of the healthy AF, making extrapolation into human models difficult.[92] Repair mechanisms in animal studies may differ compared to patients with herniated NP (HNP) due to pathophysiological changes that have occurred prior to HNP.[6] One of the biggest difficulties in translating research is the apparent difference in load bearing between quadripedal animals and bipedal humans.

Often times patients do not have just one annular fissure; annular fissures commonly develop bilaterally.[52] So when one side of the annulus is repaired, the contralateral fissure may progress and become problematic sometimes at a rapid pace.[5] There is inherent lack of vascularity in healthy AF. The lack of vasculature compromises nutrient supply and waste removal leading to failure of many regenerative therapies.[93]

## Conclusion

Conventionally, discectomies do not involve repair of annular opening may led to early recurrence of herniation in up to 20 percent of patients. Annuloplasty or annular repair is a promising technique that aims at reducing recurrent herniation, impede further disc degeneration and indirectly prevent facet hypertrophy. As the need for AF repair is increasingly recognized, various techniques and devices are being made available to achieve continuity of the annulus after discectomy. In spite of expanding usage of annular closure devices, much about physiology of annular healing, its impact on segmental stability and movement, and the best method of reversing damage remains unknown. Although devices like Xclose can be used with minimally invasive approaches, very small openings and limited operative fields increase the difficulty of annular repair. The AF plays a critical role in the functionality of intervertebral disc and in future it is reasonable to expect new regenerative and repair techniques geared towards the AF.

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# 17

# Discoplasty after Excision of Herniated Disc

*PS Ramani*

## Introduction

Once in a while, one reads in the literature attempts to reconstruct the posterior longitudinal ligament[1,2] which is disrupted 1. When the nucleus herniates outside the annulus and creates a rent 2. When the annulus is opened to excise the bulging nucleus.

The author has also been interested in this concept and had introduced discoplasty following microdiscectomy to repair the annulus in 1986 and had published the technique in a peer reviewed journal in the same year.[3]

## Author's Technique

Under magnification, the herniated disc is exposed. The posterior longitudinal ligament is cut for a distance of 6 mm with a sharp blade parallel to the edges of vertebra. The disc tissue is excised through this opening. If felt necessary the two edges of the ligament can be held apart by stay sutures. After completion of excision, the ligament is either sutures back with 3 microsutures or held in position by sticking it together with a laser beam.

## Results

Discoplasty has been done in several cases. However, it is difficult to access its efficacy. We have realized later that the rate of recurrence of disc at the same level in short-term and long-term follow-up is 2.4 percent which is comparable with the literature[4,5] and we cannot really evaluate the effectiveness of this procedure although it is a good microscopic exercise.

## Conclusion

The procedure cannot ensure further recurrences but it is a good exercise in maintaining anatomical compartments.

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# 18

# Far Lateral Disc Prolapse

*Matthew J Tait, Nicholas WM Thomas*

## Introduction

Three major patterns of symptomatic lumbar disc herniation occur; posterolateral herniation with radiculopathy; posterior herniation with cauda equina compression and far lateral disc prolapse with radiculopathy. The last of these can also be called extreme lateral, extracanalicular, foraminal or extraforaminal disc prolapses. Far lateral disc prolapses are defined as occurring outside the spinal canal either within the neural foramen or lateral to it. This location results in a different pattern of neural compression to the more common posterolateral herniation. This in-turn influences the clinical presentation and the diagnosis can be more difficult to establish—attention needs to be paid to the imaging to identify the prolapse and the neural impingement.

The first description of a herniated lumbar disc outside the lumbar canal was in 1944 in a cadaveric study by Lindblom.[1] Despite this the first clinical cases were not reported until 1971[2] and the first series and full description was published in 1974.[3] Much of the delay in recognizing this condition was due to the imaging modalities available at the time. Myelography did not detect extraforaminal neural compression and computed tomography (CT) has poor resolution in comparison with multiplanar magnetic resonance imaging (MRI). Subsequent large series has shown that 7 to 12 percent of lumbar disc protrusions are far lateral and that the most commonly effected levels are L3/4 and L4/5 followed by L5/S1.[4] There is no sex predominance. Most patients are between 50 and 78 years of age.[4]

## Anatomy

The lumbar foramen is bordered superiorly and inferiorly by the pedicles of the adjacent vertebral bodies. The anterior aspect of the foramen consists mainly of the inferolateral aspect of the posterior wall of the superior vertebral body but also contains the lateral aspect of the intervertebral disc and a small portion of the superolateral aspect of the inferior vertebral body prior to the origin of the inferior pedicle. Posteriorly the roof is formed by the ligamentum flavum and posterior to that is the pars interarticularis and the apophyseal (facet) joint.[5]

In the lumbar spine, the nerve root exits the spinal canal below its corresponding pedicle. Thus, the root foramen between L3 and L4 contains the L3 nerve root (the exiting nerve root) and is referred to as the L3 nerve root foramen. At the same level, the lateral recess is occupied by the L4 nerve root (the traversing root) (Fig. 18.1). This arrangement is present from T1 down but not in the cervical spine where the roots exit above their corresponding pedicles. In the lumbar spine, the foramen is capacious. The root tends to sit superiorly within the foramen and so is most closely related to the inferior aspect of the superior pedicle. It therefore sits superior to the intervertebral disc within the foramen. The root travels inferiorly as well as laterally as it exits the canal and so passes over the lateral aspect of the intervertebral disc. At this point, it is anterior to the transverse processes and the thin intertransverse ligament which passes between them.

Within the foramen the nerve root is surrounded by dura and epidural fat. The spinal nerve is formed within the foramen by the union of the ventral (motor) and dorsal (sensory) roots. The dorsal root ganglion is just proximal to this union and so also sits in the foramen. Cerebrospinal fluid (CSF) is only present within the nerve root as far as the proximal neural foramen but the dural sheaths extend distally to merge with the epineurium of the spinal nerves.

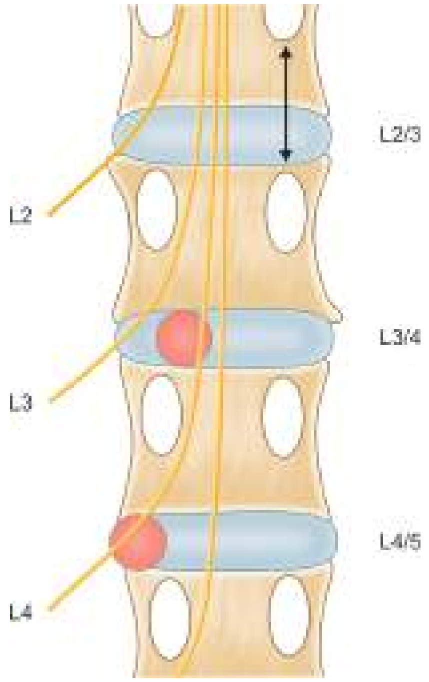



**Fig. 18.1:** The L2/3 segment shows the normal relationship of the disc to the nerve roots. The L2 (exiting) root passes under the left L2 pedicle and through the neural foramen (illustrated on the right by the double-headed arrow). The L3 (traversing) root is still within the canal but is the most lateral root. At the L3/4 segment, there is a left posterolateral disc prolapse with L4 root impingement. At the L4/5 segment, there is a far lateral disc prolapse causing compression of the L4 root again. Thus a posterolateral disc prolapse causes compression of the traversing root and a far lateral disc prolapse causes compression of the exiting root

## Etiology/Pathogenesis

Current theories of causes of lumbar disc herniation stress the gradual degeneration of the disc resulting in the inability of the disc to resist applied stress. Degenerative processes include; a reduction in disc fluid and proteoglycan content;[6] a reduction in the degree of chondroitin sulfate[7] and alterations to the disc blood supply.[8] Adams and Hutton demonstrated that distortion of the lamellae of the annulus results in radial fissures through which prolapses may occur.[9] Biomechanical studies have demonstrated that various combinations of disc compression, flexion and lateral bending lead to high pressures within the nucleus pulposus and localized points of high stress within the annulus.[10]

Several of these processes appear to be concentrated in the posterolateral region of the disc which may explain why this is by far the most common site of disc herniation. The degree of reduced chondroitin sulfate is greatest there[7] and the greatest stress is recorded in the posterolateral region.[11,12] Furthermore, differences in the arrangement, number and structure of the lamina bundles resulting in inherent structural weaknesses in the posterior portion of the annulus fibrosus when compared to the anterior part may also contribute.[13]

Unfortunately, very little data exist to explain why some patients develop far lateral disc prolapses rather than posterolateral herniation. Biomechanical studies show that axial rotation is associated with high degrees of shear strain in the more lateral annulus fibrosus,[14] however, it must be that some patients have a predisposition towards laterally positioned degenerative changes.

## Clinical Presentation

The classical presentation of far lateral disc herniation is with radiculopathy caused by compression of the exiting nerve root. The major difference to posterolateral disc herniation is the root that is involved: a posterolateral herniation compresses the axilla of the traversing nerve root within the canal. A far lateral disc prolapse at the L4/ L5 disc will therefore result in compression of the L4 nerve root as opposed to the L5 compression resulting from a posterolateral L4/ L5 disc prolapse (Fig. 18.1).

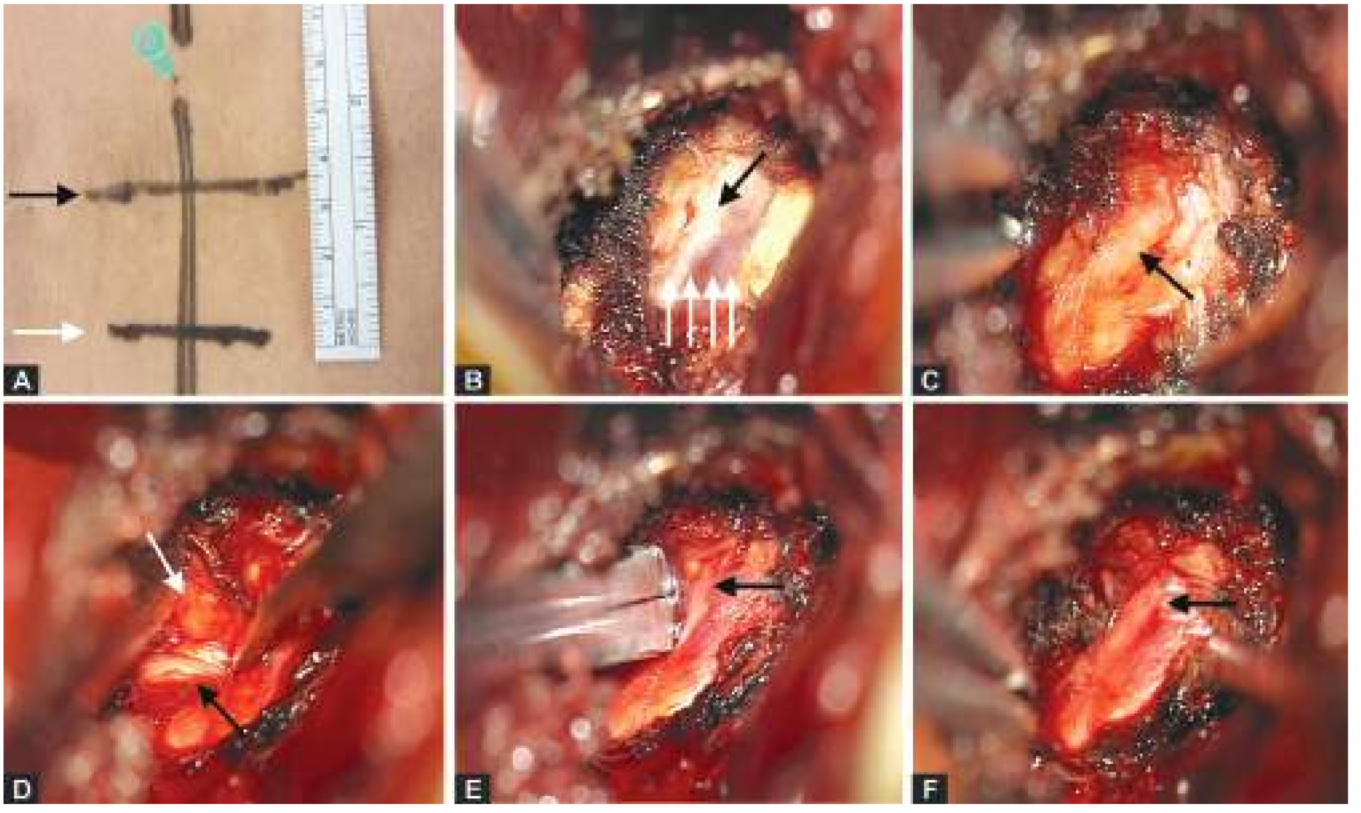
As well as affecting a different root, radiculopathic symptoms due to far lateral disc prolapse is also subtly different in nature. Pain is often reported to be more severe than that resulting from posterolateral disc prolapse. This is most likely due to direct compression of the dorsal root ganglion rather than nerve root axons.[15] Far lateral herniation results in similar rates of sensory change and motor deficit but tend not to be associated with severe back pain.

Lasegue's sign is often described as being absent in far lateral disc herniation. This is because early series contained a low incidence of L5/ S1 far lateral prolapses.[3] More recent series show that up to 38 percent[16] occur at the lumbosacral junction, resulting in L5 compression and a positive straight leg raise. Despite this, the proportionally greater incidence of far lateral disc prolapse at higher levels and the compression of the more proximal nerve root at each level does mean that Lasegue's sign is often absent. In that event the femoral stretch test is often positive.

### Imaging

It is not possible to distinguish clinically with any certainty between radiculopathy caused by different types of disc protrusion or due to other causes. Using modern imaging techniques, the diagnosis should be more straightforward. This has not always been the case: the limited extent of the CSF within the nerve roots makes traditional myelographic imaging extremely unreliable.[17]

The current investigation of choice is MRI both for the excellent resolution of the disc and nerve root and for the exclusion of other pathologies.[18] The parasagittal images give the most direct view of the neural foramen and the area lateral to it. The presence of hyperintense signal around the nerve root from perineural fat is a good indicator that there is no compression. More recently 3T magnetic resonance myelography has refined diagnosis further.[19] In cases of spondylolisthesis or scoliosis a CT scan is advisable to study the bony anatomy particularly to look for a pars defect.[20]




**Figs 18.2A to F:** A right-sided L4/5 extraforaminal microdiscectomy (*Head to the right:* A needle identifying the correct level has been placed on the contralateral side to the operative approach) (A) The level is identified using fluoroscopy. The incision (white arrow) is approximately 3 cm and is placed 3–4 cm from the midline (black arrow); (B) The transverse processes either side of the disc are exposed via a transmuscular approach. The thin intertransverse ligament (small white arrows) and the nerve root beyond (black arrow) can be seen; (C) The intertransverse ligament is removed fully exposing the root (black arrow), which appears posteriorly displaced; (D) Retraction of the root (black arrow) exposes the disc prolapse (white arrow); (E) The prolapsed disc is removed using rongeurs taking care to avoid the root (black arrow); (F) The root is now fully decompressed

## Treatment

### *Conservative Management*

Initial conservative management with analgesia or transforaminal injection of steroids and local anesthetic around the nerve root is often an effective treatment of symptoms caused by a far lateral disc protrusion. Despite this, the results of conservative management are highly variable in different series with 10 to 90 percent of patients being managed without surgery in three series.[21-23] In patients with intractable pain, progressive neurological deficit or those who have failed conservative management surgery is indicated.

### *Extraforaminal or Extreme Lateral Approach*

The microscopic far lateral approach has been established for many years.[24] This approach gives excellent access to the extraforaminal portion of the nerve root as well as the lateral portion of the foramen. It is performed entirely outside the spinal canal and so preserves motion and stability at the segment as well as avoiding epidural scarring. It does not, however, give good exposure to the medial aspect of the foramen and it is not always possible to gain sufficient lateral access at L5/S1 due to the posterior iliac crest. The operation is described fully in Figures 18.2A to F.

### *Medial Decompression*

In cases, where it is not possible to decompress the root laterally, the surgeon can perform a full facetectomy to decompress the lateral recess and the foramen. Consideration must be given to whether stability has been compromised and pedicle screw fixation is required.

### *Percutaneous Endoscopic Discectomy*

With refinement of the percutaneous endoscopic technique over the last few years, there has been increased interest in the procedure. The extraforaminal disc herniation is ideal for this approach.

The procedure is best performed under local anesthetic. In this way, if the nerves are impinged upon by the instruments there is immediate patient feedback and the trajectory re-adjusted. The patient is placed in either the lateral or the prone position and the disc space cannulated with a K-wire under fluoroscopic guidance via Kambin's triangle which is defined anteriorly by the exiting nerve root, inferiorly by the end plate of the lower lumbar segment, posteriorly by the superior articular process of the inferior vertebra and medially by the traversing nerve root. Radiopaque contrast and blue dye are injected into the disc to confirm the position and mark the disc. The needle track is widened using serial dilators and the disc entered with an endoscope. Dyed disc fragments are then removed until the root is seen to be decompressed.

Results with this technique have been encouraging. Lew et al. report 85 percent good or excellent outcome in 47 consecutive patients (Macnab criteria) with no complications.[25] Sasani et al.[26] report good outcomes using the visual analog pain scale and Oswestry scale in 66 patients, however 2 patients required conversion to an open microscopic approach and 3 required revision microsurgery within 6 months due to recurrence.[27] Endoscopic discectomy at L5/S1 can be technically challenging due to the height of the iliac crest. Even so, Lübbers et al. have reported good or excellent outcomes in 18/21 (81.8%) patients using Macnab criteria.[28]

### *Other Techniques*

Hybrid endoscopic-microscopic approaches are also employed using transmuscular trocars. Good to excellent (Macnab) outcomes in 84 to 93 percent of patients.[27,29] One other suggested solution to the lack of lateral endoscopic access to L5/S1 is the retroperitoneal laparoscopic lateral approach.[30]

## Summary

The clinician needs to be aware of the far lateral disc prolapse as a cause of sciatica particularly when no obvious posterolateral disc bulge with neural compression is identified. The imaging needs to be reviewed to ascertain whether there is foraminal or extraforaminal neural compression. The more traditional midline approach to the lateral recess may prove inadequate to decompress the foramen satisfactorily and paramedian extraforaminal approaches address the pathology more directly. The approach may be either microscopic or endoscopic and high success rates have been documented with both.

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# 19

# Extraforaminal Approach to Lumbar Disc Herniations

*Mahmet Resid Onen, Sait Naderi*

## Introduction

Lumbar disc herniations are expressed with different terminologies according to their anatomic locations. These different locations are important in determining both clinical and surgical approaches. The herniation of disc medial to the pedicle is referred to as central and paramedian herniations and they are approached using classical median approach and laminotomy. The herniation of disc in the neural foramen between the medial and lateral edges of the pedicle is called foraminal herniation, while herniation located beyond the neural foramen lateral to the pedicle is referred to as the extraforaminal (far lateral) disc herniation (EFDH) (Fig. 19.1). The approach to lumbar extraforaminal disc herniation differs from the classical middle line approaches employed for the central and paracentral disc herniations. Also, it appears more advantageous to employ external approach to the disc herniations located in the central and outer zone in the case of foraminal disc herniations.

For years, partial or total facetectomy using midline approach has been applied for the disc herniations with extraforaminal location. Due to the development of the complications such as instability and lumbar pain in this approach, the extraforaminal approach was developed.

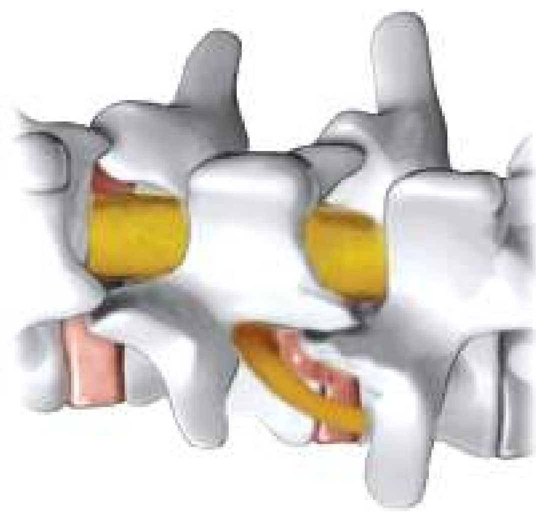


**Fig. 19.1:** A depiction of extraforaminal lumbar disc herniation

## History

Lindblom defined for the first time EFDH in a Cadaver study in 1944, while Echols and Rehfeldt reported the surgery of EFDH in 1949.[1,2] Scaglietti et al. published in 1962, a 24-case series of EFDH subjected to surgery.[3] Abdullah et al. indicated that the cases with EFDH caused the superior lumbar root compression and they defined the clinical and radiological picture for these cases.[4] With the introduction of computed tomography (CT) and magnetic resonance (MR), the radiological diagnosis became even easier for such cases.

Most of the studies of the earlier period generally used the interlaminar approach or subtotal-total facetectomy and laterally expanded approach as the surgical approach technique for these cases. Today, it is possible to approach these discs in a minimally invasive manner using the extraforaminal approach and to perform microdiscectomy with minor damage.

## Anatomy

Intervertebral foramen contains the dorsal root ganglion, Luschka's recurrent meningeal nerve, segmental artery and vein, ligamentum flavum's extension to facet joint and the fat tissue. This position of the ganglion within the foramen should be kept in mind during the extraforaminal approach and it should be known that the excessive retraction may cause the compression of the ganglion in the foramen and may cause postoperative neuropathic pains.[5-7]

The exterior of the intervertebral foramen, the extraforaminal zone, is the section remaining lateral to the superior and inferior pedicles. Extraforaminal disc herniations are situated in this zone or in alignment with the disc or in a state migrated into the cranial in alignment with the disc. This zone is bounded by the superior and inferior pedicle in the medial, the intervertebral foramen between these, pars interarticularis that forms the roof of the foramen and the superior articular process. The anterior limit is formed by the intervertebral disc and the vertebral body, and the lateral limit is formed by the fat tissue. The extraforaminal zone is covered by intertransverse ligament situated between the two transverse processes dorsally. The process of the root in this zone presents importance with respect to surgery[5-7] (Fig. 19.2).

The root angles are in the range of 36, 1°–40, 4° with respect to dural sac and this angle increases towards the inferior lumbar. The increase of the root angle in the inferior lumbar zone facilitates the transaxillary approach for accessing the disc distance. The distance between the lumbar root and the superior articular process is in the range 6.5 to 11.4 mm, said distance increasing towards the inferior lumbar levels.[5,8] In other words, the depth of the root with respect to the transverse processes decreases when going towards the levels higher than L4-5, i.e. the root proceeds closer to the surface. This requires a careful in levels such as L3-4 and L2-3 to avoid nerve injury, which is located just below the membrane.

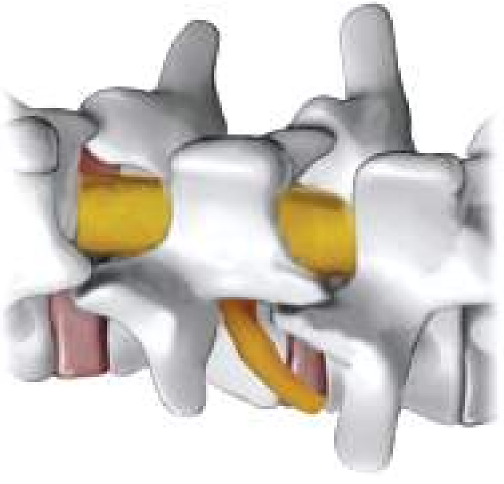


**Fig. 19.2:** Regional anatomy of the lumbar extraforaminal area

## Clinical Findings

Of all the lumbar disc herniations, 7 to 12 percent is comprised by extraforaminal disc herniations. Typically, a single sequestered piece has migrated from the disc interval into the superolateral. The migrated disc imparts pressure on the root and ganglion emerging from the same foramen. The leg pain is significant. The lumbar pain is not a typical finding. The three basic characteristics of the extraforaminal and foraminal disc herniations are the presentation of the superior root finding, the accompanying burning pain in case of ganglion pressure and a generally negative straight leg rise test.[9-20]

### Indications of Extraforaminal Approach

- Extraforaminal disc herniations
- Zone 3 and zone 2-3 herniations
- As part of the combined approach for the paramedian and foraminal and/or extraforaminal disc herniations with bi-radicular symptoms
- Isolated external intervertebral foraminal stenosis
- Extraforaminal lumbar interbody fusion (ELIF)
- Foramen and extraforaminal zone tumors (neurofibroma, metastasis).

## Surgical Technique

Usually, the general endotracheal anesthesia is carried out for extraforaminal approach. However, spinal-epidural anesthesia may also be performed.

The prophylactic 1 gram Cephazolin IV must be administered 20 min prior to the preoperative skin incision.

The patient is operated in prone position. Here the particular points to be considered are that the abdominal region is free, the venous circulation is relaxed and the required position is provided to open the intertransverse gap.

C-arm fluoroscopy is used prior to and during the surgical intervention.

### Skin Incision

The lateral and anteroposterior (AP) images of the lumbar region are obtained by means of C-arm fluoroscopy. The disc level to be operated is detected by lateral imaging, and in the AP imaging, a line is marked along the middle line and the lateral edge of the pedicles. The incision should be designed to be along the external border of the pedicle. For this purpose, a 3-cm skin incision is made about 4-cm lateral to the middle line.

### Soft Tissue Dissection

After the skin incision, the thoracolumbar fascia is incised. After the incision of the erector muscle fascia, the multifidus and longissimus muscles are stripped in cranial and caudal directions by means of finger dissection. The superior and inferior transverse processes are sensed. The transverse processes are exposed by monopolar cautery or dissector. For a good exposure

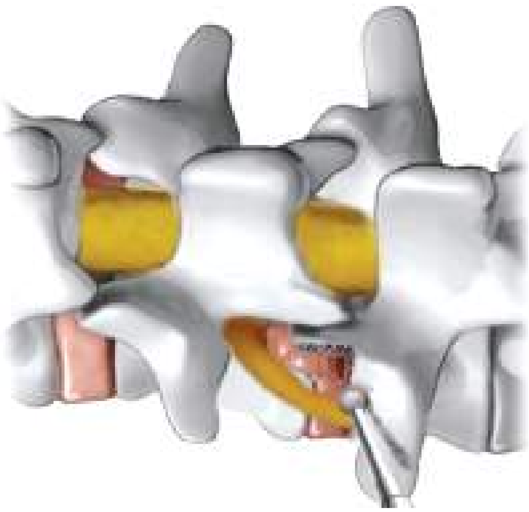


**Fig. 19.3:** Resections of lateral part of the facet joint and pars interarticularis using high speed drill

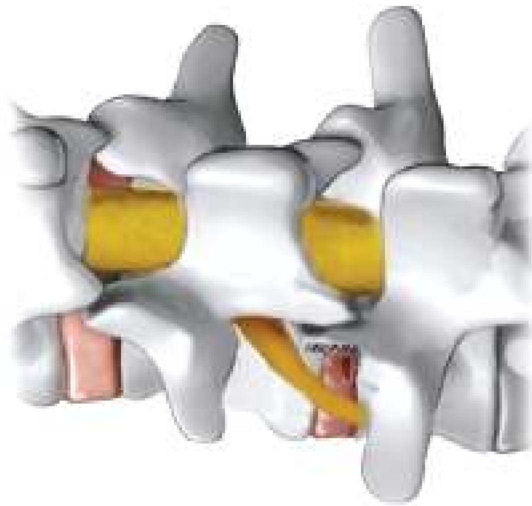


**Fig. 19.4:** A depiction of extraforaminal area after microdiscectomy

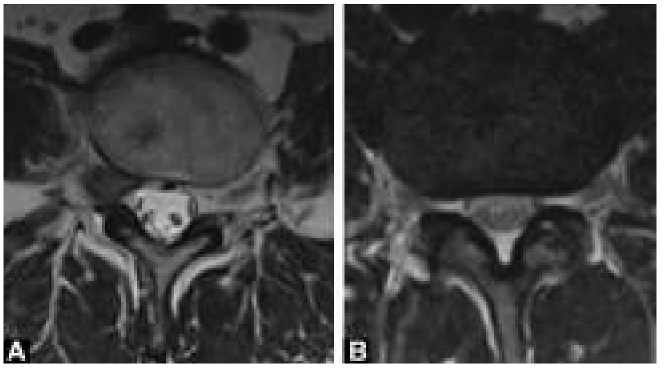
and surgical orientation, the dissection must be performed until the point where the two transverse processes join the vertebra.

One of the lumbar speculum or Scoville retractor systems is positioned. Once the retractor is positioned, we must be facing the superior and inferior transverse processes, and the facet and pars interarticularis in the medial.

The ligament or intertransverse membrane is dissected between the two transverse processes. The exposure of the lateral wall of the pars interarticularis on the medial side facilitates the surgical work. At this stage, the level may be checked by C-arm fluoroscopy. For exposure, the lateral of the pars interarticularis is partially resected and external foraminotomy is performed (Fig. 19.3). However, it must be kept in mind that the excessive removal of pars may lead to iatrogenic pars defect. In case of excessive bone excision, the dura lateral wall may be seen and mistaken for the root. The root courses near the inferior wall of the superior vertebra pedicle, and goes from the lateral of the disc level towards the lateral of the inferior vertebra transverse process. Depending on the pathology, the nerve root may be retracted towards the medial or lateral. In order to be sure about the root, one should try to sense the pedicle and the foramen immediately below with a nerve hook. The exiting nerve root is generally located close to the superior transverse process, while the disc interval is generally located closer to the inferior transverse process.

Since there is no or very little annulus defect in many cases of EFDH, it is sufficient to remove big extruded disc, however, the standard microdiscectomy must be performed in the cases where the annulus defect is large (Fig. 19.4). In addition, the procedure must be carried out generally towards the medial. The procedure towards the lateral may damage the visceral organs. Figures 19.5A and B show preoperative and postoperative images of a case of EFDH.

For the approaches to the disc level, there is no need for nerve root manipulations. Since the root angle is large at the inferior lumbar distances, this allows the interaxillary approach.



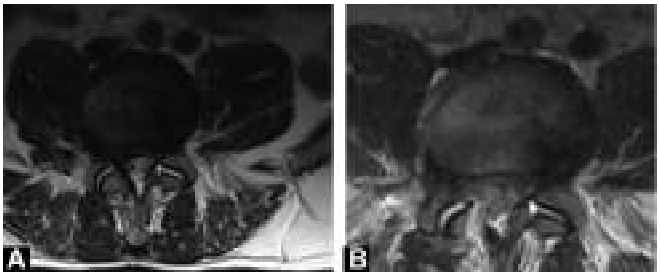

**Figs 19.5A and B:** Preoperative (A) and postoperative (B) axial MR images of a case with extraforaminal disc herniation that underwent microdiscectomy using extraforaminal approach

During the extraforaminal approach to the L5-S1 level, it may be necessary to drill the inferior of the superior transverse process and a part of sacral ala, as opposed to the other levels. For the L5-S1 foraminal and extraforaminal disc herniations, the iliac crest must be assessed by means of the preoperative axial BT sections and the suitability thereof must be checked for intervention.[17,21]

As in the conventional middle line approach, the anatomic relations between the root and the bone structures must be well known and the possible variations must be prepared for in the case of lateral extraforaminal approach.

## Combined Extraforaminal: Medial Approach

Particularly in the cases with biradicular symptoms due to extraforaminal/foraminal disc herniation and the paramedian disc herniations a combined approach may be needed. It is



**Figs 19.6A and B:** Preoperative (A) and postoperative (B) axial MR images of a case with biradicular symptoms due to paramedian and extraforaminal disc herniations that underwent microdiscectomy using combined approach

possible to perform first the standard interlaminar microdiscectomy by a 3 to 4 cm incision 1 cm lateral to the middle line, then to perform the extraforaminal discectomy by a separate fascia incision 3 cm away from the middle line. Since both discs are removed at one session owing to this method, the complaints of the patient completely disappear.[22,23] Figures 19.6A and B show preoperative and postoperative images of a case that underwent microdiscectomy using combined extraforaminal and medial approach.

## ELIF Applications with Far Lateral Extraforaminal Approach

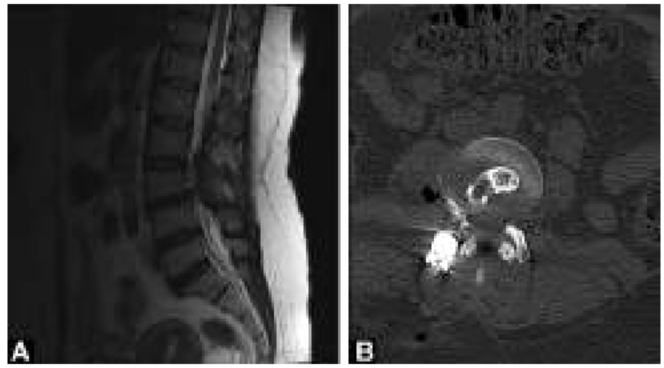
Along with an increase in the minimally invasive surgical interventions, the extraforaminal lumbar interbody fusion (ELIF) procedures have also begun. As is known, the PLIF operation performed with posterior interlaminar approach and the TLIF practices performed by the removal of facet require the excessive traction of the root and the dural sac. On the other hand, the anterior lumbar interbody fusion procedure, although being an effective method, may cause significant potential morbidities such as major vein injury, abdominal herniation, sympathetic damage and sexual dysfunction.[24,25]

Extraforaminal lumbar interbody fusion is a good alternative for the cases, which do not require medial decompression, but which are indicated for lumbar interbody fusion. According to this procedure, after the zone exposure is carried out, the screw is fitted on the superior and inferior levels, the discectomy is undertaken, and once the distraction is performed, the rod fixation may be employed by placing the cage. This method is not suitable for the L5-S1 interval.[9,24-26]

Extraforaminal lumbar interbody fusion procedure is a minimally invasive method compared to other fusion applications, and it has the advantage of the ability to be combined with percutaneous instrumentation. Figures 19.7A and B show preoperative and postoperative images of a case with L3-4 instability that underwent ELIF and unilateral segmental instrumentation.

## Complications

The most frequently encountered complication is the opening of the incorrect distance during the surgery. The check of the level



**Figs 19.7A and B:** Preoperative (A) and postoperative (B) images of a case with L3-4 instability that underwent ELIF and unilateral segmental instrumentation

by means of preoperative and peroperative C-arm fluoroscopy reduces the chance of incorrect level to the maximum extent possible.

Spondylodiscitis may develop after the surgery. Although the infection risk is reduced by peroperative prophylactic antibiotic therapy, the discitis may develop as in the conventional disc surgeries.[10,15,18,26]

The excessive excision of pars interarticularis and facet joint may cause instability.[9,24]

Recurrent disc herniations may be observed. The recurrence may develop in the surgical region as well as in the paramedian region.[15,18]

The most important complication of the extraforaminal approach is the postoperative neuropathic pain. This condition emerges as a result of the compression of the ganglion at the edge of the pedicle during the root retraction. The way to avoid this complication is to perform some external foraminotomy and to avoid over-retracting the root. Moreover, the patient's use of gabapentin may be recommended for a certain time for the prophylaxis of the neuropathic pain during the postoperative period.[15,18,26]

## Conclusion

The lumbar extraforaminal approach yields significant results in the discectomy and fusion surgery for the suitable indications. It is an important type of approach in the minimally invasive surgery owing in particular to the very low risk for instability in the disc surgery, rapid ambulation and effective results. Although its use in the fusion surgery is not yet widespread, the facts that it is a minimally invasive approach for achieving anterior fusion and that the neural damage risk is low will increase the extent of its use with time.

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# 20

# Surgical Management of Extraforaminal (Far Lateral) Disc Herniations

*Enrique Klériga-Grossgerge, Jesús Carlos Bustamante-Vidales, Christian Andrés Chalita Pérez-Tagle, Gerardo Francisco Zambito-Brondo*

## Introduction

The intervertebral disc is an extraordinary structure. It appears to be very simple and static, but in fact it is quite the opposite. Each disc is a junction that articulates with the vertebral body above and below, it is probably the largest avascular structure in the body. The intervertebral disc has three main parts: the annulus fibrosus (AF), the nucleus pulposus (NP) and the vertebral endplates (VEP). The AF surrounds the NP and forms the major part of the disc. These two structures are different in composition.

The AF is a fibrous structure composed mainly of collagen. It also contains some proteoglycan (Protein and carbohydrates) and mostly collagen, mostly near the VEP. The annulus collagen is mainly type I in the outer portion and type II near the nucleus. It also contains a small proportion of collagen type III, V, VI and IX. This collagen is arranged into approximately 10 to 20 concentric bands called lamellae that assist the NP to bear loads, resisting the outward axial forces of the nucleus as it receives these loads. The outer lamellae are attached to the vertebrae above and below. The inner part of the AF is attached to the endplates.[1,2]

The NP has less collagen and more proteoglycan than the AF. It consists of a central core of well hydrated proteoglycan matrix, called aggrecan. This aggrecan has the function to trap water in this matrix. There is also an irregular meshwork of mainly type II collagen fibers. These aggrecan molecules are assembled onto long hyaluronic acid chains to produce larger aggregate molecules. The outer part of the NP is called the transitional zone, where growth and remodeling occur. The nucleus water content is approximately 80 percent.[1,3]

The vertebral endplates consist mainly of a 1 mm thick cartilage layer without collagenous connection to the bone underlying the endplates. The collagen content is highest and the proteoglycan and water contents lower compared to the adjacent nuclear and annular regions. The role of proteoglycans at the end plate is important, regulates the transport of essential solutes into and out of the disc.[4]

Each disc joins with the vertebral body above and below and it and provides three functions to the spinal column: (1) To support the outward axial loads on the spine, when it is delivered by body mass and gravity; (2) to assist in segmental movements and the range of motion at the spine; and (3) to serve as a ligament between the vertebral bodies.[5]

The wear and tear of the AF may cause rupture of part of this ligament causing protrusion or prolapse of the NP. The complete rupture of the AF will produce an extrusion of disc material. This prolapse or extrusion of the contents of the NP, occur usually towards the vertebral canal, but sometimes, it happens at the level of the foramina or beyond and even lateral to this foramen, the so-called extraforaminal or far lateral disc herniations. A 1-C or 2-C type according to the MSU classification.[6]

Abdulla et al. in 1974 described probably for the first time this lateral or far lateral disc herniations. With improvement in imaging studies, it has become easier to diagnose these uncommon disc herniations.[1] Of all the disc herniations, the extraforaminal herniation occurs in approximately 2.6 to 11.7 percent of the cases.[7,8] If the herniation is missed at the clinical evaluation, the patient will continue with persistent pain and/or neurological deficit.[9]

They usually are free fragments that tend to migrate laterally and upwards from the point of herniation. It is said that the disc prolapses placed in front of the articular facet, that is a foraminal disc herniation occurs in about 3 percent of the cases. About 4 percent have a mixed position, foraminal and extraforaminal.[10]

## Clinical Findings

In spite of increase awareness of these type of lesions, they still are a cause of concern in terms of diagnoses and management to spinal surgeons. They occur in older population compared with the conventional herniated disc, average age of 58 years at Porchet study with a 2:1 male to female ratio.[7] These lesions compromise the exiting nerve root and at times as well, the radicular ganglion with signs and symptoms from those structures instead of the root at the vertebral canal, that is, the symptoms are those found with herniated discs at the above level, when there is compression of the nerve root at the lateral recess.[10]

The more commonly affected levels are L3-4 and L4-5, and occasionally L5-S1. Very seldom L1-2 and L2-3 may be involved, even though there are some reports with a very high and unusual frequency of involvement of the higher levels, up to 28 percent.[10]

Lindblom in 1944, in a postmortem study was able to demonstrate disc herniation in a lateral position, out of the vertebral canal boundaries. At that time the clinical diagnoses was difficult due to the lack of adequate image studies.[9] In 1971, Macnab reported 2 cases with compression of the L5 nerve root with an L5-S1 extraforaminal disc herniation.[10] Abdullah et al. described a clinical syndrome for the "extreme lateral" disc herniations, found in 1.7 percent of their cases. These clinical findings include pain in the anterior thigh or leg, usually no back pain, paresthesias same region, absent knee jerk reflex and a negative Lasègue sign, the femoral stretch sign may be positive, that is, a femoral nerve or L4 nerve root distribution with an L4-5 herniated disc in an extraforaminal position that compresses the exiting L4 nerve root.[11] Even so, Maroon found in 76 percent of his cases a positive Lasègue sign with hip pain, 78 percent of quadriceps weakness and atrophy with L3-4 herniated discs.[8]

It seems the pain is more severe and a times of a dysesthetic quality due to compression of the nerve root ganglion. The presence of neurological deficit, sensory or motor is more frequent as well in the far lateral herniations, in some series up to 75 percent.[11]

The most important point is to keep in mind this type of pathology when one evaluates a patient with a lumbar radiculopathy. If not so, the diagnoses will be missed and the patient will continue to get pain.

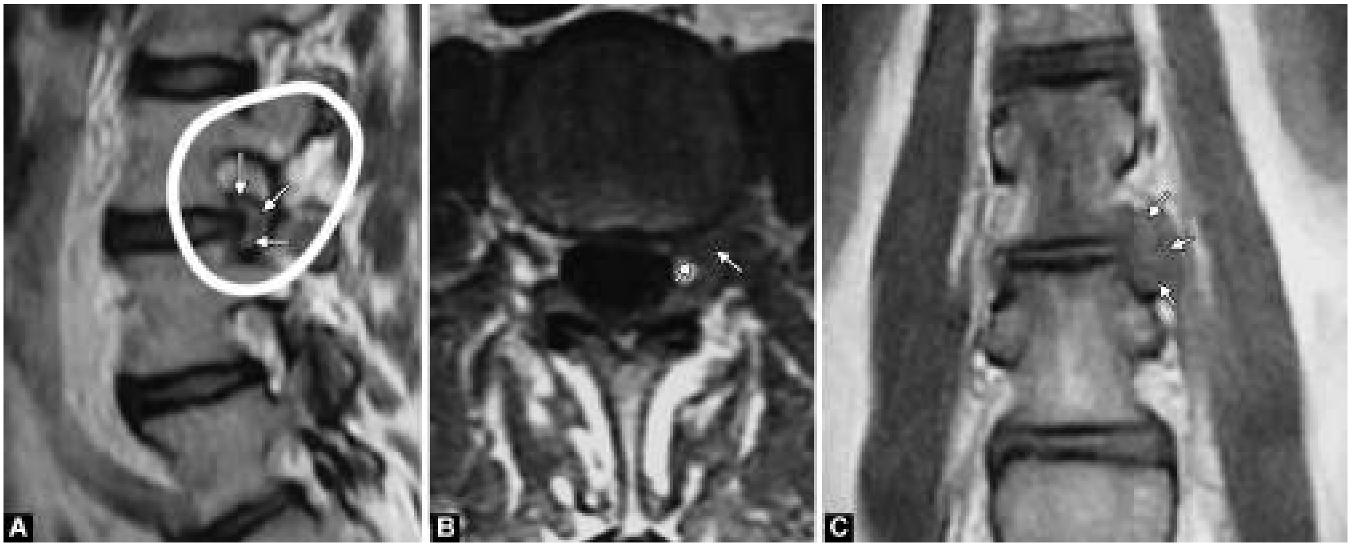
The key diagnostic studies are magnetic resonance imaging (MRI) (Figs 20.1A to C) and computed tomography (CT). The coronal views may demonstrate the nerve root compression better (Fig. 20.2). The CT scan may at times, show the extraforaminal herniation (Figs 20.3A and B). They will show the extruded disc, their position and if there is a migration the position of it. With this information one can plan what is the best management for each case.

The diagnostic work up may be completed with electromyography, nerve conduction velocities, somatosensory evoked potentials if needed to refine the diagnoses, but they are not essential. In the past, before MRI, a CT discography was advocated, but we feel nowadays it is not indicated.

The differential diagnoses are with conjoined nerve roots, an enlarged ganglion, a neurofibroma, primary schwanoma, metastatic tumor, paraspinal abscess, etc. In case of doubt, a contrast enhanced MRI or CT may be helpful.

## Treatment

In patients without neurological deficit a non-surgical treatment is indicated, it may include non-steroidal and steroidal anti-inflammatory drugs. Rust and Olivero reported successful non-surgical treatment in 71 percent of their cases.[12] Epstein in 170 reported cases found a 10 percent success with this treatment.[13] Weiner and Fraser in 1997 using transforaminal injections of




**Figs 20.1A to C:** MRI showing from (A to C) in sagittal, axial and coronal views an extraforaminal extruded disc (arrows)

**Fig. 20.2:** An L5-S1 extraforaminal disc prolapse (arrow) pressing the exiting right L5 nerve root

local anesthetics and steroids found long-term relief in 22 out of 28 patients. [14]

If there is a neurological deficit or failure of the non-surgical treatment, then surgical treatment should be advocated.

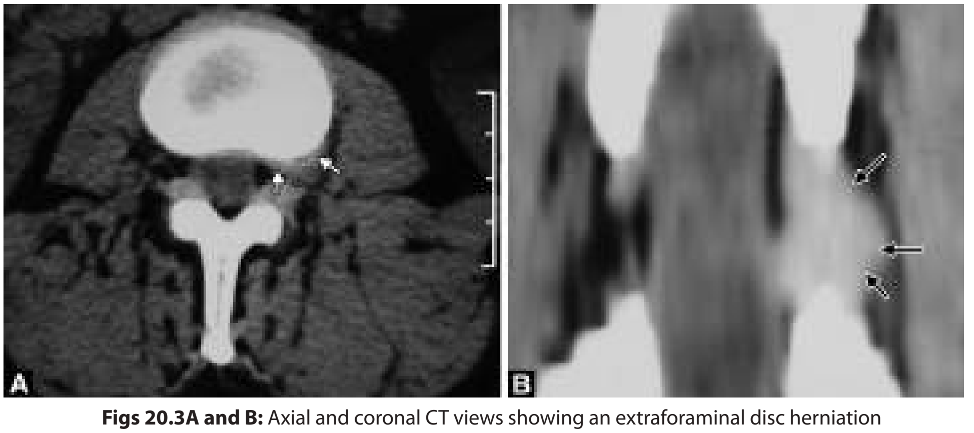
Through the years several surgical approaches have been devised. The most common are: Medial facetectomy,[15] intraspinal and paramedian approach,[16] intertransverse approach,[7-9] anterolateral retroperitoneal,[17] microendoscopic intertransverse,[18] percutaneous endoscopic transforaminal[19] and transpsoas (like in a X-lif approach).[20] All these procedures have merits and complications.

Medial facetectomy is usually carried through a midline incision with a unilateral laminotomy and complete unilateral facetectomy. Through this approach the affected nerve root can be visualized in the spinal canal and then can be followed up to the foramen and a bit beyond. The disc fragments can be removed with no retraction of the nerve root, and the contents of the disc space may be removed. A partial facetectomy would limit the exposure of the herniated disc, especially if there is cephalic migration of the disc fragments. Segment instability with this procedure has been found to be low in clinical series,[13,15] even though in the lab, there is under extension, an increase in angular motion, meaning there is a rotational instability after unilateral facetectomy.[21]

More clinical observations are needed to solve this issue; to be sure a patient with unilateral facetectomy will not require a fusion and/or instrumentation later on.

Jane et al. reported in 1990 an intraspinal and paramedian approach to the far lateral disc herniations.[16] It is carried out like a regular laminotomy for a regular disc herniation inside the vertebral canal. The exposure is carried out laterally to the lateral border of the facet. This lateral border is removed away to expose the intertransverse ligament, and the nerve root and disc above it can be approached and removed. Through this approach one can access intraforaminal fragments as well as medially situated herniations. The problem we have seen with this approach is that to better reach the extraforaminal fragment, one has to take a good piece of the lateral edge of the facet, and the angle of view does not allow you to reach the lateral third of the affected foramen or to enter the disc space without muscle stripping and retraction. With this approach theoretically there is also the risk of segmental instability since you may damage the articular facet medially and laterally.

The anterolateral retroperitoneal approach to far lateral lumbar disc herniations requires a lateral incision to gain access to the affected disc space. The dissection should be retroperitoneal and posterior to the psoas muscle to reach the diseased disc. Once in place you may remove the herniated or extruded fragments. There are some variations of this technique. One may do it laparoscopically, which theoretically may cause less perineural and peridural scar formation. The dissection is done more ventral than lateral. Another modality is using the X-lif instrumentation to access the lateral part of the foramen through the psoas muscle.[20] With these approaches the posterior elements are left undisturbed minimizing the risk of segmental instability. The disadvantages are the transabdominal morbidity associated; ureteral, large blood vessel, bowel injuries. Also the use of the laparoscope requires certain expertise, and at times




**Figs 20.3A and B:** Axial and coronal CT views showing an extraforaminal disc herniation

does not allow to visualize the more medial part of the nerve root, increasing the risk of leaving retained extruded disc fragments. With the X-lif technique, one must use neurophysiological monitoring during surgery to avoid injury the femoral nerve, thus, increasing the cost of the procedure.

Percutaneous endoscopic transforaminal approaches have been described; in 1993, Bonafe et al. performed nucleotomies, Kambin in 1998 described an arthroscopic procedure for this type of pathology with good results in about 82 percent of the cases.[22,23] The advantage of these procedures is that they can be performed under local anesthesia as an outpatient, with good clinical results. The disadvantages would be that one has to be skilled in the use of the endoscope; and perhaps the migrated fragment could be missed since the view of the field may be limited. In 1999, Foley et al. described a microendoscopic approach to far lateral lumbar disc herniations,[18] and since then, there have been several reports of this technique with some small variations.[24-26] Some cases are done with local epidural anesthesia as an outpatient basis.[18] In these procedures the incision is limited to 15 to 16 mm, and with the use of the image intensifier, K-wires and dilation tubes you may access the lateral part of the disc space and the protruded or extruded fragments may be removed through the use of different angled endoscopes. This approach may be done with good postoperative results.

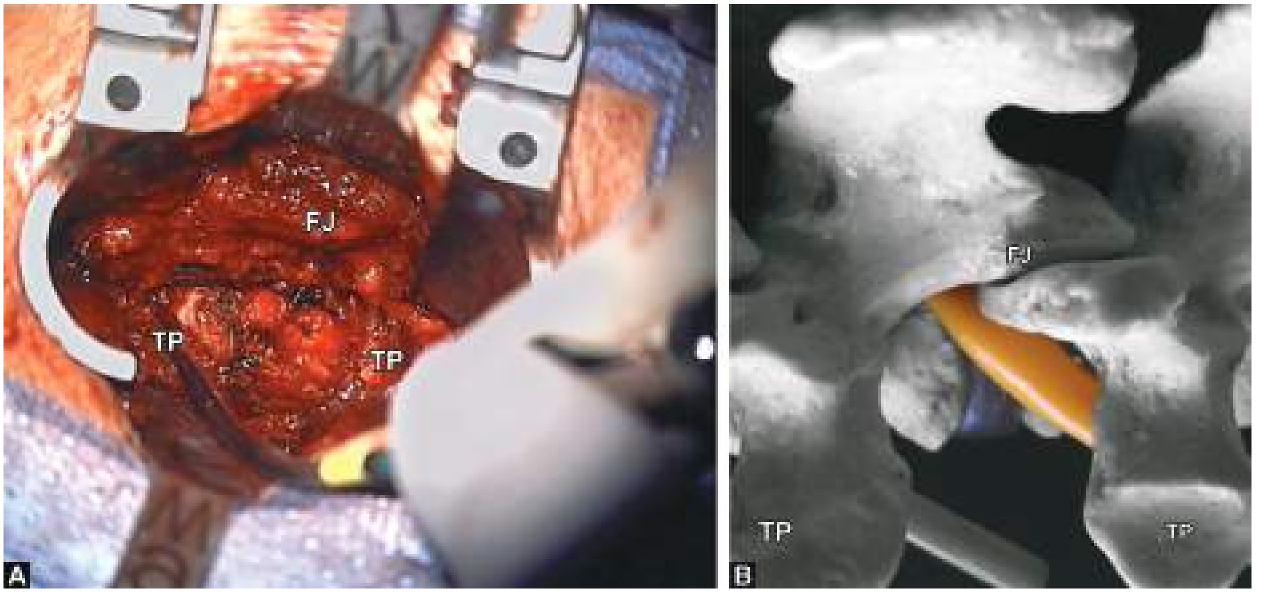
The intertransverse approach with the aid of the microscope was described by Maroon et al in 1990.[8] They presented 25 cases of far lateral disc herniations, but do not report how successful this technique is. They described a 3 cm paramedian incision, but probable a 4 to 5 cm is adequate to have a good angle to the lateral portion of the affected foramen.

It is performed with local epidural or general anesthesia, we prefer general for better patient control during the procedure that occasionally may take longer than expected. Usually, the patient is placed in prone position on a Wilson frame or an Andrews table, we use the later one. For magnification one may use loupes or the surgical microscope, the later one with its coaxial light may give a better field view. In all the above approaches one may use the image intensifier or plain X-ray films to find the appropriate disc level and at times to help find the extruded and migrated disc fragments.

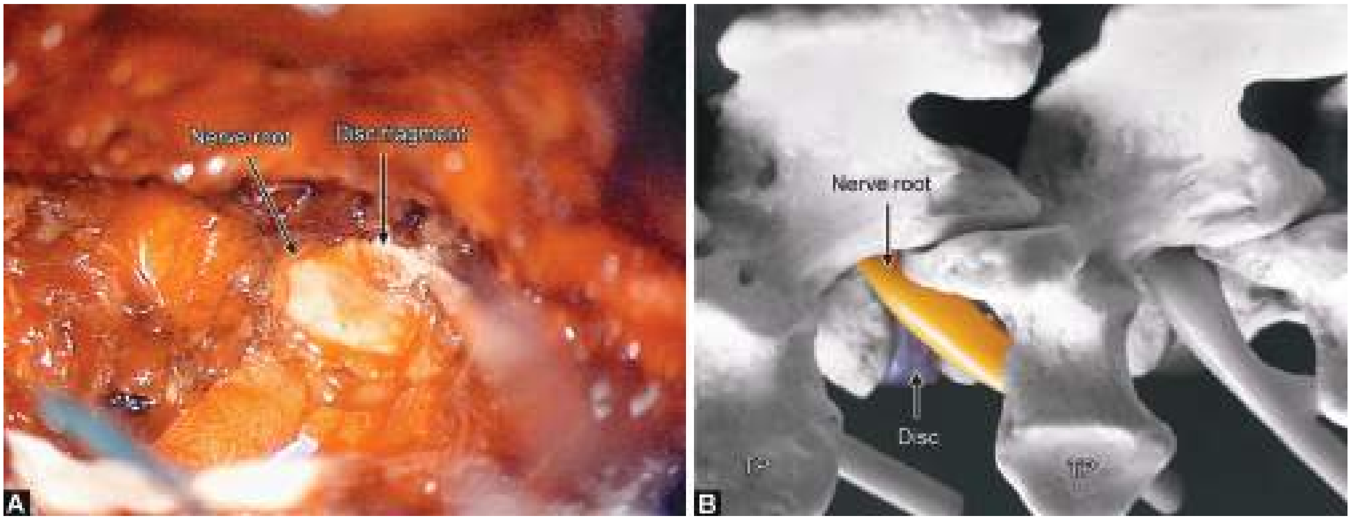
You may access the disc space bluntly in between the multifidus and the longissimus muscles. A self-retaining retractor is mandatory (Figs 20.4A and B). In general there is no need for bone drilling, except at the L5-S1 level and if the extruded fragments have migrated far from the disc space. The intertransverse ligament is opened at its medial edge. An attempt is made to identify the posterior primary ramus since it may help to find the dorsal root ganglion which is surrounded by fat. Once the nerve root is found (Figs 20.5A and B), it can be retracted very gently and the disc fragment removed (Figs 20.6A and B). Once the spinal nerve is decompressed it advisable to leave a Gelfoam previously soaked with steroids. If necessary a drain may be left in place to avoid blood from irritating the dorsal root ganglion.

Through this approach a good an excellent results may be obtained in 90 percent of the operated cases.[9] The possibility of spine instability is very rare and it may happen when part of the pars intermedia or the facet joint are removed.

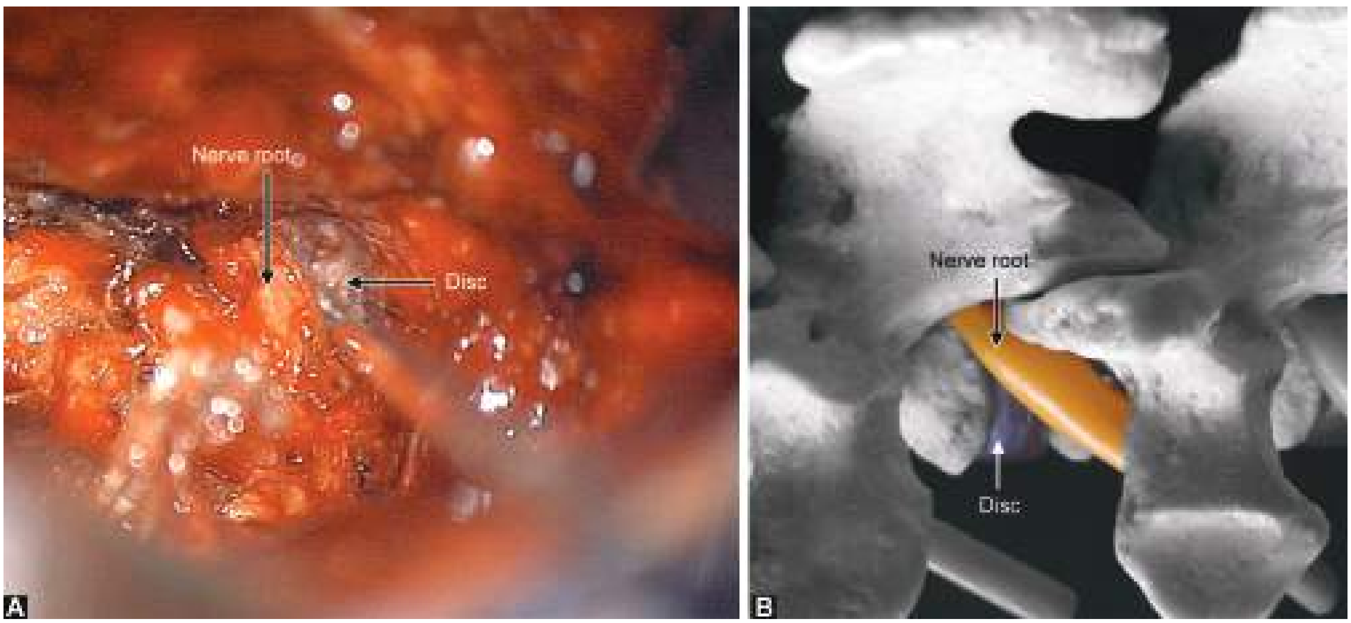
With all the above-mentioned techniques we can expect an excellent postoperative course. The complications are usually neurological, like dysesthesia, paresthesia, from an injured dorsal root ganglion due to the disc compression or surgical manipulation, it is usually short lived; weakness that fortunately usually resolves with time.




**Figs 20.4A and B:** Through a lateral intertransverse approach, the retractor in place, the surgical area as well exposed. The transverse processes (TP) are seen above and below the exposure as well as the area of the facet joint (FJ)




**Figs 20.5A and B:** Disc prolapse on the left side at the L4-5 level. TP-Transverse processes




**Figs 20.6A and B:** The extruded disc material is being removed

## Conclusion

This pathology is more common than one may think and if one is not aware of it, then it may be missed. While studying patients with lumbar radiculopathy if one does not find the cause at the usual segment, one must look at the level below especially at the foraminal and extraforaminal level. The pathology might be there and with one of the procedures listed above one may treat it successfully.

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# 21

# Minimally Invasive Treatment for Back Pain: A Review

*Jin-Sung Kim, Chun-Kun Park*

## Introduction

According to the literature, the lifetime prevalence of low back pain is estimated from 54 to 80 percent.[1] At any given time, the prevalence of low back pain is 30 percent.[1] Chronic low back pain (CLBP) lasting 3 months or more has been also reported from 4 to 10 percent.[2] Although most people with back pain recover within a few months, back pain with chronic nature and frequently relapsed pattern is one of the important causes of job loss.[3] It is also the third leading cause for disability in the 45 to 65 age group.[3,4] They have been associated with substantial health care costs.[5] In the United States and the Western world, disability due to back pain has been estimated to cost approximately $100 billion annually.[5] Therefore, CLBP has been main concern of not only patients and their family to employers, providers, and government health administration. Proper treatments of postoperative back pain have been great issues to rehabilitation doctors, interventional pain doctors, and spine surgeons. Table 21.1 demonstrates the costs for the management of low back pain in Belgium, 1999.[6]

The intervertebral disc, zygapophyseal (facet) joint, and sacroiliac joint are the three primary structures within the spinal component that are sources of chronic back pain. Following three kinds of pain are the most common causes of CLBP.[7,8]

- *Discogenic pain:* 30 to 60 percent
- *Facet pain:* 10 to 40 percent
- *Sacroiliac joint pain:* 7 to 23 percent

Interventional pain management procedures are shown in Table 21.2.

**Table 21.1:** Costs for the management of low back pain, Belgium, 1999

| | **Total cost ∈ × $10^3$** | **% cost** |
|---|---|---|
| Conservative treatment | | |
| Medication | 34,717 | 18.56 |
| Rehabilitation | 114,528 | 61.24 |
| TENS | 515 | 0.28 |
| **Total conservative treatments** | **149,759** | **80.08** |
| Nonsurgical interventional treatments | 7,707 | 4.12 |
| Surgery | 29,539 | 15.80 |
| **Total** | **187,005** | **100** |

TENS: Transcutaneous electrical nerve stimulation

## History and Evolution

Minimally invasive spinal treatment (MIST) (Table 21.3) for back pain embodies the purpose of achieving favorable clinical outcomes comparable to those of traditional open surgery, while minimizing the risk of injury and swift recovery to daily normal activity. Recently updated laparoscopic techniques used by general and urologic surgeons, have also evolved into procedures performed by spinal surgeons. Since the late 20th century, technological developments and advanced equipment (Radiofrequency, endoscopy, video, laser, etc.) have greatly contributed to the expansion of MIST. Further technology designed for minimally invasive procedures will inevitably lead to further applications.

**Table 21.2:** Interventional pain management procedures

| | |
|---|---|
| **Before 1980** | |
| | • Epidural steroid injection |
| | • Selective nerve root block |
| | • Trigger point injection |
| | • Sympathetic block |
| | • Sacroiliac joint injection |
| | • Discography |
| **1980-1995** | |
| | • Radiofrequency thermocoagulation |
| | • Superior hypogastric plexus neurolysis |
| | • Splanchnic nerves RF |
| | • Adhesiolysis |
| | • Intrathecal infusion—implantable pumps |
| | • Spinal cord stimulation |
| | • Brain stimulation |

## Pathophysiology and Clinical Symptoms

### Discogenic Back pain

Degeneration of lumbar disc is usually classified into two categories: Internal disc disruption (IDD) (Fig. 21.1), and degenerative disc disease (DDD) (Fig. 21.2).[9-11]

**Fig. 21.1:** Cadaveric dissection showing the internal disc disruption (IDD)

- Internal disc disruption (IDD), although it is the single most common cause of chronic back pain, its etiology remains still conjectural.[12]
- Annular tear do occur and dark disc disease is observed in MRI (Figs 21.3 and 21.4). The endplate fracture due to compression of the disc interferes with the homeostasis of the nuclear matrix, causing to disc degradation.
- If the degeneration process becomes progress, biochemical degradation of the matrix of the nucleus pulposus may

**Table 21.3:** Minimally invasive spinal treatment (MIST)

| | |
|---|---|
| **Before 1980** | |
| • 1934, Mixter and Barr | Exploratory laminectomy |
| • 1937, Pool | Modified otoscope for myeloscopy |
| • First endoscopic instruments | |
| – 1959, Harold H Hopkins<br>– 1960, Karl Storz | Invention of a rod-lens optical system<br>Fiberoptic light transmission |
| • 1964, Lyman Smith | Chemonucleolysis |
| • 1973, Kambin | Percutaneous posterolateral approach |
| • 1975, Hijikata | First nonvisualized percutaneous nucleotomy |
| • 1977, Yasargil and Caspar | Minimally invasive concept of microdiscectomy |
| • 1985, Onik | Automated percutaneous nucleotomy |
| • 1988, Kambin | The first intraoperative discoscopic view was obtained |
| **2000-present** | |
| • 2001, Knight | Endoscopic foraminoplasty using Ho: YAG laser |
| • 2002, Yeung and Tsou | Comparable outcome of endoscopic discectomy with conventional open surgery; 91.2% clinical success in noncontained disc herniation |
| • 2004, Ahn Y | Endoscopic discectomy for recurrent disc herniation |
| • 2005, Schuber and Hoogland | Endoscopic foraminoplasty for sequestrated disc |
| • 2007, Choi G | Endoscopic discectomy for extraforaminal disc |
| • 2007, Lee SH and Kang BU | Operative failure of endoscopic discectomy |

**Fig. 21.2:** Cadaveric dissection showing the degenerative disc disease (DDD)

develop radial fissures that extend into the annulus fibrosus. Then other structural degenerative changes (e.g. loss of disc height, loss of nuclear signal, minor facet arthrosis) may also develop.

### Five Cardinal Symptoms of Degenerative Disc Disease

1. Sitting intolerance
2. Frequent standing-up or get-up difficulty (extension catch)
3. Frequent back pain attack after physical loading such as working, golf, and exercises
4. No intention to lift heavy materials
5. Difficulty to maintain same position.

## Facetal Pain

In 1933, Ghormley first described the term facet syndrome as a cause of referred pain and the sciatica coming from direct root compression by the facet.[13] Since Badgley first reported that the facet joint could be an independent source of referred pain in greater detail,[14] many studies have been published about its clinical importance of chronic back pain, diagnostic image, and treatments.[15-17] Facet joints have synovial linings and capsules and they are highly innervated as some free nerve endings in the tissues.[18] In terms of pain generator, facet joints become inflamed and progressive joint degeneration develops more frictional (bone on bone) pain. With the progression of facet arthropathy, additional pain follows as results of bone spurs or synovial cysts, even though bone spurs and synovial cysts do not directly cause pain. The characteristic of facetal pain is exacerbated by patients motion including extension and rotation, or is associated with lumbar rigidity. Clinical symptoms and imaging studies suggest no other obvious cause of the spinal pain (e.g. spinal stenosis, disc degeneration or herniation, infection, tumor, fracture).

### Classification of Facet Degeneration

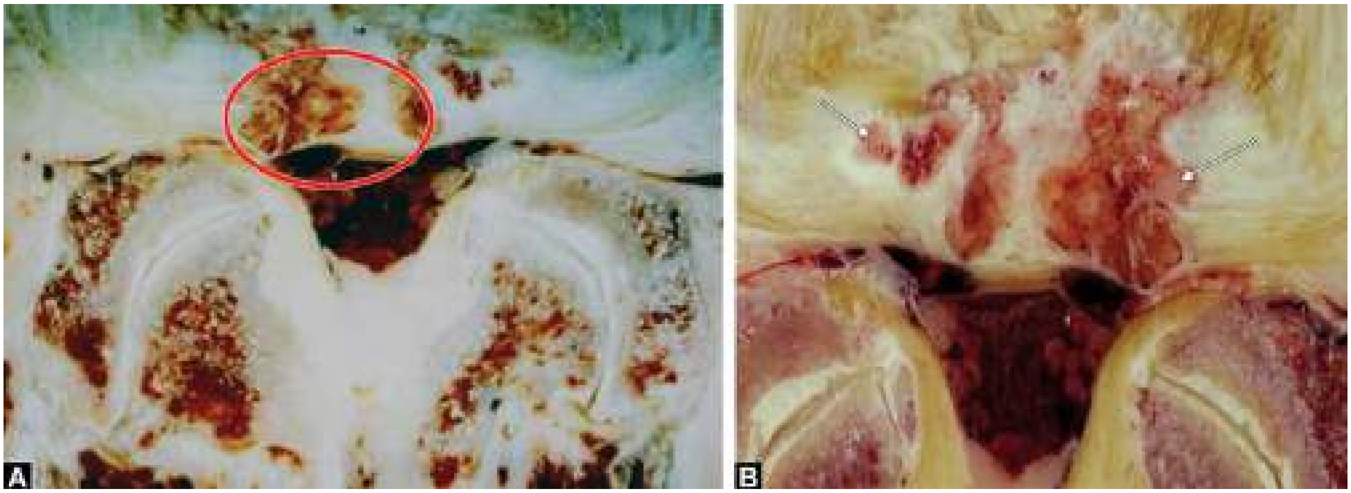
One study was conducted to investigate the effect of both disc degeneration and facet joint osteoarthritis on lumbar segment motion using human cadaver (Figs 21.6A to D).[19]

Another cadaveric study was done to analyze human lumbar facet joints from donors with advanced age macroscopically for degenerative changes (Figs 21.7A to D).[20]

- *Grade I:* Uniformly thick cartilage covers the articular surfaces completely.
- *Grade II:* Cartilage covers the entire surface of the articular process but an eroded irregular region is evident.
- *Grade III:* Cartilage incompletely covers the articular surfaces with regions of underlying bone exposed to the joint.
- *Grade IV:* Cartilage is absent except for traces on the articular process.

## Sacroiliac Joint Pain

The sacroiliac joint (SIJ) had been considered the main cause of low back pain in the early 20th century.[21] Since Mixter and Barr in




**Figs 21.3A and B:** Cadaveric dissection showing the annular tear and granulation tissue: (A) Red circle; (B) White arrows

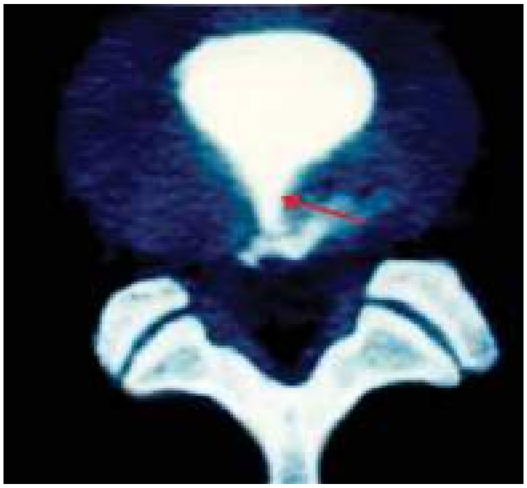


**Fig. 21.4:** CT scan after discography showing the annular tear (red arrow)

1934 publicated the concept of radiculopathy due to herniation of the intervertebral disc,[22] the diagnosis of SIJ pain had been discarded. Because herniated nucleus pulposus (HNP) could be simply diagnosed compared with the diagnosis of SIJ pain. In practice, although clinical symptoms and physical examination suggest a strong presumption of SIJ pain, the differential

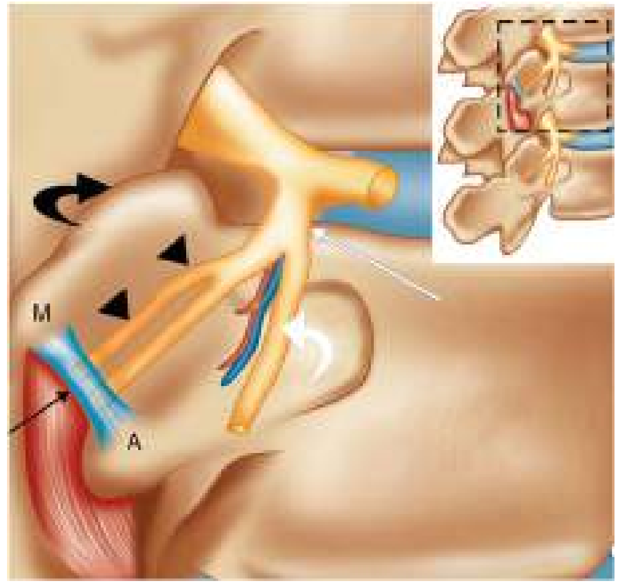
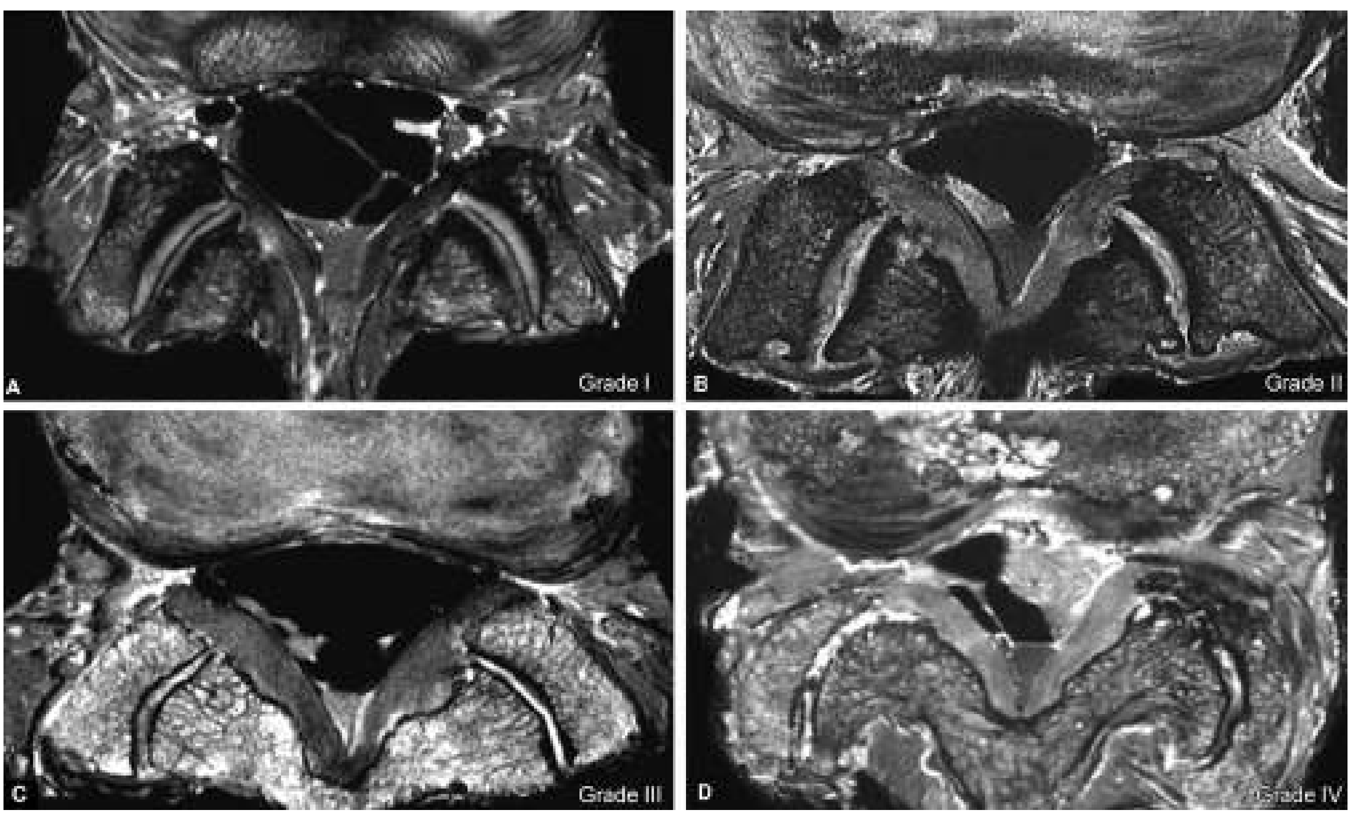
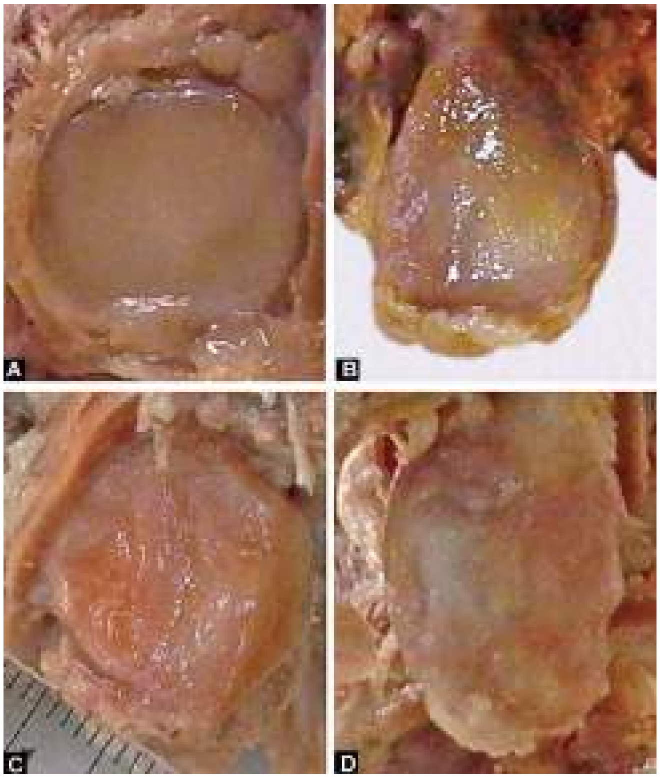



**Fig. 21.5:** The facet is innervated by the medial branch (black arrowheads) of the dorsal ramus at its own level and to the level below. When the radio-frequency (RF) rhizotomy is done, denervation targets the medial branch crossing the transverse process. Lateral branch of the dorsal ramus (white arrow) innervate longissimus muscle and lateral soft tissues




**Figs 21.6A to D:** Magnetic resonance images were used to assess the disc degeneration from Grade I (normal) to Grade IV (advanced) and the osteoarthritic changes in the facet joints in terms of cartilage degeneration, subchondral sclerosis, and osteophytes




**Figs 21.7A to D:** Macroscopic images were used to assess the facet joint degeneration from Grade I to Grade IV and the osteoarthritic changes in the facet joints

diagnosis is usually done after exclusion of other causes such as discogenic or facetal pain, and the examiner has to keep in mind of SIJ pain could coexist with other causes of back pain. It is not easy to make a diagnosis whether the CLBP is originated from sacroiliac joint degeneration or not. However, while most of examinations alone have low sensitivity to determine whether the SI joint is a main source of CLBP, if combined examinations done, they have a greater change of providing the rationale for treatment of SIJ pathology.

### Sacroiliac Joint

- Synovial, fluid-filled diarthrodial joint enveloped by a fibrous capsule between the sacrum and ilia.[23,24]
- Thick 6 mm sacral cartilage and thin 1 mm iliac cartilage.
- Many ligaments around SIJ contribute to anatomical stability.[25]

### Innervation

- Cunningham's Textbook of Anatomy States, "The sacroiliac joint is supplied: (1) by Wigs directly from the sacral plexus and the dorsal ramus of the first two sacral nerves; and (2) by branches from the superior gluteal and obturator nerves."[26]
- Nakagawa reported that innervation of the sacroiliac joint come from the ventral rami of L4 and L5, the superior gluteal nerve, and the dorsal rami of L5, S1, and S2.[27]

### Clinical Symptoms and Physical Examinations—Few Pathognomonic Tests for SIJ Pain

- The Fortin finger test
- Distraction (Gapping) test
- Compression (Approximation) test
- Patrick's (Faber's) test
- Thigh thrust/Femoral shear/Posterior shear
- Gillet's test for aberrant sacroiliac motion
- Gaenslen's (Pelvic torsion) test
- Sacral thrust (Tenderness over the ipsilateral sacroiliac joint).

### Diagnosis

- Controlled diagnostic block utilizing IASP criteria[28]
- False-positive rate is about 20 to 54 percent
- Since Frymoyer reported that fusion surgery leads to increased stress on the sacroiliac joint and may be a cause of failed back surgery syndrome, many investigators have demonstrated the results supporting the evidence.[29]

## Treatment

The treatment modalities can be classified into four major stepwise categories: Conservative (pharmacological and physiotherapy), rehabilitation and exercise programs, interventional treatments, and surgical procedures. A stepwise approach to CLBP may be effective to reduce the economic burden with proper use of the less invasive treatments. This algorithm is adapted from the World Health Organization ladder for cancer pain management.[30] This treatment approach is illustrated in Figure 21.8. Interventional pain managements or surgical techniques should be only considered when conservative treatment fails to provide successful pain control and improvement of the quality of daily activity in life. Moreover, in the present era of evidence-based medicine, this kind of stepwise approach to CLBP is strongly recommended for achieve successful outcomes with best available level of evidence.

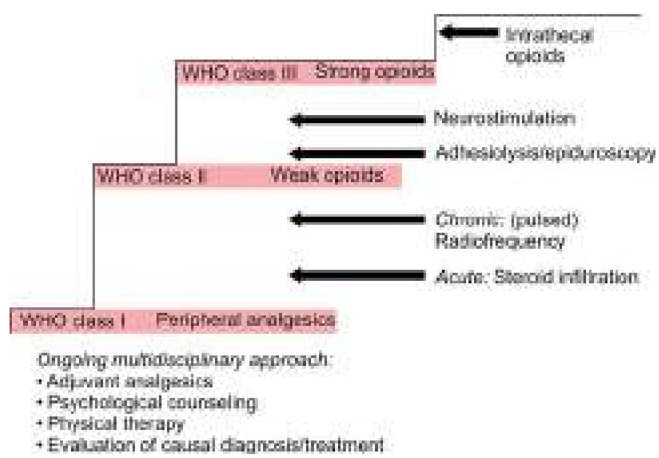



**Fig. 21.8:** An algorithm for the management of chronic noncancer pain. (From Pain Pract. 2002;2:269-78)[5]

**Table 21.4:** Interventional approaches for chronic back pain

| Treatment options | Percent |
|---|---|
| Interventional pain procedures | 80 |
| Minimally invasive spinal surgery | 15 |
| Conventional surgery | 5 |

Spinal pain is the second most frequent cause for patients to visit the clinics, and the third most frequent cause for patient to be undergone the surgical interventions. So, overall research about the distribution of health care market, overall percentage from industrialized countries including USA, Europe and Australia is like Table 21.4.

## Minimally Invasive Treatment for Back Pain (Figs 21.5 to 21.17)

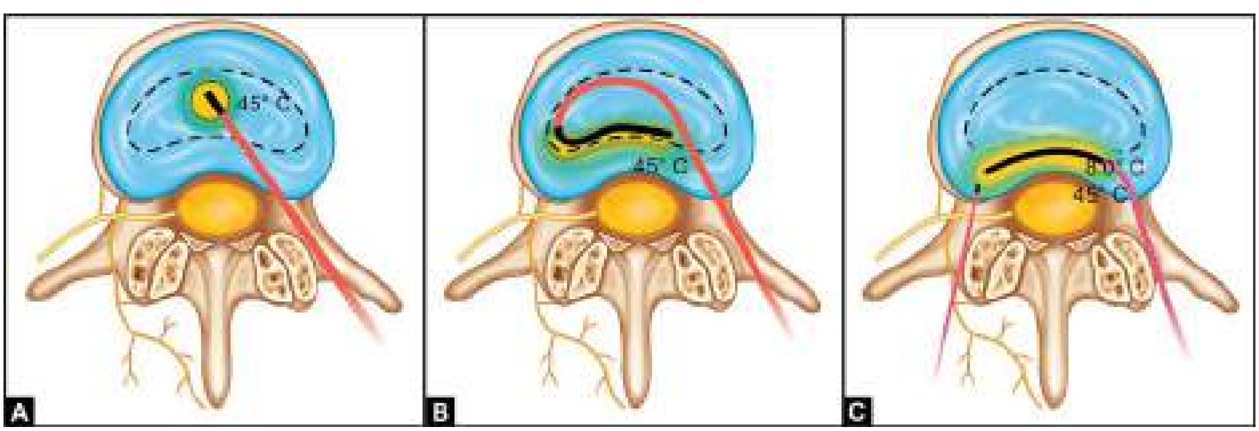
### *Discogenic Back Pain*

Up-to-date, many kinds of interventional treatments and MIST have been introduced (Table 21.5).

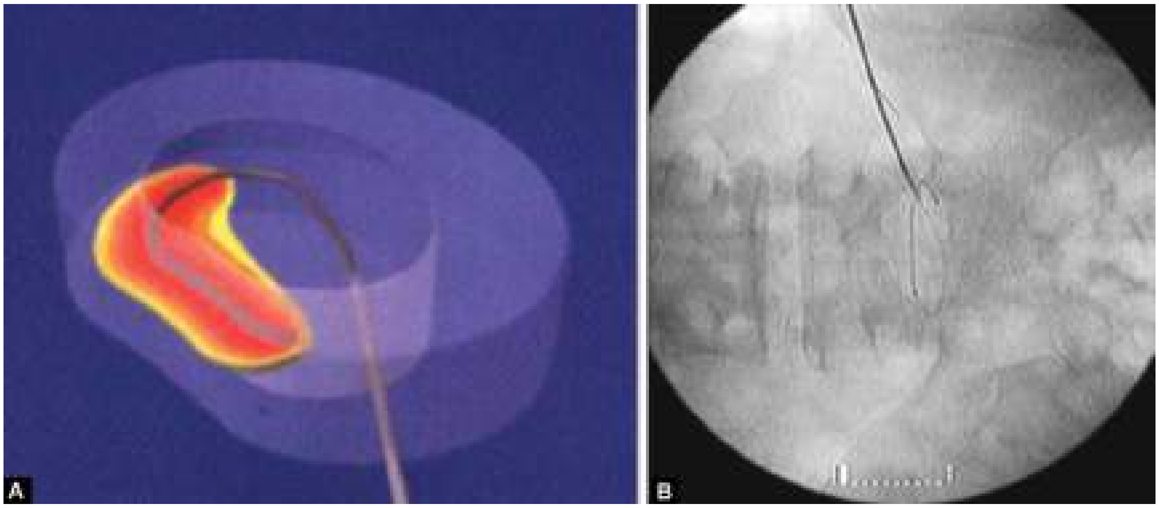
1. *Intradiscal thermal lesioning:* This procedure direct RF heating of the disc was first attempted by Sluijter and Van Kleef.[31] However, a recent trial of nucleus heating at 70ëC showed no beneficial effects.[32] Although the mechanism of pain relief using heating for discogenic back pain is unclear, two hypotheses are usually suggested: The first is denervation of the disc tissue or destruction of the overgrowth of nociceptors, the second is the changing and remodeling the structure of the collagen fibers in the annulus, causing an increase in annular stability. However, histological studies involving intradiscal electrothermal therapy (IDET) did not support these two hypotheses (Figs 21.9A to C).[33]
2. *Intradiscal electrothermal therapy (Figs 21.10A and B):*
   - This procedure began to be performed in 1998 and represented a deviation from the focus of disc decompression. This put forth the theory of "annuloplasty": Thermal heating of the annulus could seal annular tears and denervate the annulus by destroying the Type C afferent nerve fibers that innervate the outer one third of the annulus. Saal et al. first reported the clinical outcomes in a group of patients with CLBP who met the criteria for interbody fusion surgery in 25 patients.[34]
   - According to a multicenter study of 1,675 patients, 6 nerve root injuries, 19 catheter breakages (16 left in disc), six cases of post-IDET disc herniation at the treated level and 1 bladder disfunction (extradiscal catheter) developed.[35] However, it seems that there may be more complications that have not been reported due to concern of litigation.[36] Moreover, there is one randomized double

**Table 21.5:** Summary of treatments IDD/DDD/herniated disc

| Internal disc disruption/Degenerative disc disease | Denervation |
|---|---|
| • Intradistal electrathermal therapy (IDET) | |
| • Disctrode | |
| • Bilateral Disc RF (Diskit II) | |
| • Biacuplasty (Cooled RF) | |
| • Gray Communicans Ramus RF | |
| • Sympathetic plexus RF | |
| **Herniated Disc** | **Decompression** |
| • Chymopapain Injection | |
| • Nucleoplasty (Plasma) | |
| • Laser Discectomy | |
| • Percutaneous endoscopic lumbar discectomy (PELD) | |
| • Microdiscectomy | |
| **Devices for Lesioning** | |
| • Laser | |
| • Bipolar Radiofrequency (Nucleoplasty) | |
| • Thermoresistive Catheter (Spinecath) | |
| • Radiofrequency Electrode (Disctrode) | |
| • Bipolar RF (Transdiscal heating) | |




**Figs 21.9A to C:** Three different images of (A) Intradiscal RF (Sluijter, 1994); (B) IDET (Smith and Nephew, 1998); (C) Disc TRODE (Tyco/Radionics, 2000)




**Figs 21.10A and B:** (A) Illustration of IDET; (B) C-arm image of IDET

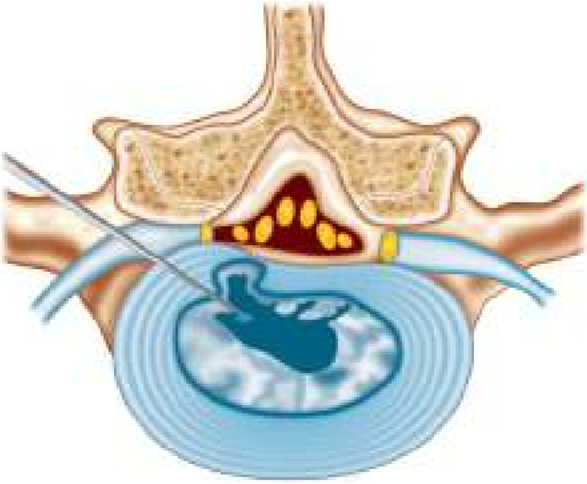


**Fig. 21.11:** Illustration of Disc-FX

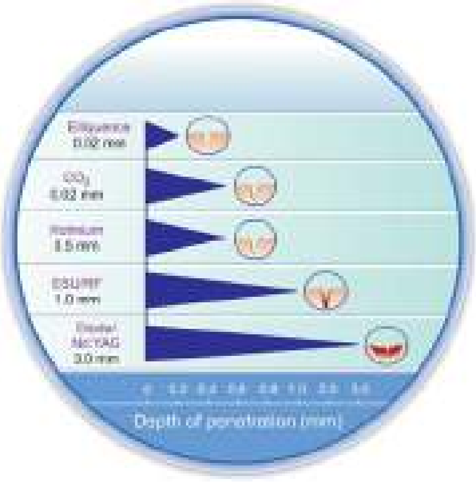



**Fig. 21.12:** Absorption comparison of various surgical energy sources

blind trial that show no significant benefit from IDET over placebo.[37]

3. *Disc-FX (elliquence-Oceanside, NY) (Figs 21.11 and 21.12):*
   - Some investigators suggest that most common cause of IDET failure may be due to incorrect target lesioning because most pain generators in discogenic pain is located in interposed disc tissue in posterior annulus. Duration of clinical success is dependent on thickness of annulus after thermal modulation.
   - The flexible RF elliquence probe could ablate ingrown granulation tissue and nerve endings already in the posterior annular defects, and shrinks the annular openings.
   - High specific ablation rate and targeted modulation of the annulus with a significant shrinkage by a negligible temperature distribution are demonstrated by research. The steerable delivery system permits targeted application in the region of the pathology.
4. *Laser annuloplasty:*
   - Percutaneous endoscopic laser annuloplasty (PELA), a minimally invasive technique, uses laser-assisted spinal endoscopy (LASE) to directly shrink and coagulate the interposed disc tissue in posterior annulus associated with annular tears.[38]
   - PELA using the Ho:YAG laser provides favorable clinical results for discogenic low back pain (Fig. 21.13).
     - Targeted removal of granulation tissues in the posterior annulus (Figs 21.14A and B)
     - Laser during PELA has effect of blocking the sensory nerve surrounding the annulus (Figs 21.15A and B)
     - Continuous saline irrigation with saline remove chemical irritant.

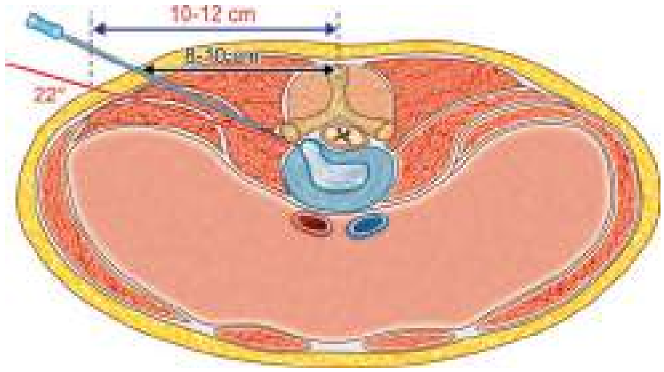
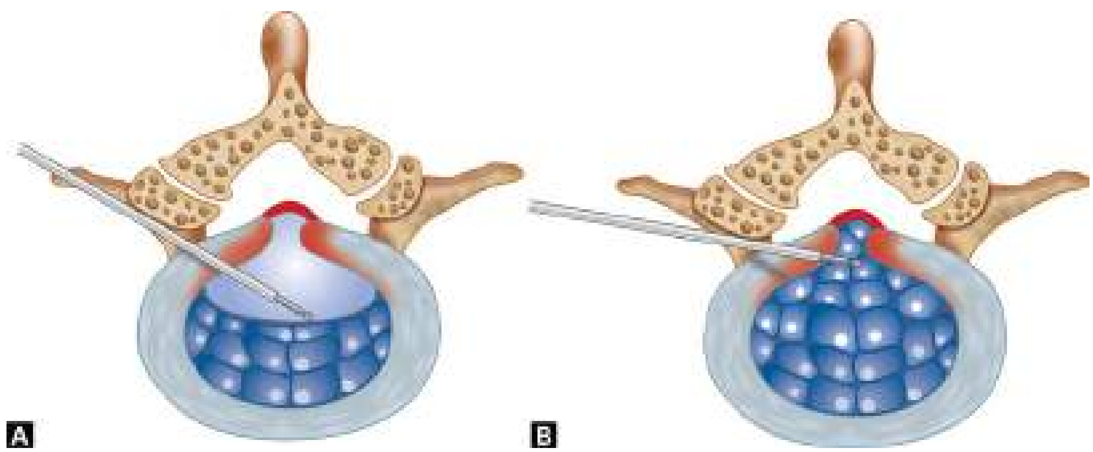
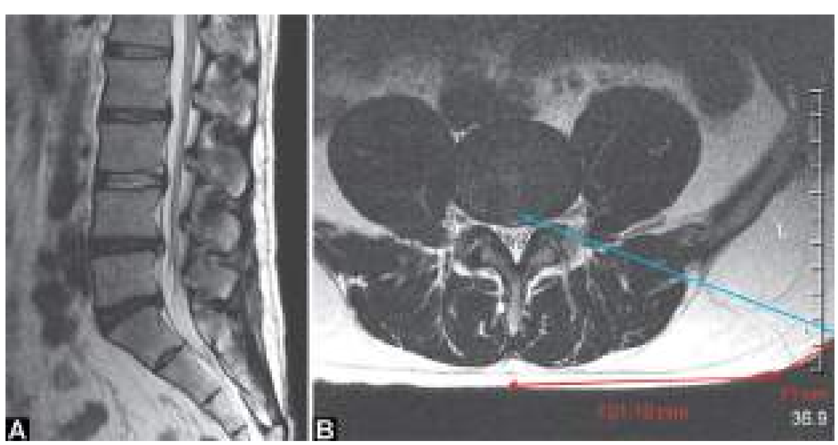



**Fig. 21.13:** Tip of the PELA is located just beneath annulus tear

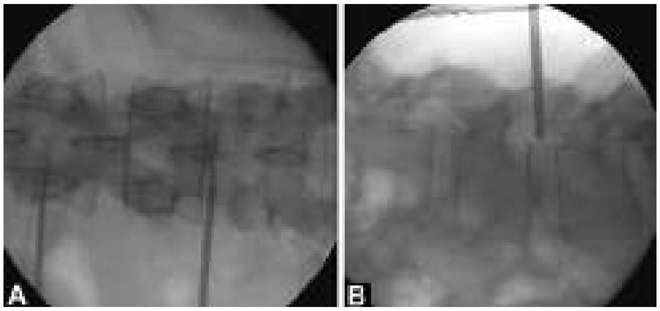
5. *Percutaneous endoscopic lumbar discectomy and annuloplasty (PELDA) (Figs 21.18 to 21.20)*
   - Although many patients who underwent discectomy have suffered from residual back pain, there are only a few papers showing association between back pain and lumbar disc herniation.[39,40] According to their reports, the back pain associated with lumbar disc herniation may originate from an annular tear or compressed ventral dura and PLL. Rauschning suggested that if outer annular is torn, neovascularization, which is frequently accompanied by nociceptive pain fibers, happens to sprout into the disc. When the annular surface occurs to tear, its surface is usually sealed by cellular tissue, which is richly vascularized and innervated.[41] PELDA may be effective in treating not only the leg pain associated with



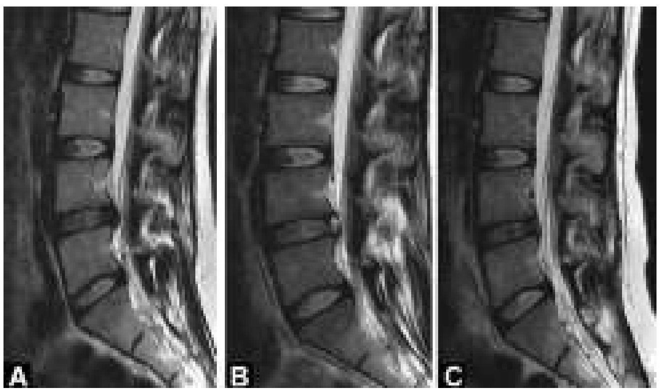

**Figs 21.14A and B:** Tip of laser located on the junction of annulus and nucleus pulposus (A) and annulus tear (B)



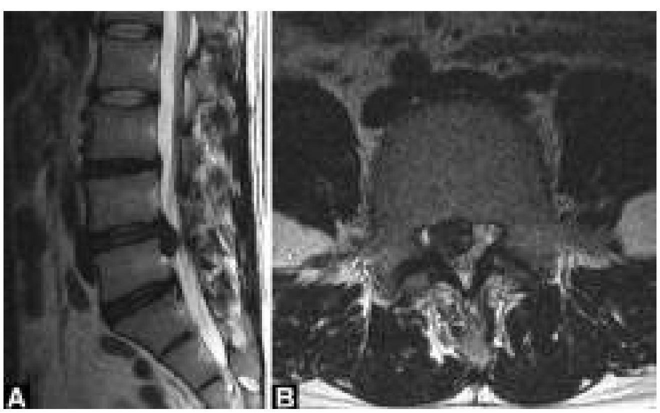

**Figs 21.15A and B:** Sagittal (A) and axial (B) MRI images show disc bulging with annulus tear at L4-5 and skin entry point of PELA




**Figs 21.16A and B:** Anteroposterior (A) and lateral (B) fluoroscopic images show the proper positioning of catheter. The tip should be located in intra-annular portion when it is at the center on the AP view



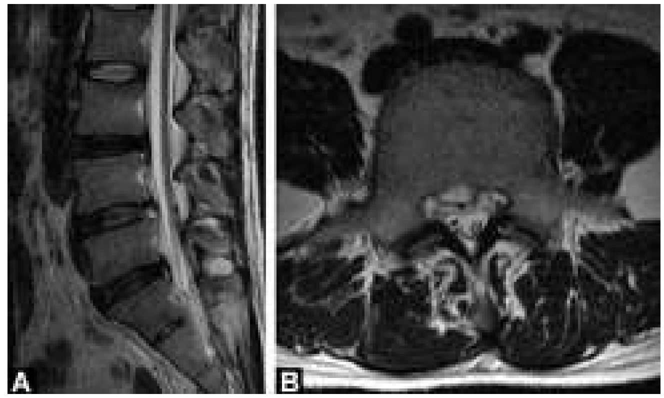

**Figs 21.17A to C:** Preoperative sagittal MRI of 53-year-old male suffering from CLBP for 2 years shows disc bulging at L4-5 (A), postoperative sagittal MRI immediately after PELA shows the well removal state of target fragment (B), and MRI 3 months after procedure shows healing state of L4-5 disc level (C)



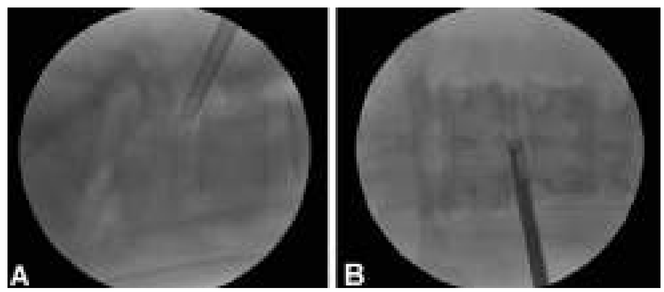

**Figs 21.18A and B:** Preoperative sagittal (A) and axial images (B) show huge down-migrated lumbar disc herniation

disc herniation but back pain associated with interposed disc tissue in posterior annulus associated with annular tears.[38,42]

- *Failure of IDET vs Success of PELDA:* According to recent randomized and placebo-controlled trial, whereas approximately 40 percent of the patients achieved



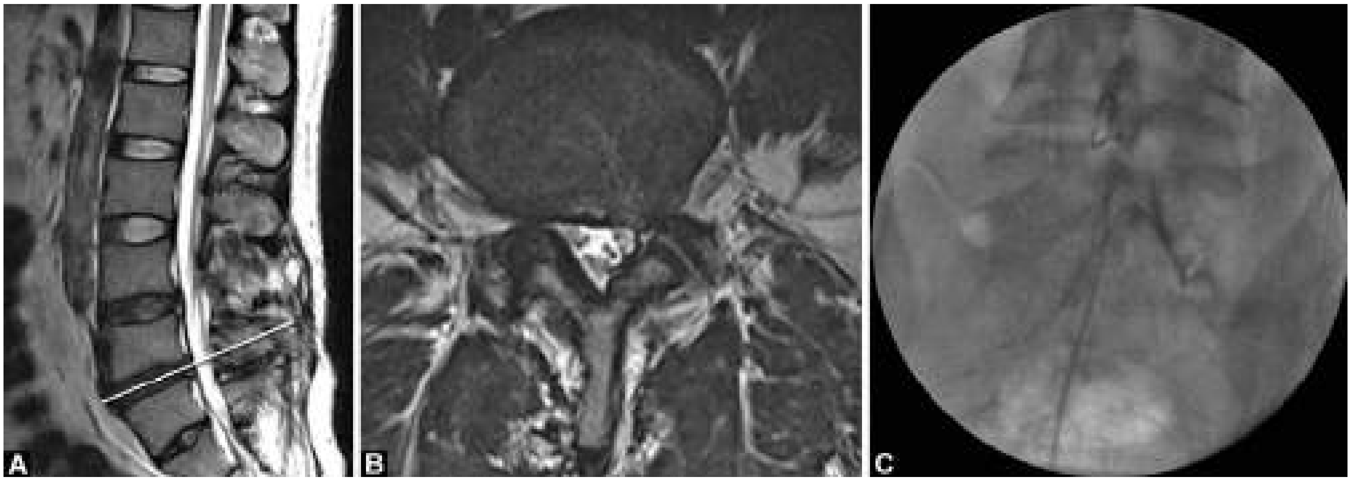

**Figs 21.19A and B:** Postoperative sagittal (A) and axial images (B) show complete removal of herniated disc fragments




**Figs 21.20A and B:** Fluoroscopic lateral (A) and AP (B) show the location of working cannular during PELDA

greater than 50 percent relief of their pain, approximately 50 percent of the patients experienced no appreciable benefit.[43] Relative high failure rate may be due to blind thermocoagulation and indirect decompression. In contrast, PELDA directly achieved the removal of the compressing extradural fragment and anchoring disc fragment in the annular fissure. It could achieve: (1) decompression through removal of the disc fragment and reduction of the intradiscal pressure; and (2) thermal ablation with RF and laser, which repaired the annular defect of neoinnervation and neovascularization. However, to validate the clinical successful results, well-designed randomized controlled trial should be considered.

6. *Percutaneous adhesiolysis* (Figs 21.21A to C)
   - *Introduction:* Percutaneous lysis of adhesions (also known as decompressive epidural adhesiolysis) is a procedure developed by Dr. Gabor Racz in 1989 for the patients with CLBP who have failed to respond to conservative treatments. The purposes of this interventional procedure, although it remains debate for adhesion scars in epidural space to make CLBP, are to break down fibrous adhesion scar tissues in the epidural space and deliver proper medication (i.e. local anesthetics and corticosteroids). Fibrous epidural scars can develop after surgical laminectomy, or can occur secondary to annular tear, hematoma or infection. The



**Figs 21.21A to C:** A 36-year-old male underwent two times lumbar operation at L4-5 and L5-S1 level. He suffered from back and radicular leg pain along the S1 dermatome. MRI revealed no definite neural entrapment. Sagittal and axial MRI images show black disc and postoperative changes of laminectomy at L4-5 and L5-S1 level. Percutaneous adhesiolysis was done and fluoroscopic image show tip of catheter located in lateral recess and well-traced S1 nerve root

adhesion scars could make a limitation of free movement of neurovascular bundles in the intervertebral foramen and the central spinal canal. By the epidural adhesiolysis, it is possible to deliver medications to targeted structures directly.

- *Indication*
  - CLBP and/or lower leg pain due to:
    - Epidural fibrosis, failed back surgery syndrome
    - Spinal stenosis
    - Eisc herniation with radiculitis
  - Duration of pain of at least 3 months
  - Pain causing functional disability
  - Failure to respond to conservative treatment.
- *Technique:* Procedure is done under fluoroscopic guidance in a sterile operating room. Patients are monitored with equipment for blood pressure, pulse rate, and pulse oximetry. After the proper positioning of fluoroscopy, the needle is inserted through the sacral hiatus after the infiltration of local anesthetics. A small incision is made around skin entry point and a 15-gauge Tuohy needle with an introducer is inserted via the sacral hiatus. An epidurogram must be taken to confirm whether the needle is placed well in the epidural space or not. The Tuohy needle is withdrawn. Then, a NaviCath is introduced through the introducer under fluoroscopic guidance, and contrast media is injected to visualize the contrast flow into the nerve roots. Finally, adhesiolysis and decompression is performed by distension with normal saline and by mechanical force using the catheter. Then, a mixture of 4 mL of 1 percent lidocaine and 40 mg of triamcinolone is gently injected at target site. Hyaluronidase is also injected in most cases for the following purposes: To facilitate spread of the steroid through the scar tissue, to prolong the effect of therapeutic drugs and to increase the synergistic effect for pain relief.

## Facetal Back Pain

Most patients who suffer from CLBP usually have not only discogenic but also facetal pain. Once the diagnosis of facet joint pain is proven, there are 3 modalities of treatments available. These include *intra-articular injections*, *medial branch blocks*, and *radiofrequency neurotomy*. However, based on the available evidence, therapeutic intra-articular facet joint injections are not recommended.

Endoscopic techniques could easily access the disc or facet pain. In selected patients who have both pain sources, percutaneous endoscopic techniques for facet pain can be combined with intradiscal treatment such as posterior laser annuloplasty or thermal annuloplasty using Disc-FX.

### *Treatment*

- *Conventional RF rhizotomy (Fig. 21.22):* Many clinical trials suggest that radiofrequency denervation of lumbar facet joints provides significant pain relief, success rate is about 50 to 70 percent. Moreover, its clinical improvement usually lasts a few months. Some patients experience recurrence of pain as the medial branch of dorsal ramus regrows. In patients who have recurrence of back pain, repeated procedures are needed.
- *Endoscopic dorsal ramus rhizotomy (Figs 21.23 and 21.24)*
  *Procedure:* All procedures are performed under fluoroscopy with light anesthesia using fentanyl and midazolam. Skin anesthesia via 22-gauge spinal needles is performed with 1 percent lidocaine. The target point is the junction of the transverse process with the base of the superior articular process (SAP). Dock 18G needle onto target point. The anteroposterior (AP) fluoroscopic view is obtained with maximal exposure of the target. Then K-wire, obturator, and beveled working cannula are serially inserted. After checking the proper location of cannular, forceps are used to remove fatty tissue between muscles. RF probe is inserted through

**Fig. 21.22:** The target of RF rhizotomy is the junction of the transverse process with the base of the superior articular process (SAP)

endoscope. Then, removal of soft tissue at base of transverse process including medial and lateral branch.

- *Clinical outcomes:* Yeung et al. reported the clinical success rate is more than 90 percent and it last more than 1 or 2 years. No patients got worse after this procedure. They also suggest that endoscopic dorsal ramus rhizotomy helps surgeons to getmore aggressive ablation than conventional RF rhizotomy, which improves results and delays recurrence of pain.
- *Complications:* Larger nerves have more changes of neuroma formation.

## Sacroiliac Joint Pain (Fig. 21.25)

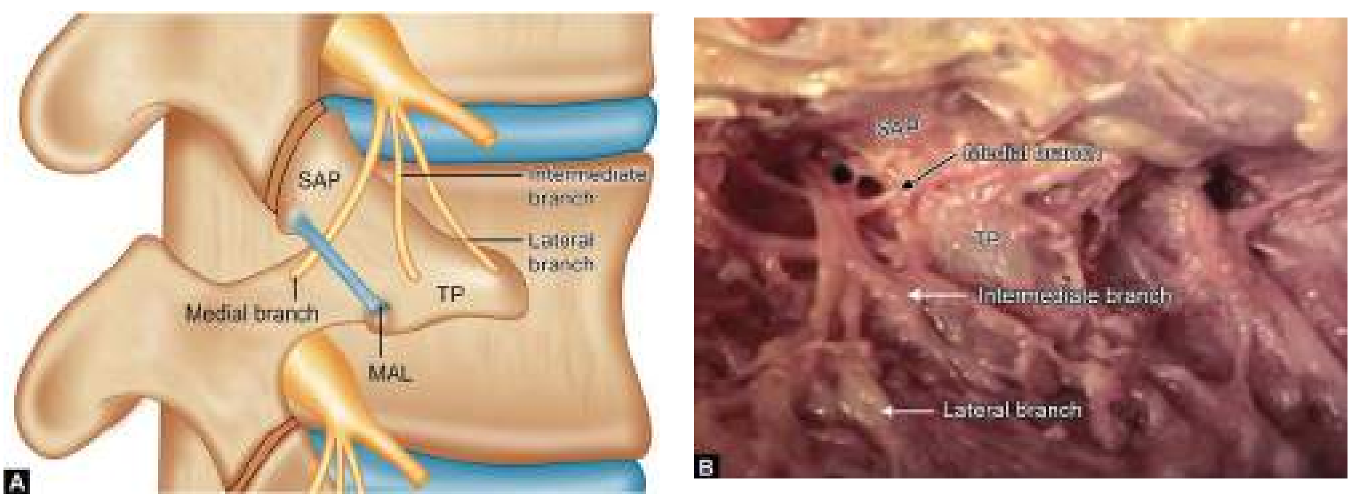
Most patients who suffer from CLBP usually have not only discogenic but also facetal or SIJ pain. According to the news release, estimates are that 15 to 25 percent of individuals who present with CLBP actually had pain from SIJ. Once the diagnosis of SIJ pain is proven, there are 3 modalities of treatments available.

These include *intra-articular injections*, *medial branch blocks*, and *radiofrequency (conventional and cooled) neurotomy.*[44-46]

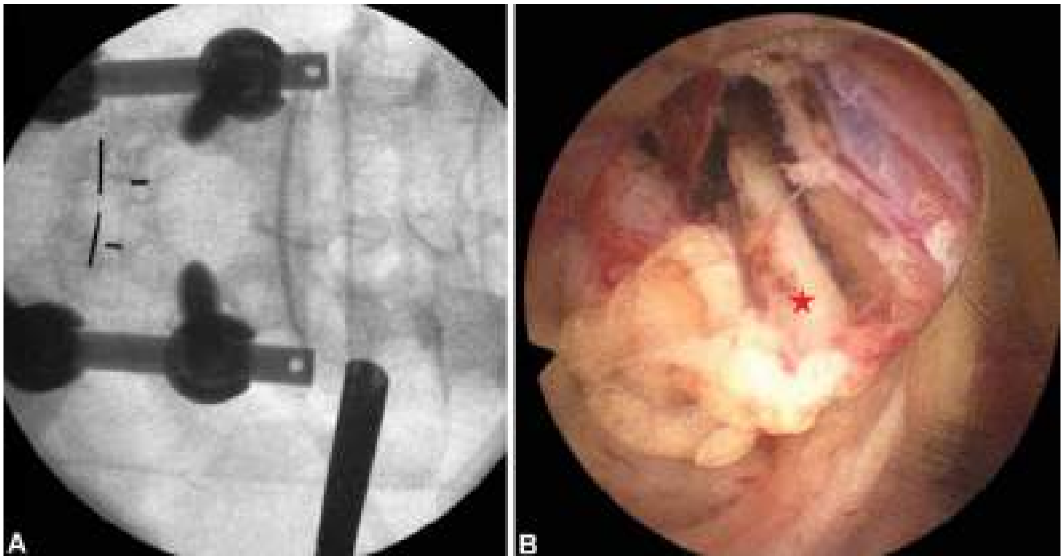
Recently, SIJ fusion is carefully recommended to patients who suffered from pain in spite of interventional pain managements such as blocks or radiofrequency neurotomy.[47,48]

### *Treatment (Figs 21.26 and 21.27)*

1. Conservative treatment
   - Rehabilitation
   - Physical therapy
2. Pharmacologic therapy
3. Intra-articular steroid injections
4. RF denervation
5. Surgical treatments: SIJ fusion
   - Anterior approach
     - ▪ Anterior ilioinguinal approach
     - – Underneath/deep to iliacus
     - ▪ Limitation: retraction of L5 nerve root medially
   - Smith-Petersen approach
     - ▪ Elevate gluteus musculature
     - ▪ Limitation: cluneal nerves posteriorly, sciatic notch with superior gluteal neurovascular bundle
   - Transiliac approach
     - ▪ Mini-open muscle splitting
     - ▪ Limitation: anterior common iliac, external iliac vessels, L5 nerve root, lumbosacral plexus, posteriorly S1, S2 neural canals.
   - Posterior approach
     - ▪ Midline either muscle splitting Wiltse or midline muscle elevating
     - ▪ Limitations: posterior ligamentous structures.




**Figs 21.23A and B:** Cadaveric dissection of medial and lateral branch of dorsal ramus which are target of endoscopic RF rhizotomy




**Figs 21.24A and B:** Fluoroscopic view (A) of endoscopic working cannula and endoscopic view (B) showing the medial branch of dorsal ramus (red star)

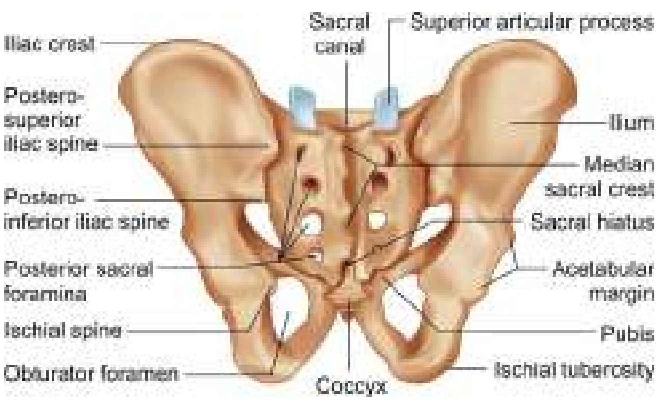



**Fig. 21.25:** The anatomic structure of sacrum, iliac bone and SIJ

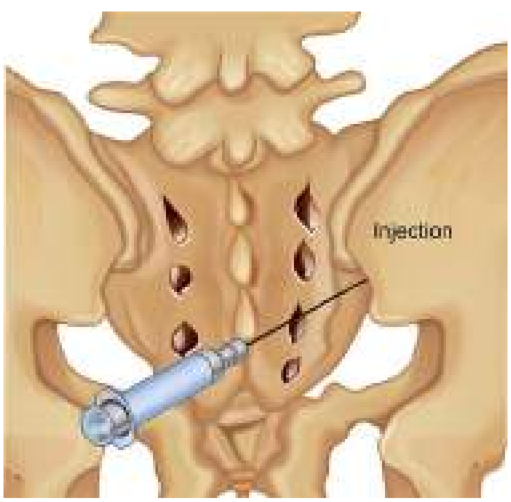



**Fig. 21.26:** intra-articular steroid injection to SIJ

**Fig. 21.27:** Sacroiliac joint fixated by SI-bone system

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22

# Percutaneous Transforaminal Endoscopic Lumbar Discectomy: Transforaminal Endoscopic Spinal System Method

*PD Kulkarni*

## Introduction

At present, it seems that microdiscectomy is recognized worldwide as the gold standard for the decompression of radicular syndrome caused by lumbar disc herniation.

For the past 20 years the magnitude of spinal surgical procedures has been increasing. We are expecting a trend where spinal surgical procedures are likely to become increasingly less invasive. There is increasing trend to use endoscopic spinal procedures by spinal surgeons adding another method of minimally invasive procedure to their armamentarium.

Endoscopic surgery has been widely embraced in many surgical disciplines but it has been logged in spinal surgery. The importance of preserving normal tissue has become increasingly clear in the field of surgery.[1]

Endoscopic spinal procedure is a fundamental addition to the list of minimally invasive spine surgery. Endoscopic surgery is practiced in the cervical, thoracic and lumbar regions and gives readers an appreciation that there is another type of approach to treat the disc prolapse.

The primary goal of minimally invasive spinal surgery (MISS) is to achieve outcomes comparable to those of open surgery while minimizing normal tissue damage and reducing recovery times. MISS by percutaneous endoscopic discectomy has attracted attention from the global spine surgery community and has undergone tremendous development.

In the last decade, endoscopic techniques have been developed to perform discectomy under direct vision and local anesthesia.

Only transforaminal endoscopic lumbar discectomy will be discussed here.

## Various Types of Approaches Used for Lumbar Discectomy (Past and Present)

- Laminectomy and discectomy
- Microlumbar discectomy
- Stereotactic lumbar microdiscectomy
- Automated percutaneous discectomy
- Chymopapain chemonucleolysis
- Endoscopic discectomy (open posterior approach)
- Anterior approach to lumbar spine for discectomy; fusion or disc replacement
  - Extraperitoneal
  - Intraperitoneal.

  Again, it can be:
  - Open surgical approach
  - Laparoscopic approach
- Percutaneous transforaminal lumbar discectomy
- Percutaneous lumbar discectomy using laser
- Percutaneous endoscopic interlaminar approach for lumbar discectomy
- Percutaneous endoscopic lumbar discectomy and fusion.[2]

## Historical Developments

Mixter and Barr (1934): Exploratory laminectomy for 19 surgical cases for radicular pain.[3]

Hult (1951): Spinal canal decompression by anterolateral abdominal extraperitoneal approach.[4]

Lyman Smith (1964): Chemonucleolysis by injection of chymopapain.

Kambin (1973): Percutaneous indirect spinal canal decompression by nucleotomy using Craig cannula.[5]

Hijikata (1975): Posterolateral percutaneous nucleotomy.[6]

William Friedman (1983): Encouraged direct lateral approach for percutaneous nucleotomy—but was associated with increased bowel injury.[7]

Forst and Hausmann (1983): First reported introduction of modified arthroscope into the intervertebral disc space.[8]

Onik (1985): Introduced motorized aspiration nucleotomy shaver for automated percutaneous nucleotomy.[9]

Kambin (1988): First intraoperative discoscopic views of herniated nucleus pulposus.[10]

Schreiber (1989): Biportal approach with a discoscope to inject indigo carmine to stain abnormal nucleus and annular fissures.[11]

Kambin (1990): Described and illustrated triangular working zone called 'Kambin's triangle'. This opened the door for more sophisticated endoscopes with larger working channels.[5,12,13]

Mathews (1996) and Ditsworth (1998): Success of foraminoscopic approaches—this opened the era of transforaminal endoscopic surgery for lumbar disc herniation.[14,15]

Foley (1999): Endoscopic working channel portal for far lateral disc herniation.[16]

Kambin and Zhou (1996): Decompression of nerve roots by nucleotomy and osteophytectomy using mechanical tools (forceps and trephines) and 0° and 30° scopes.[17]

Knight (2001): Endoscopic foraminoplasty by using Ho-YAG laser.[18]

Yeung and Tsou (2002): Efficacy of endoscopic discectomy in 307 patients and reported it to be comparable with conventional open surgery.[19]

Ruetten et al (2005): Presented extreme lateral access using the full endoscopic unilateral transforaminal approach.[20]

Schubert and Hoogland (2005): Presented their technique of endoscopic transforaminal nucleotomy and foraminoplasty using reamers.[21]

Choi (2007): Reported extraforminal targeted fragmentectomy technique.[22]

Lee (2007): Classification of migrated discs and results.[23]

## Laser Lumbar Discectomy

Ascher (1980s): Performed first laser discectomy using Nd-YAG laser.[24]

Quigley (1991): Compared efficacy of Ho-YAG and Nd-YAG lasers.[25]

Casper (1995): Typical trial of the use of side-firing Holmium-YAG laser.[26]

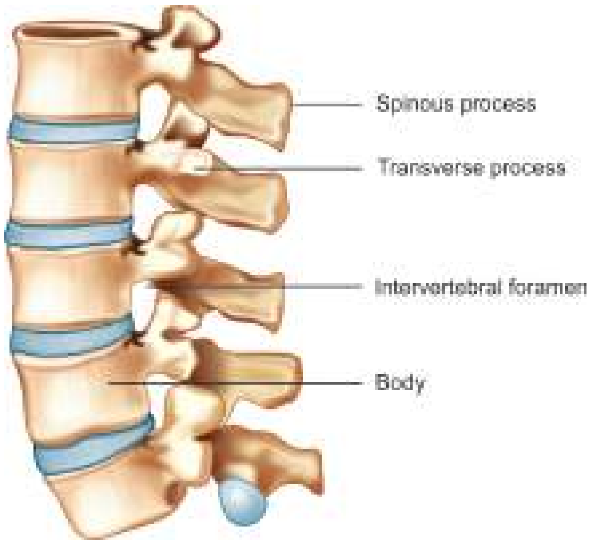



**Fig. 22.1:** Lumbar spine

Knight (2001): Reported endoscopic laser foraminoplasty for the management of chronic low back pain and sciatica using a side-firing Ho-YAG laser.[27]

Choy (1995): Efficacy of laser ablation study—study of reduction in intradiscal pressure in cadavers.[28]

## Applied Anatomy of the Lumbar Spine (Fig. 22.1)

Here the applied anatomy relevant to the transforaminal endoscopic lumbar disc surgery is discussed.

### Surface Anatomy

Iliac crest is in line with the L5 spinous process but in 20 percent of the cases the L4 spinous process is in a horizontal plane with the superior boundary of the iliac crest. This is especially useful to know when accessing L5/S1 disc.

### Radiological Anatomy

While preparing for needle trajectory, distance from the midline is chosen at the appropriate length. Care should be taken not to go through the peritoneal or extraperitoneal organs. Axial CT scan at the level of the interested disc is very useful. This will avoid intestinal perforation and disc space infection with colonic organisms.

## Anatomy of the Intervertebral Foramen (Fig. 22.2)

Knowing the anatomy of the intervertebral foramen (IVF) is of great importance for the transforaminal approach.


**Fig. 22.2:** Intervertebral foramen (IVF)

The intervertebral foramen is oval or inverted drop shaped. Its size depends upon the length of the pedicle, height and protrusion of the disc and hypertrophy of the facet joints. L2-L3 has the greatest superoinferior dimension of the IVF and the dimension decreases from superior to inferior, which means it is smallest at L5/S1.[29]

Intervertebral foramen is an osteofibrous canal and lower part of the canal is used for passing the endoscope. The upper part of the foramen is occupied more than 50 percent by the neural tissue. The nerve root comes out of the foramen under the medial edge of the pedicle and it goes inferiorly obliquely away from the foramen. It is important to identify the foraminal structures through the endoscope, e.g. adipose tissue, annulus, posterior longitudinal ligament, disc space, traversing and exiting nerve roots.

Anteroposterior dimension of the IVF is less than the superoinferior dimension. The anteroposterior dimension remains more or less constant at all levels. At L5/S1 anteroposterior dimension is greater than the superoinferior dimension. IVF dimensions are larger in males than females.

## Boundaries and the Contents of the IVF

See Figure 22.3.

## Boundaries of the Intervertebral Foramen

### Roof

Inferior vertebral notch of the pedicle of the superior vertebrae, ligamentum flavum at its outer free edge.

### Floor

Superior vertebral notch of the pedicle of the inferior vertebrae, posterosuperior margin of the inferior vertebral body.

### Anterior Wall

Posterior surface of the adjacent vertebral bodies, intervertebral disc, lateral expansion of the posterior longitudinal ligament and anterior longitudinal venous sinus.

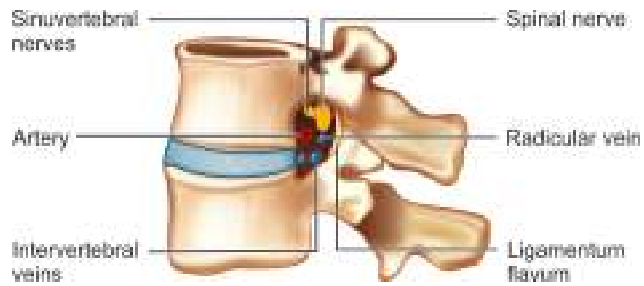



**Fig. 22.3:** Boundaries and the contents of the intervertebral foramen

### Posterior Wall

This is bounded posteriorly by the superior and inferior articular process and the lateral prolongation of the ligamentum flavum.

### Medial Wall

Dural tube.

### Lateral Wall

Psoas muscle with fascia.

## Structures in the Intervertebral Foramen

### Nerves

- Spinal nerves (combined ventral and dorsal root into a sheath)
- Dural root sleeve which becomes continuous with the epineurium of the spinal nerve at the distal end of the foramen
- Two to four recurrent meningeal nerves (sinuvertebral).

### Artery

Spinal branch of the segmental artery enters the foramen. After entering the foramen it divides into three branches to supply the posterior neural arch and intracanal structures and the posterior part of the vertebral bodies.

### Veins

- Communicating veins between the internal and external vertebral venous plexus
- Other structures in the foramen are lymphatic channels, ligaments and adipose tissue.

## Anatomy of the Triangular Safe Zone of 'Kambin' (Fig. 22.4)

This was described by Dr Parviz Kambin in 1991. Putting a needle or endoscope through this zone avoids injury to the foraminal structures. This triangular zone is bordered anteriorly by the exiting nerve root inferiorly by the endplate of the lower lumbar

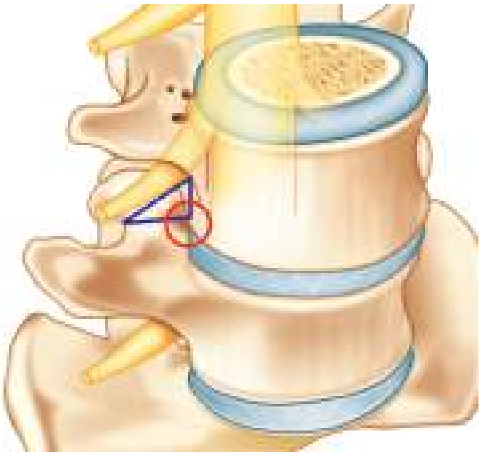


**Fig. 22.4:** Kambin's triangle

vertebra, posteriorly by the superior articular process of the inferior vertebra and medially by the traversing nerve root.

The medial end of the triangle is the maximum safe area for insertion of the endoscope.

Annulus is rich in nerves and vascular supply and is covered by adipose tissue.

## Applied Anatomy and Safe Needle Passage

Passing the needle through the foramen with the help of fluoroscopic imaging is the crucial part of this operative technique. One has to remember three-dimensional anatomy while doing this. One has to see the type of disc pathology and whether it has migrated up or down when processing the needle trajectory. Use of the preoperative computed tomography (CT) scan or magnetic resonance imaging (MRI) of the lumbar spine is useful to calculate the needle entry point (Figs 22.5 and 22.6). This will help to prevent needle injury to the intra-abdominal structures.

Directing the needle is difficult especially at L5/S1 region due to:
- Foramen is narrow at this level compared to other levels
- High iliac crest
- Because of the angulation at L5/S1 (lumbosacral angle) the distance between intertransverse processes is also smaller.

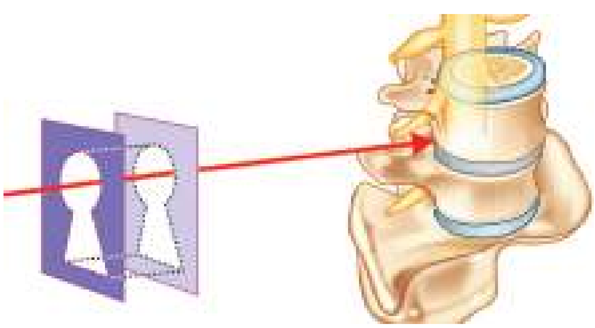


**Fig. 22.5:** Trajectory of the needle

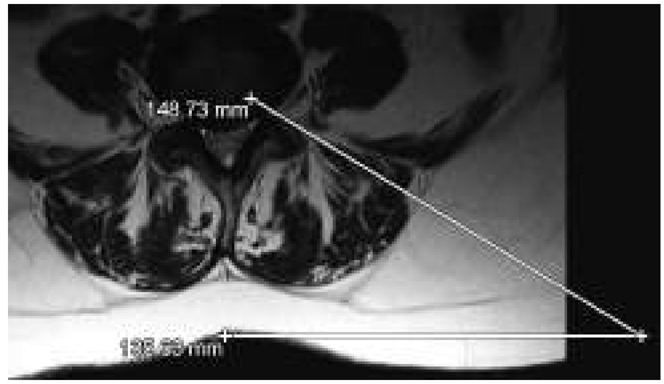



**Fig. 22.6:** Calculation of needle entry point

Putting needle at L5/S1 is technically difficult and sometimes one has to abandon this approach and use standard microdiscectomy.

During the procedure anteroposterior (AP) and lateral X-rays are taken. Tip of the needle is seen at medial border of the pedicle in AP view and posterior spinal line at the disc space in the lateral view.

Exiting nerve is vulnerable for injury and patient's response should be assessed for leg pain while doing this.

## Endoscopic Anatomy (Fig. 22.7)

Continuous fluid irrigation helps to wash away the blood, toxins and disc fragments. It also helps to create space in front of the endoscope which is a requirement for endoscopic surgery. Endoscopic surgery is usually done in cavities, e.g. third ventriculostomy in the brain, urinary bladder, etc.

When the endoscope is introduced one can see the floating fatty tissue. Once this is cleared with radiofrequency cautery (coagulation probe) annulus and posterior longitudinal ligament (PLL) are seen. Gradually with the help of forceps and coagulation probe disc space is explored. Disc fragments are stained blue due to indigo carmine/methyline blue which is injected during discography.

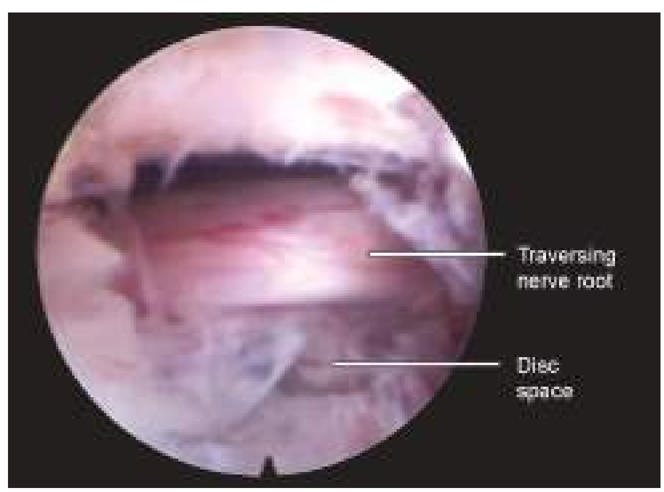



**Fig. 22.7:** Endoscopic view

With further exploration and discectomy one can see the disc space, PLL, dural tube, traversing nerve root and under surface of the superior facet. Exiting nerve root is usually not seen but one can see it while taking out the working cannula and rotating and directing the open end of the cannula cranially and posteriorly.

Traversing nerve root goes over the pedicle towards its exit. When this nerve root is freed after discectomy, the ‘recess’ is well felt beyond the pedicle with the help of a dissector.

When disc is adequately removed one can see that the dural tube and traversing nerve root are pulsating well.

## Percutaneous Transforaminal Endoscopic Lumbar Discectomy

### Indications

- Symptomatic lumbar disc prolapse not responding to conservative line of treatment
- Foraminoplasty for spinal canal stenosis.[1,30-32]
- Recurrent lumbar disc prolapse—if there is ‘scarring’ due to previous posterior open operation, it is difficult to go through the same approach. So this alternative approach is useful. One can do percutaneous transforaminal endoscopic lumbar discectomy (PTELD) at the same level and site for a recurrent disc prolapse as this operation produces very little scar.[33,34]

### Advantages of the Operation

- Early recovery and fast mobilization, patient may be discharged as early as two hours after operation. As consequence, outpatient procedure is possible (day care surgery)
- It can be used in obese patients
- As this is done under local anesthesia and sedation, it is suitable for patients with medical problems, those who are not suitable for general anesthesia or those who do not want general anesthesia. Also, it is suitable for pregnant patients.
- Reduced risk of infection
- Reduced risk of instability
- Less subsequent scars and hence redo operations can be done through the same approach.
- Reduced rehabilitation time and therefore can join[35] job early.

### Disadvantages

- Demanding for the patient as it requires more cooperation by the patient during the procedure.
- Demanding for the anesthetist—requires continuous monitoring of the patient visually and verbally. He or she needs to monitor level of consciousness during the procedure to assess neurology.
- Demanding for the surgeon—long learning curve—use of endoscope requires skill and surgical exposure available is limited. Also the surgeon needs to have good three-dimensional imaginative power.
- Surgeon needs to communicate with the patient during surgery.

### Contraindications

- Very old or calcified disc
- Uncooperative patient—not suitable for local anesthesia
- Deformed spine
- Severe foraminal stenosis with central canal stenosis
- Technically inaccessible area, especially at L5/S1 region due to:
  - High iliac crest
  - Narrow foramen.

### Operation Theater and Equipment

The theater is specially used for endoscopic procedures and equipment are organized in such a way that they are easily accessible and convenient for use to theater staff. Operation table is radiolucent and helps to hold the patient in lateral position during surgery.

- Endoscopy tower (Fig. 22.8) contains light source, monitor, video recorder and irrigation pump (Fig. 22.9) or stand.

**Fig. 22.8:** Endoscopy tower

**Fig. 22.9:** Irrigation pump

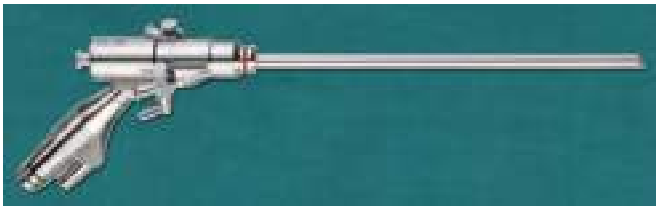


**Fig. 22.10:** Endoscope

- Endoscope (Fig. 22.10) and endoscopy instruments
- C-Arm with its monitors
- Radiofrequency generator
- Fully equipped anesthesia trolley with facilities for an open procedure whenever required.

There is need for well-trained theater staff, experienced radiographer, company representative and experienced endoscopic spinal surgeon to do this procedure smoothly.

## Endoscopes and Surgical Instruments

Initially, surgeons used arthroscope but later on endoscopes were specially developed for spinal surgery. Joimax (Germany), Carl Storz (Germany), and Richard Wolf Medical Instruments Corporation (USA) are some popular companies producing spinal endoscopes.

We use Joimax endoscope system (Germany).

Spinal endoscopes are specially designed. Surgical microscopes give 3D view but endoscopes give 2D view. But unlike microscopes, endoscopes produce illumination at depth and can be positioned directly near the area of interest to provide direct vision.

Endoscopes may be 0° or 20° or 30°. Lumbar and thoracic spine endoscopes are usually 30° and cervical spine endoscopes are 0°.

Endoscope barrel (Fig. 22.11) contains:
- Fiber optics
- Irrigation channel
- Larger working channels which allow passage of larger sized forceps, endoscopic reamers and shrills (drills)
- Video camera which is incorporated into the endoscope.

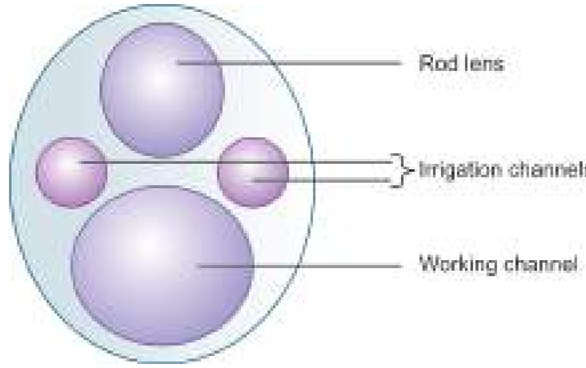


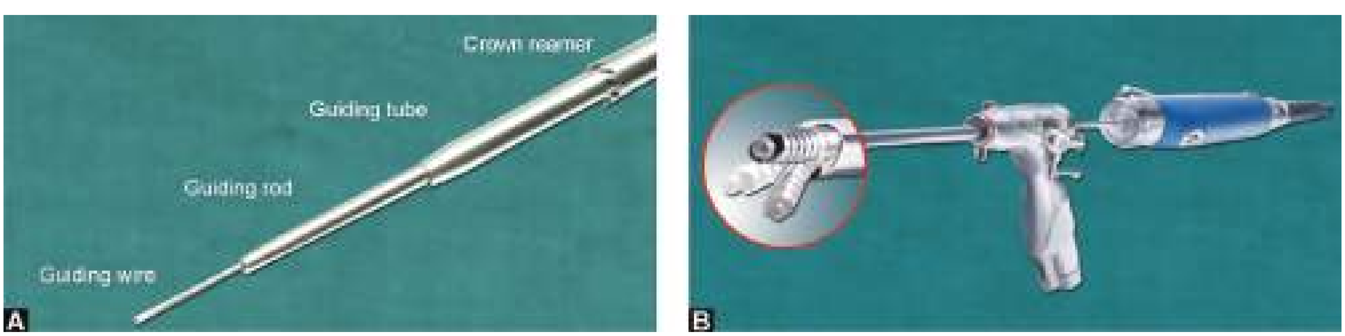

**Fig. 22.11:** Endoscope barrel

Endoscopically used instruments are larger and surgeons who are not familiar using them may bend the forceps or coagulators during use or may occasionally break them.

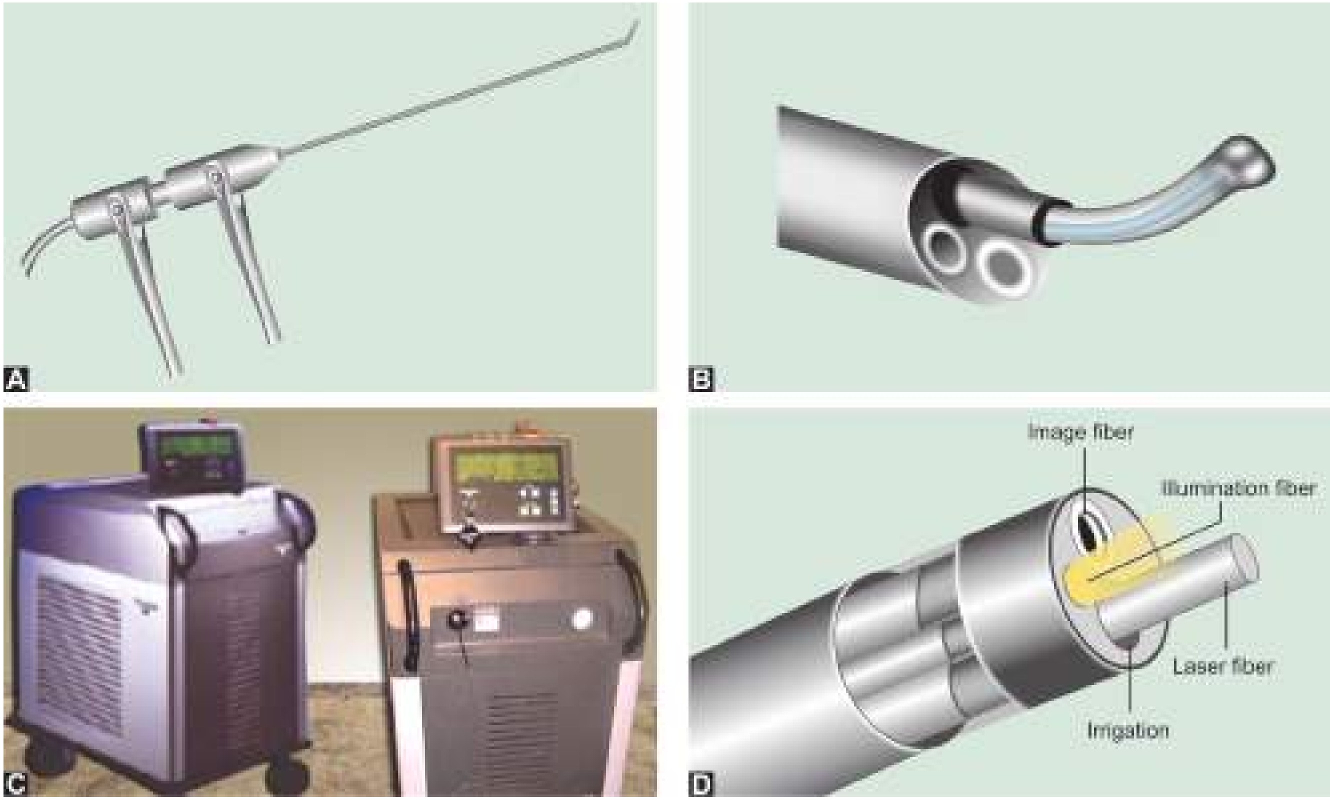
*Following instruments are used through the endoscope:*
- *Mechanical instruments:* Rigid forceps, dissectors, probes etc.
- *Special instruments:* Conical rod, conical tube, endoscope sheath, reamers and shrills (Figs 22.12A and B)
- *Electronic instruments:* Radiofrequency bipolar unit (Figs 22.13A and B)
- *Laser:* Laser probes using Ho-YAG laser machines (Figs 22.13C and D)
- Endoscopic instruments (Figs 22.14A and B).

### Anesthesia

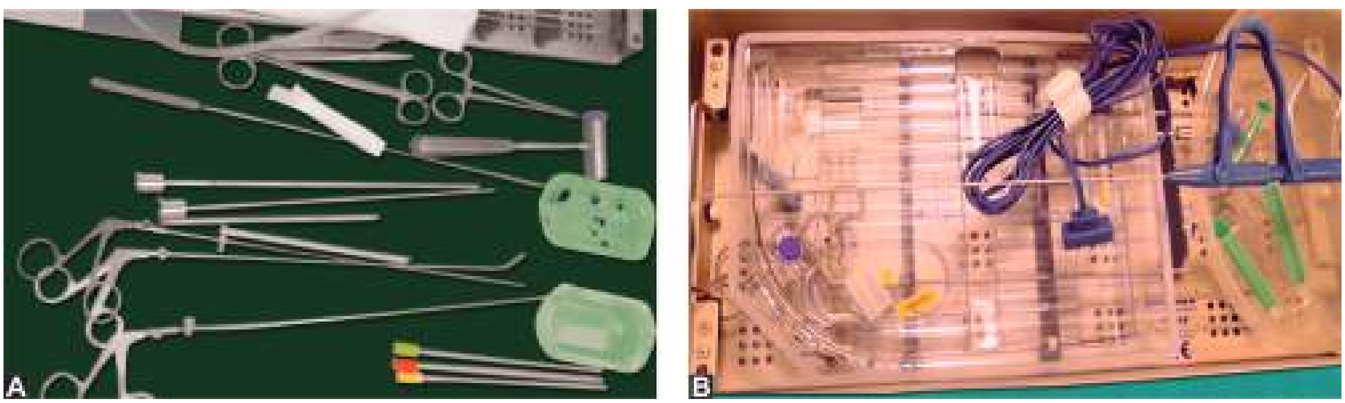
Percutaneous transforaminal endoscopic lumbar discectomy (PTELD) can be done under local anesthesia or general anesthesia. We prefer to do it under local anesthesia and conscious sedation. Doing this under local anesthesia is more challenging for surgeon and anesthetist. Of course we need a cooperative patient as well. To do this procedure under local anesthesia is suitable for patients who are not fit for general anesthesia, especially elderly people with medical problems. Pregnant patients may be other suitable candidates. This operation can be done under general




**Figs 22.12A and B:** (A) Staged guidewire access principal; (B) Shrill




**Figs 22.13A to D:** (A and B) Coagulator and its tip; (C) Laser machines; (D) Laser probe




**Figs 22.14A and B:** Endoscopic instruments

anesthesia but doing it under local anesthesia helps to monitor the neurology of the patient during surgery.

To do this operation under local anesthesia particularly presents demands for the patient, anesthetist and the surgeon. The procedure under local anesthesia needs to be discussed properly with the patient by the anesthetist and the surgeons, explaining how the patient has to cooperate during operation. The patient needs to tell especially if there is a leg pain during the surgery. If the patient complains of leg pain during surgery, the surgeon needs to stop coagulation, etc. and he knows probably he is very close to the nerve root.

The surgeon also needs to tell the patient or anesthetist when he is going to cause more pain during the procedure, especially when reaming the facet joint.

Anesthetist needs to keep anesthesia light or deep according to the requirement and be familiar with using various types of short-acting anesthetics. The surgeon needs to use sufficient and effective amount of local anesthesia for pain relief and top up during the procedure as and when required.

One percent Xylocaine is used for initial infiltration of skin and muscles, which is fast acting and works for 1 to 1.5 hours. A lower concentration 1 percent Xylocaine (1% instead of 2%) is used because the drug in lower concentration blocks the sensory nerve fibers without impairing the motor response.

### Conscious Sedation

With the help of anesthetic agents the level of consciousness is depressed, but still the protective reflexes are maintained. The patient keeps his airway intact, breathes spontaneously and at the same time permits appropriate response to physical and verbal stimuli.

Midazolam is used in combination with either Remifentanil, Fentanyl or Propofol. These drugs can be used in different combinations as per requirement.

Remifentanil does not have analgesic effect which makes it easier for the surgeon to assess leg raising test immediately at the end of the operation.

## Operative Technique

The endoscopic method is not a simple one. It requires three dimensional imaginative powers. For those who have no experience with endoscopic procedures, it will be harder to master. It seems sensible to perform the procedure under experienced guidance after an adequate cadaver workshop using slim patients with the disc prolapse at the level of L4/5. We prefer to do percutaneous transforaminal endoscopic lumbar discectomy (PTELD) under local anesthesia with sedation in lateral position.[1,36]

The patient is explained the procedure both by surgeon and anesthetist. The technical difficulties are told to the patient and if need arises then patient is fully anesthetized and standard lumbar microdiscectomy procedure is performed. This is especially true for disc prolapse at L5/S1.

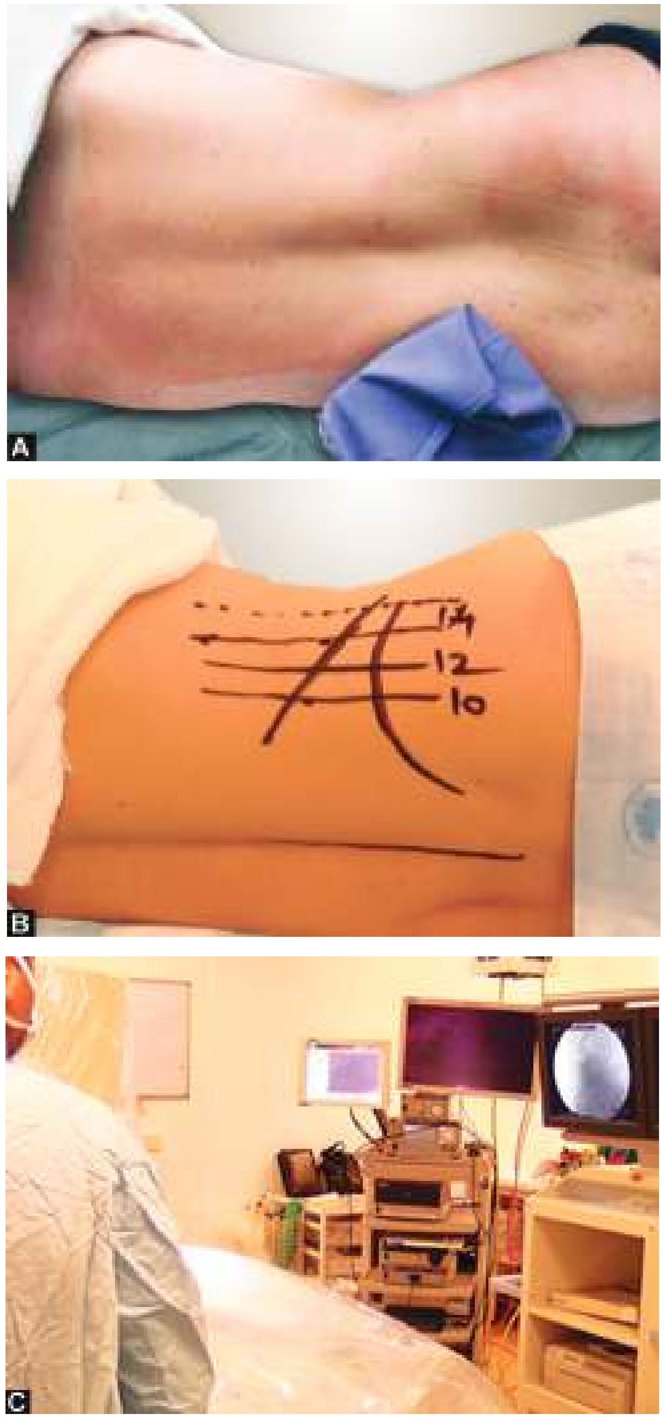
Conscious sedation with controlled use of midazolam and other narcotic drugs allow continuous feedback from the patient during surgery. The patient is told about back pain and leg pain and especially told to alert if gets "leg pain" during surgery. Preoperative imaging (MRI, CT scan) rechecked and patient's back is marked with permanent ink marker for site and side of discectomy. Also a ruler is used to calculate the distance of the skin entry point of the needle as shown in the diagram. The needle trajectory is aimed to target the ruptured fragment while avoiding contents of peritoneal sac.

### Step 1

*Theater Set-up and Position of the Patient (Figs 22.15A to C)*

The patient can be positioned into prone or lateral position.
The advantages of the lateral position are:

- In the lateral position, a soft jelly pad or bolster is put under the lumbar spine which helps to open up the lumbar foramen.
- There is no pressure on the abdomen, so the intraoperative bleeding is less.
- There is no pressure on the chest. Therefore breathing is comfortable for the conscious patient.




**Figs 22.15A to C:** (A) Patient positioned in lateral decubitus; (B) Iliac crest marked with ink and parallel lines marked at 10,12 and 14 cm from midline; (C) Theater set-up

- Anesthetist and surgeon can easily access the patient.
- Testing of the patient's foot or leg movements (SLR test) in this position is easier during surgery.

Others have used prone position.

In prone position, the disc prolapse on the opposite side can be operated at the same time.

Patients with spinal stenosis requiring foraminoplasty from both sides can be operated at the same sitting.

We prefer lateral position. Bolster or a soft jelly pad is put under the loin which helps to open up the foramen. Back is kept perpendicular to the floor and patient is kept as comfortable as possible.

Iliac crest and midline lumbar spinous processes are marked with ink. From midline parallel lines are drawn with the pen at 10, 12, 14 cm from midline as shown and a gentle strap is put around the hip and table to stabilize the patient. The shoulder is supported and the floating upper limb is supported on hand rest.

C-arm monitors and endoscope video monitor are placed at appropriate positions so that surgeon can easily see them. Saline irrigation pump is connected to saline bottle with tubing.

### Step 2

*Needle Insertion and Discography (Figs 22.16A to H)*

After painting and draping, X-rays are taken to select appropriate disc level and needle entry point is marked. We use **TESSYS** (**T**ransforaminal **E**ndoscopic **S**urgical **SYS**tem by Joimax, Germany) which uses a disposable tray containing sterile, initially required instruments, e.g. needle, guidewire, conical rods, conical tubes, sheath, reamers, etc.

At the needle insertion point, local anesthetic (1% Xylocaine) is infiltrated subcutaneously and along the needle track. The needle is directed towards the foramen and inclined to make 10° angle with the lower endplate.

First bony resistance is lateral facet joint. Needle tip is further mobilized under the ventral side of the facet towards the disc (Kambin's triangle).

Fluoroscopic imaging is used to achieve proper placement of the needle tip. The needle tip should be at medial pedicle line in AP view and the posterior vertebral line in the lateral view of the X-ray. This corresponds to Kambin's safe triangle in the axillary area between the exiting and traversing nerve roots. A 5 mL of (1 mL Indigo Carmine or methylene blue plus 4 mL of contrast) dye is injected through the needle which stains the degenerated acidic disc material blue. Some dye may leak into epidural space.

### Step 3

*Dilators, Reamers (Figs 22.17A to G) and Endoscope Sheath (Figs 22.18A and B)*

A guidewire is introduced through the needle and its position is checked. 1 cm skin is incised with knife. First conical rod is introduced over the guidewire and consequently the first, second and third conical tube, in order to stretch the muscles. Afterwards second and third conical tubes are removed and the first reamer (green) is brought in counter clockwise.

With the help of imaging, reaming is carried out till 1 mm medially from the medial interpedicle line at the most.

Reaming is painful and anesthetist is informed during this period to deepen the sedation. Afterwards first reamer, conical tube and rod are removed.

Over the guidewire second conical rod is introduced followed by the second conical tube and second reamer (yellow). Similarly third conical rod, conical tube and reamer (red) are used. The patient is asked if he gets pain in the back or leg. Anesthetist is talking to the patient at this time which helps to identify and prevent injury to the exiting nerve root.

The working cannula (endoscope sheath) is then introduced over the third conical rod (after taking out third reamer and the third conical tube out). Conical rod and guidewire are removed and working cannula is hammered in at appropriate place and direction which is again checked with imaging.

### Step 4

*Endoscopic Discectomy (Figs 22.19A to D)*

For protection, the protruding lip of the working tube is initially rotated in the direction of the nerve root. Fluid irrigation is started and then endoscope is then pushed in through the working cannula.

Initially epidural fat is coagulated with coagulator. Image orientation and identification of the structures is important. The figure shows the endoscopic picture of the structures seen during this period. Furthermore, exploration shows the posterior longitudinal ligament (PLL), below which is the blue-stained disc and above the PLL is the dura and the traversing nerve root.

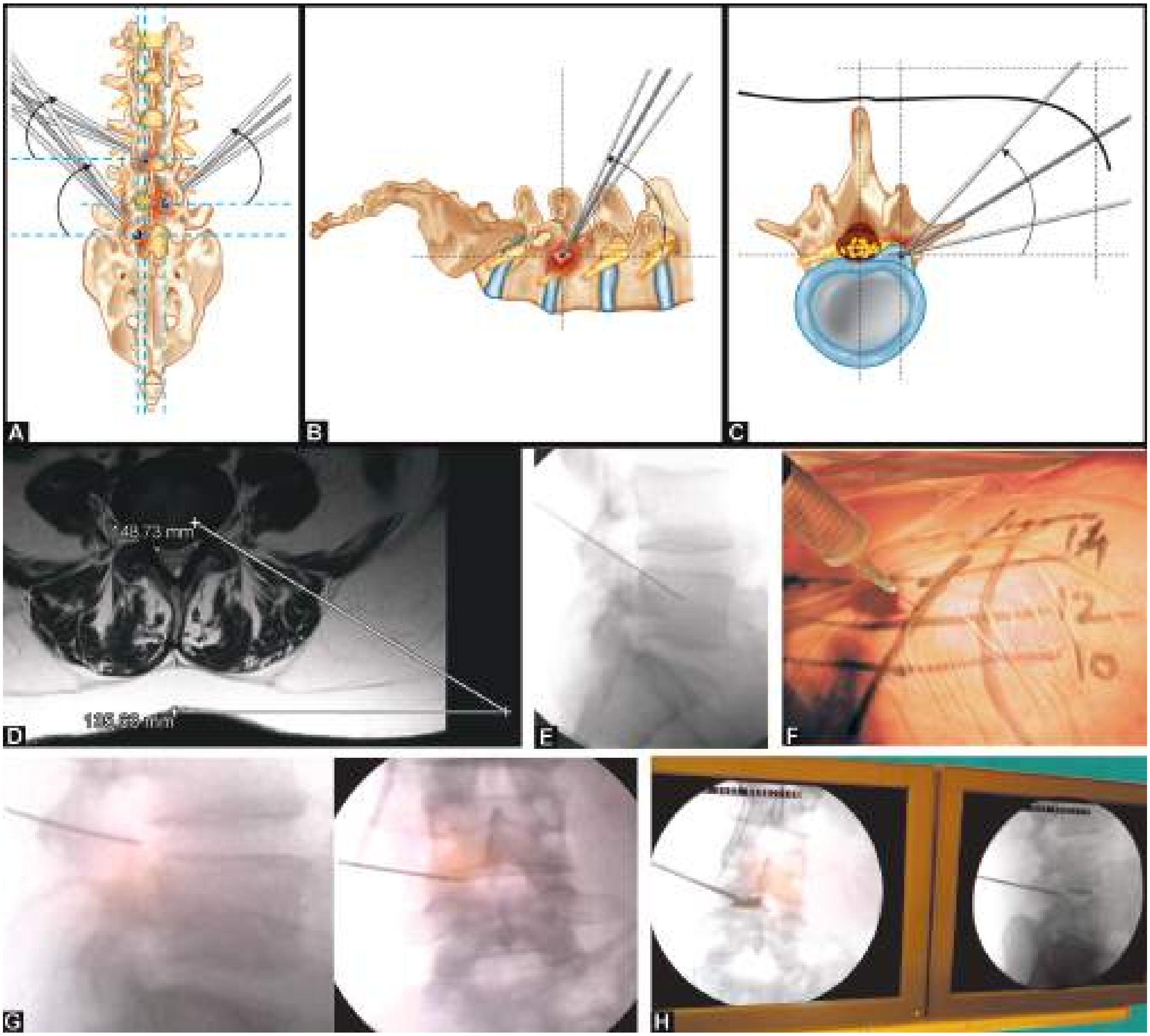
The disc material is taken out bit by bit (with the help of forceps and coagulator) with lot of patience. Intraoperatively one can talk to the patient and also ask to move foot or leg. After proper hemostasis wound is closed with a single subcutaneous absorbable stitch and Steri-Strips.

### Postoperative Period

With adequate analgesic cover patient is shifted to the ward. Physiotherapist checks the patient's neurology and then mobilizes the patient. Necessary instructions regarding analgesics and exercises are given. Patient may be given a lumbar support for 2 weeks for comfort. Patient is then discharged home on the same day.

## Transforaminal Operative Technique (Further Considerations)

The success of PELD procedure depends considerably on appropriate placement of the working instruments in optical trajectory to directly visualize and access the migrated disc fragments. Also a note should be made of the type of disc migration as shown in Figure 22.20. Herniated discs which are displaced either above or below the endplate level are called migrated discs.[29] Depending upon their extent of migration they can be classified as low or high grade migrations (Fig. 22.20).



**Figs 22.16A to H:** (A) Angular trajectories for transforaminal access planning in the coronal plane (dorsal view) for the L3/4 level (25–35°), the L4/5 level (30–40°) and the L5/S1 level (40–50°); (B) Angular trajectories for transforaminal access planning in the sagittal plane (lateral view) for the L3/4, L4/5 and the L5/S1 level (55–65°); (C) Angular trajectories for transforaminal access planning in the axial plane for the L3/4, L4/5 and the L5/S1 level (10–40°); (D and E) Calculation of needle entry point and needle trajectory; (F and G) Inserting the needle with the help of fluoroscopy; (H) Position of the needle in AP and LAT views and discography

### Low-grade Migration

If the disc herniation height is smaller than the disc space height then it is classified as low-grade migration of the disc.

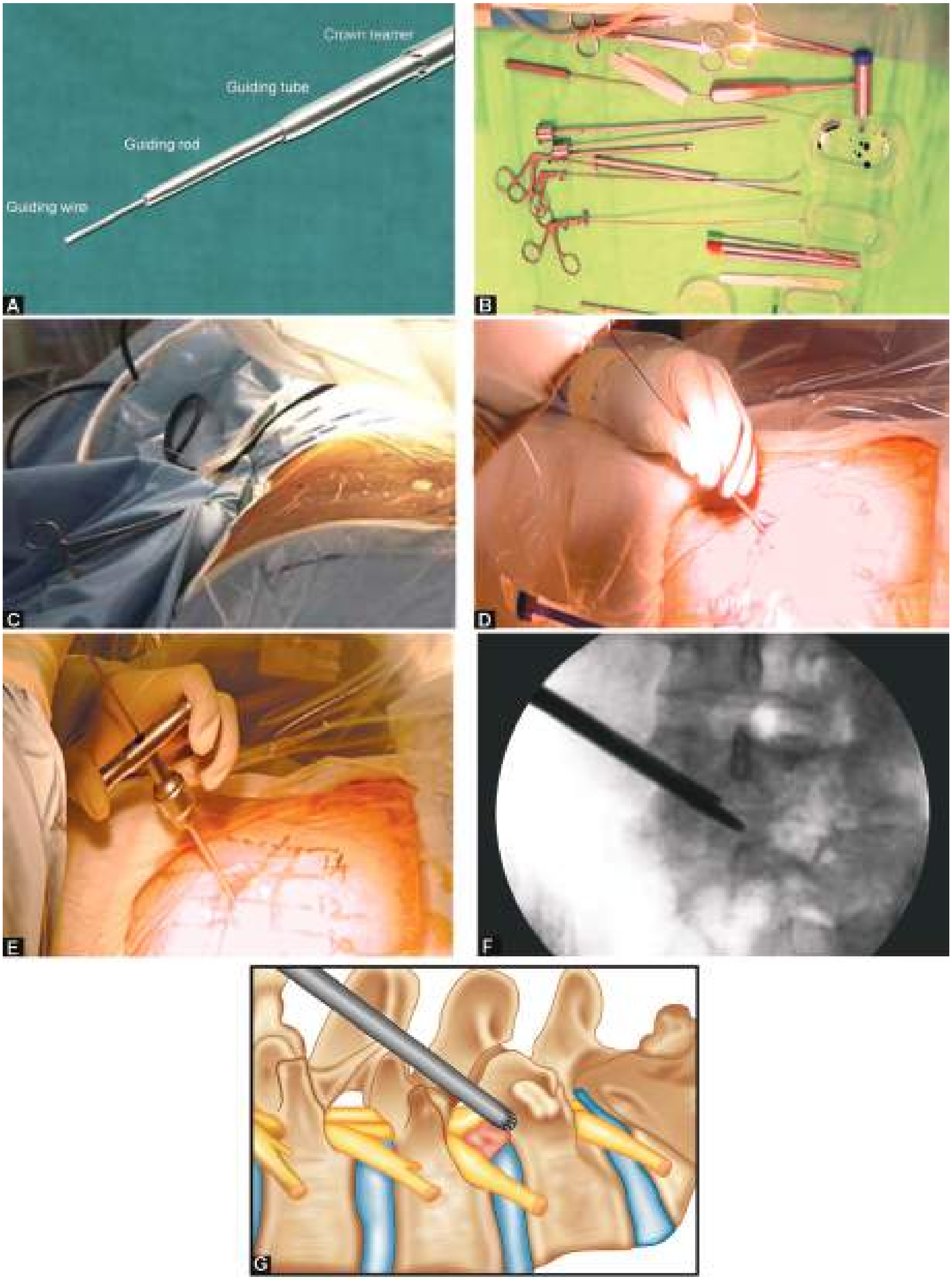
### High-grade Migration

If the herniation height is larger than the disc space height then it is called a high-grade migration of the disc.

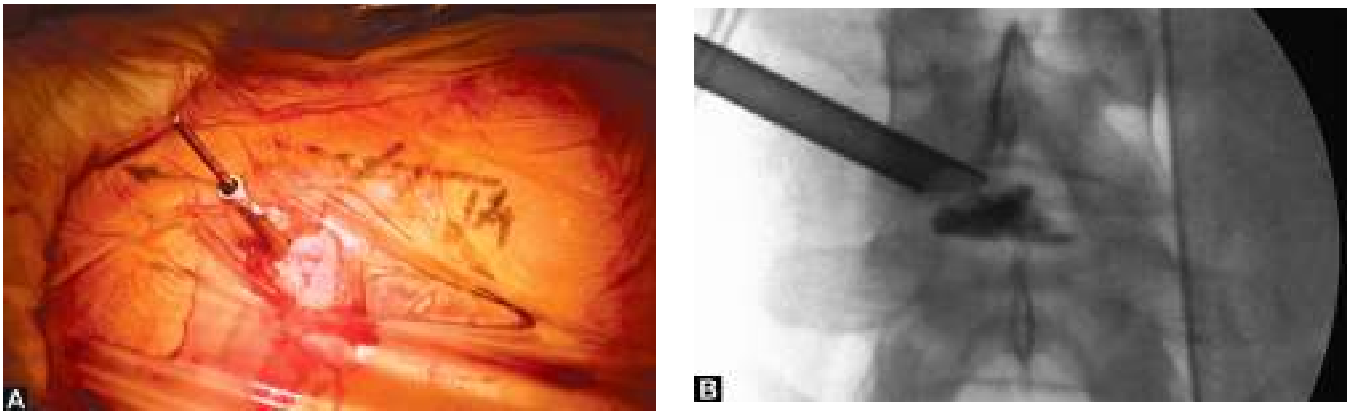
## Anatomical Considerations and the Need for Foraminoplasty

Lumbar disc herniations are more common at the lower lumbar levels where the diameter of the intervertebral foramen is small as compared with higher levels.

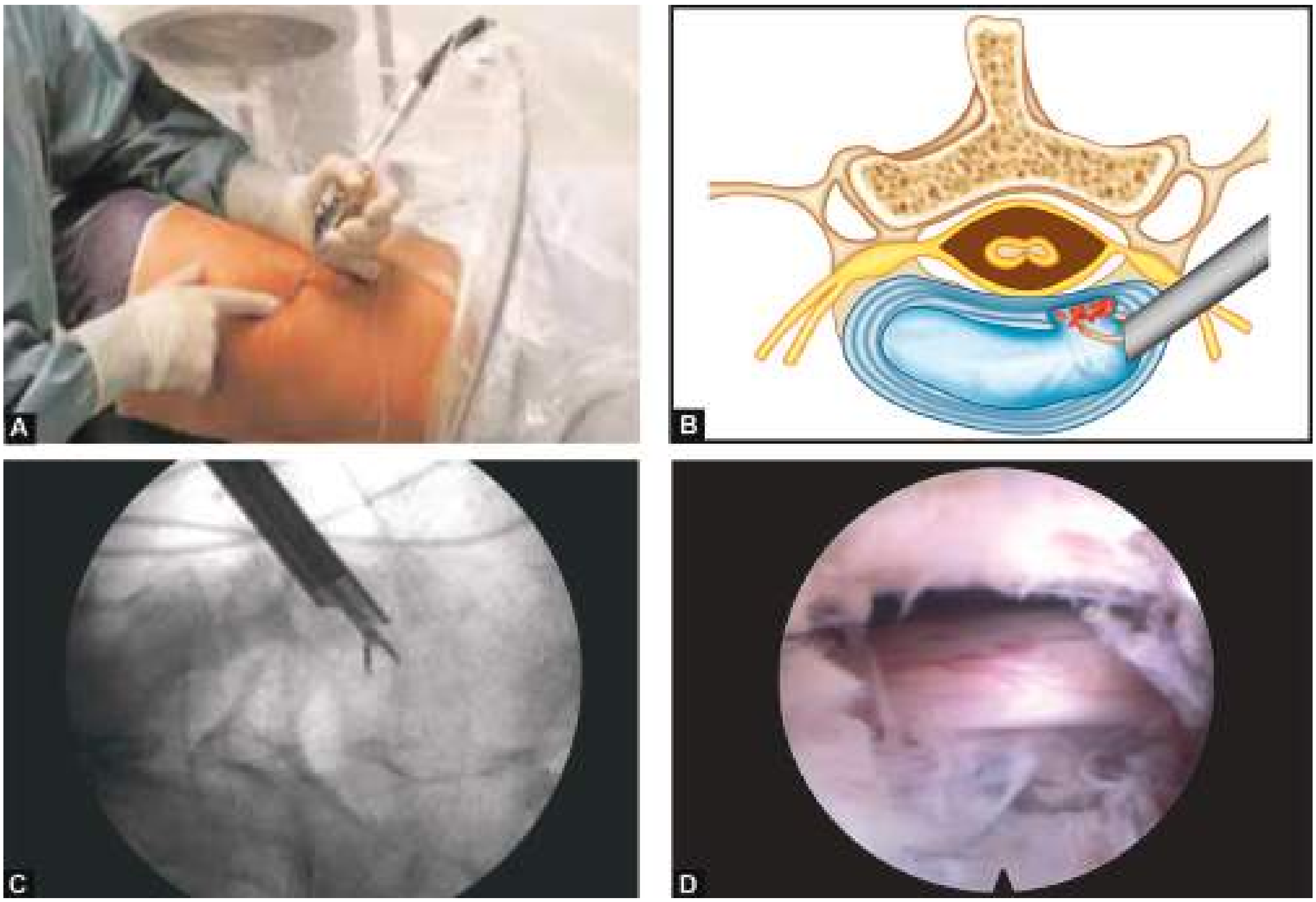
Degenerative changes, e.g. facet hypertrophy and thickening of the foraminal ligaments may cause additional narrowing of the transforaminal window.




**Figs 22.17A to G:** Use of guidewire, conical rods, conical tubes and reamers as described



**Figs 22.18A and B:** Endoscope sheath—ready to put endoscope in



**Figs 22.19A to D:** (A and B) Endoscope in position; (C) Forceps used for discectomy; (D) Good decompression of the nerve root

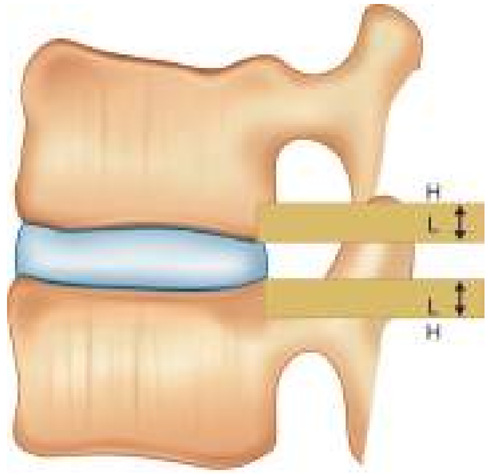



**Fig. 22.20:** High or Low grade disc migration. L—Low grade migration H—High grade migration

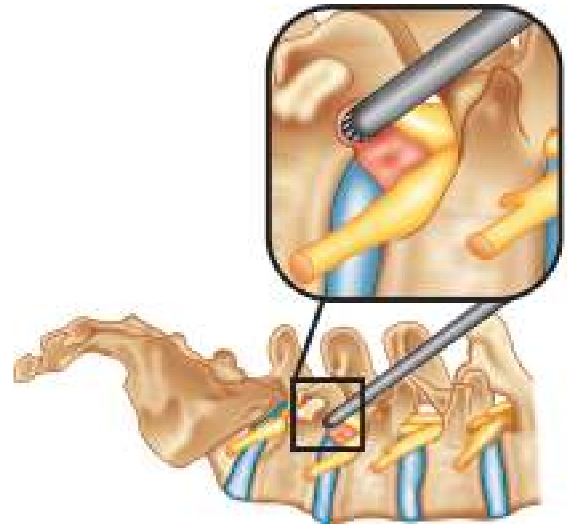


**Fig. 22.21:** Foraminoplasty

Natural anatomic barriers like superior facet and pedicle can obstruct the direct endoscopic vision of the extruded disc.

### Foraminoplasty

This provides adequate working space needed for the excision of the ruptured fragment under direct endoscopic vision through the enlarged foramen. Foraminoplasty can be done by using reamers (trephines or endoscopic Shrills (drills)). We prefer using reamers (green, yellow and red reamers). The use of these reamers is described in the operative technique.

### Conventional Foraminoplasty (Fig. 22.21)

This essentially involves undercutting of the nonarticular part of the superior facet joint and removal of the lateral edge of the ligamentum flavum. Foraminoplasty may not be needed in higher lumbar vertebrae as their foramina are wider. On the contrary, one has to be very careful here as neural structures are very close to the endoscope and liable for direct injury.

### Extended Foraminoplasty

It involves the removal of upper and medial part of the pedicle along with undercutting of the superior facet. In severely downward high-grade disc herniations, the ruptured disc fragment lies in close contact with the medial wall of the pedicle, extended foraminoplasty (foraminoplasty with oblique pediculotomy) would be indicated in this situation.

## Downward or Upward Migrated Disc Herniations

### Downward Migrated Disc Herniations

Undercutting of superior facet (foraminoplasty) is normally needed to access downward migrated herniations. There may be need for extended foraminoplasty if the disc fragment is hiding behind the pedicle.

### Upward Migrated Disc Herniations

In upward migrated discs, the needle is targeted at the lower part of the disc space to protect posteriorly displaced exiting nerve root.

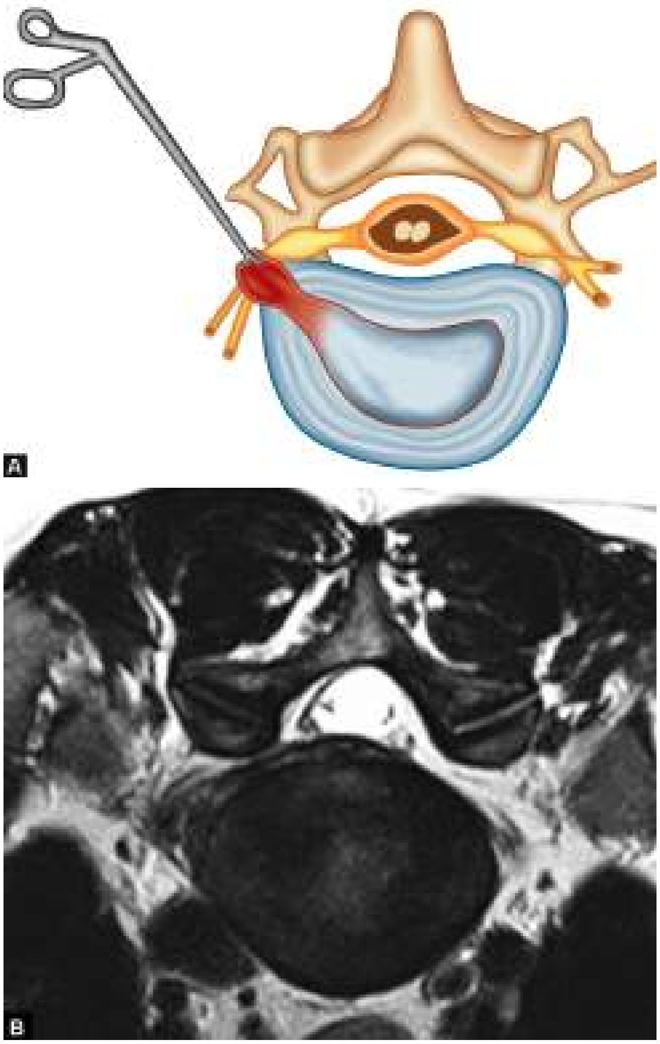
Usually, the aim is to remove only the migrated disc fragment without damaging the central disc. This is described as targeted fragmentectomy. Precaution should be taken to prevent damage to exiting nerve root.

### Far Lateral Disc Prolapse (Special Scenario) (Figs 22.22A and B)

When a disc migrates laterally, it can be in the foramen or go outside and become extraforaminal.[16,22,37] Extraforaminal disc protrusions are also called far lateral disc prolapses in the lumbar spine. These were first described by Abdullah in 1974.[38] These disc prolapses were missed previously because myelographic contrast failed to reach the lateral areas.

With modern imaging methods such as CT and MRI the frequency of diagnosis is on the rise. In far lateral disc prolapse the disc is usually pushed laterally and therefore the exiting nerve root is pushed posteriorly and superiorly. One has to be careful using this approach to prevent injury by the endoscope to the exiting nerve root. These discs are difficult to approach by usual posterior spinal approach. It may destabilize the spine while decompressing and excising the disc (extended facetectomy). Extraforaminal or foraminal disc prolapses are ideal indications for percutaneous transforaminal endoscopic approach.

Precaution must be taken to prevent injury to exiting nerve root. As patient is awake during the operation, he should alert the surgeon of pain shooting down the leg. More pressure and handling of the exiting nerve root may lead to dysesthesia or reflex sympathetic dystrophy.



**Figs 22.22A and B:** Extraforaminal approach for far lateral disc prolapse

This extraforaminal approach is also described as extraforaminal targeted fragmentectomy.[22] Here the extruded disc is targeted and removed in fragments and usually disc space is not entered.

With the extraforaminal approach the target points for needle insertion is identified first from preoperative images and the needle track starting point is determined according to the location of the herniated disc. The skin entry point is relatively steep compared to usual approach.

As pathology lies at extraforaminal region there is usually no need to go into the disc space for disc removal. Occasionally, large fragments are difficult to remove through the endoscopic working channel. One can then grab the large sequestered disc fragment and remove the endoscope along with forceps and leave the working cannula in position.

### Complications

*Immediate*

- Persisting or increased pain in the back or leg
- Missed fragments
- Wrong level or side exploration
- Injury to nerve root leading to weakness
- Injury to the psoas muscle causing hematoma
- Breaking of instruments inside or outside the wound
- CSF leak.

*Early Complications*

- Postoperative hematoma
- Psoas hematoma
- Dysesthesia
- Infection.

*Delayed Complications*

- Recurrence of disc herniation
- Spinal instability
- Failed back syndrome.

## Future Developments

Conservative treatment for lumbar disc herniation is of approximately 6 to 8 weeks. This period is gradually coming down as people cannot afford to remain off sick for longer period. There is worry that they may lose their job. If they are self-employed, they will like to go back to their job as quickly as possible.

If conservative line of treatment fails and if the patient needs to go for surgery, that increases their off sick period further.

Special pain clinics may give spinal injections and oral medications to the patients for pain relief initially but if they do not respond to that, PTELD may be a good option to help them to go back to their job earlier.

Percutaneous transforaminal endoscopic lumbar discectomy has more developed in the last 10 years. The efficacy of this technique is still not proved but I think the future studies, technological improvements and appropriate training will improve its efficacy.

This technique might replace conventional microdiscectomy operation in the future.[36,39]

*This approach may be used in future to treat following types of spinal conditions:*

*Lumbar Disc Prolapses*

There will be more developments in taking out all kinds of lumbar disc prolapses in the future with the improvement in the technology.

*Foraminal Stenosis*[30-32]

Foraminal and lateral recess stenosis are being treated. The reports are being published in the literature.

### *Spinal Fusion*[40,41]

This approach may be used for spinal fusion. There is study where B-twin cages were put into intervertebral space through this approach. If cages are put like this through bilateral transforaminal approach and percutaneous pedicle screws are put posteriorly for spinal stabilization, this will be really a minimally invasive transforaminal lumbar interbody fusion.

### *Spinal Infections*

Infected disc material along with epidural collection can be aspirated to get appropriate diagnosis. This will also help to decompress the spinal canal. Pyogenic and tubercular infections can be diagnosed and treated like this. There are already reports of discitis material aspirated for diagnosis by this approach.

### *Tumor Biopsy*

Tumors can be biopsied under direct vision with this approach.

## Laser in Endoscopic Spinal Surgery

Laser is used to ablate disc material and tends to shrink and contract the disc further (laser thermo discoplasty). It has been used to cut bone (facetectomy) during foraminoplasty.

National Institute for Health and Clinical Excellence (NICE) guidance after studying this has understood uncertainty about its safety and efficacy. So it is said that clear information should be given to the patient and there is need of more audit and research in this area. It also said about further research into safety and efficacy outcomes to reduce current uncertainty.[42]

## Review of Literature

In 2010, Nellensteijn and colleagues published a systematic review of the literature on transforaminal endoscopic surgery for symptomatic lumbar disc herniations.[43] One randomized controlled trial, 7 nonrandomized controlled trials, and 31 observational studies were identified. Analysis of the 8 controlled trials found no significant differences between the endoscopic and open microdiscectomy groups for leg pain reduction (89% vs. 87%), overall improvement (84% vs. 78%), re-operation rate (6.8% vs. 4.7%) or complication rate (1.5% vs. 1%, all respectively). The methodological quality of these studies was described as poor, providing insufficient evidence to support or refute this procedure.

The above systematic review included a randomized trial by Hermantin et al. (1999).[44] This was rated as the only study with a low risk of bias. Sixty patients who had objective evidence of a single intracanalicular herniation of a lumbar disc were randomized into 2 groups; endoscopic microdiscectomy or open laminotomy and discectomy. A similar percentage of patients were considered to have a satisfactory outcome (97% of the microendoscopic group and 93% of the open group). The mean duration of use of narcotics (7 vs. 25 days) and return to work (27 vs. 49 days) were significantly less in the microendoscopic group. This study is limited by the lack of validated outcome measures.

In 2008, Ruetten and colleagues published controlled trials comparing outcomes from full-endoscopic discectomy with conventional techniques in the lumbar spine.

One study (Ruetten et al. 2008)[45] compared full-endoscopic interlaminar or transforaminal lumbar discectomy versus conventional microdiscectomy for clinically-symptomatic lumbar disc herniation in 200 patients.The mean operating time for endoscopic discectomy was approximately half that of conventional microdiscectomy (22 vs. 43 minutes). Access-related osseous resection was required in 91 cases (91%) of the microdiscectomy group and 13 cases (13%) of the endoscopic group. The complication rate was significantly greater in the microdiscectomy group, with 1 delayed wound-healing, 1 soft tissue infection, and 3 cases of transient urinary retention. Postoperative pain and pain medication were significantly reduced in the endoscopic group (data not reported), and the postoperative work disability was shorter (25 vs. 49 days). At 24 months after surgery, 178 patients (89%) were available for follow-up. The 2 groups had similar improvement in leg pain; 79 percent of microdiscectomy and 85 percent of endoscopic discectomy patients reported being pain-free. More patients in the microdiscectomy group (5% vs. 1%) underwent revision spinal canal expansion and fusion.

Another study (Ruetten et al. 2009)[34] compared revision endoscopic interlaminar or transforaminal lumbar discectomy versus conventional microdiscectomy in 100 patients who had recurrent lumbar disc herniation after conventional discectomy. Patients were enrolled who had undergone previous conventional discectomy, presented with acute occurrence of radicular leg symptoms on the same side after a pain-free interval, and who showed a recurrent disc herniation in the same level by magnetic resonance imaging (MRI). Operating time was significantly shorter with the endoscopic approach (24 vs. 58 minutes), and access-related osseous resection was required in 3 cases (6%) of the endoscopic group compared with 47 cases (94%) of the microdiscectomy group. There were 4 cases of dural injury (3 microdiscectomy and 1 endoscopic discectomy) and an overall serious complication rate that was significantly greater (21% vs. 6%) for the microdiscectomy group. Postoperative pain and pain medication were significantly reduced in the endoscopic group, as was postoperative work disability (28 vs. 52 days). At 24 months, 87 patients (87%) were available for follow-up. Seventy-nine percent had no leg pain at follow-up; there was no significant difference between the groups for any of the clinical outcomes (VAS, NASS, oswestry disability index [ODI]).

Lee and Lee described the learning curve for endoscopic discectomy in 51 patients in 2008.[46]

## Summary

The evidence consists of a number of randomized controlled trials. The majority of these trials were conducted at a single center in Germany, and the comparison groups were not the same. While the trials from Germany report outcomes that are at least as good as traditional approaches using either a laparoscopic transforaminal or interlaminar approach to the lumbar spine, a large randomized controlled trial from Italy reports a trend toward increased complications and reherniations with an interlaminar approach. There are few reports from the United States. At this time, evidence is considered insufficient to evaluate health outcomes from endoscopic discectomy and therefore, it is considered investigational.

## Clinical Practice Guidelines

The National Institute for Health and Clinical Excellence (NICE) published guidance in 2005 on automated percutaneous mechanical lumbar discectomy, indicating that there is limited evidence of efficacy based on uncontrolled case series of heterogeneous groups of patients, and evidence from small randomized controlled trials shows conflicting results.[42] The guidance states that in view of uncertainty about the efficacy of the procedure, it should not be done without special arrangements for consent and for audit or research.

2009 clinical practice guidelines from the American Pain Society found insufficient evidence to evaluate alternative surgical methods to standard open discectomy and microdiscectomy, including laser or endoscopic-assisted techniques, various percutaneous techniques, coblation nucleoplasty, or the disc decompressor.[47]

Guidelines for percutaneous endoscopic spine surgery[48,49] are described by International Society for Minimal Intervention in Spinal Surgery (ISMISS).[35]

## Conclusion

The procedure directly attacks the pathology without violating the spinal canal. Postoperative scarring is minimal. So far results are comparable with standard microdiscectomy procedure. This is especially very useful when posterior approach has caused tremendous scarring due to single or multiple operations. This has been proved by various papers that this approach is very successful in recurrent discs.[33, 50]

The future developments in technology, attending education courses and cadaver workshops and personal training with experienced surgeons will popularize this approach.

This approach may emerge as a gold standard for lumbar discectomy in the future.[36, 39]

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# 23

# Percutaneous Endoscopic Lumbar Discectomy

*Yasuhiko Nishimura*

## Introduction

Percutaneous endoscopic lumbar discectomy (PELD) is the most minimally invasive surgical procedure among current spinal surgical procedures that permits excision of disc herniation under local or general anesthesia, without damaging the structural and supporting elements of the spine. Excluding cases in which there is pronounced degeneration and the intervertebral disc space is lost, and cases of advanced migration of a hernia to a disc to the craniocaudal side of the intervertebral disc space, it is applicable for all intervertebral hernias, from level L1 to level S1.

All three forms of this surgical technique (transforaminal approach, posterolateral approach, and interlaminal approach), are inside-out methods that reach the targeted hernia from inside the intervertebral disc (Fig. 23.1).

Percutaneous endoscopic procedure has originated from percutaneous nucleotomy (PN) performed by surgeons in 1975 in which by introducing endoscope, the technique was changed to directly arrive at the herniated portion in the posterior part of the nucleus pulposus. In all three forms of surgical technique, the skin incision is 6 mm, and while deploying an intraoperative scope. The procedure is performed using physiological saline irrigation machine (Fig. 23.2).

Irrigation is possible with free drip, but a reflux apparatus that can be shared by the urinogenital as well as obstetrics and gynecology departments, with pressure and flow sensors attached, is recommended.

There are differences depending on the surgical company, but the operating sheath to be used has a diameter of 6 to 8 mm and a length of 16 to 25 cm. A scope with a working channel of 3.5 to 2.8 mm is passed through the operating sheath and surgery is performed.

The scope angle used is generally 15°, 20°, or 25°, and along with the shape of the operating sheath. The type of scope to be used is based on the three forms of surgical procedures (each of these is described later, according to the procedure). For example, the recommended scope angle for the transforaminal

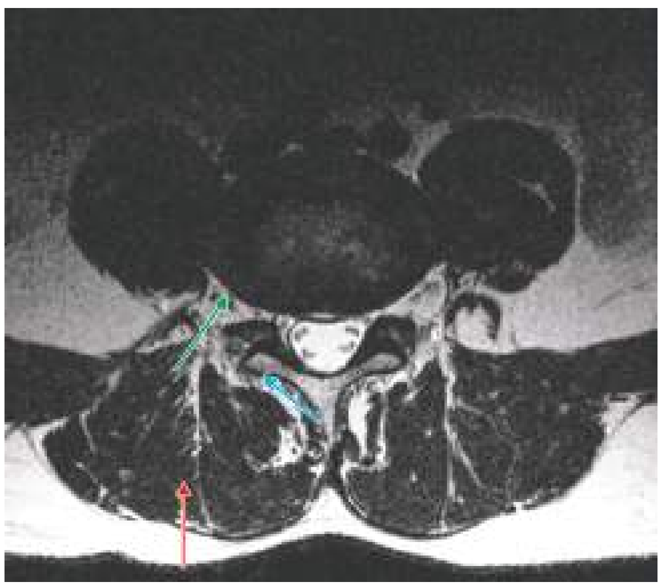


**Fig. 23.1:** Blue arrow: transforaminal, green arrow: posterolateral, red arrow: interlaminar


**Fig. 23.2:** Physiological saline irrigation machine

**Fig. 23.3:** Bipolar cautery with high frequency radiation

approach is 25°, while for the posterolateral approach it is 15°, and for the interlaminal approach it is 25°. For hemostasis, there are a number of companies selling bipolar cautery equipment (Fig. 23.3), which uses high frequency radiation, and which permits passage through the working channel. All the dissectors, hooks, punches, trephines, etc. used for excision of the herniated portion also permit passage through the working channel.

## Procedure

### Transforaminal Approach (Distal End of Operating Sheath is Duckbill Type) (Fig. 23.4)

The patient is placed in a prone position with slight flexion, and the procedure is carried out under fluoroscopic control, at 11 to 13 cm from the midline and 22 to 24° externally, oblique to the horizontal plane, via the intervertebral foramen, reaching the external portion of the canalis vertebralis. The closer to the horizontal plane (0°) it reaches, especially at the upper lumbar spine, the greater the damage to the liver and the kidney, so it is important to check the angle of puncture in the axial view of the magnetic resonance imaging (MRI) before the operation so as to avoid intra-abdominal organs.

For the landmarks of the intervertebral foramen that are passed when entering the intervertebral disc space by puncturing initially with the the needle under fluoroscopic control, the lateral side is located at the lateral posterior edge of the

**Fig. 23.4:** Duckbill type

target intervertebral disc (LR-view of lateral vision) and the craniocaudal side is located at the medial edge of the lower pedicle of the vertebral arch (AP-view of frontal vision) (Figs 23.5A to F).

This results in passing through the safety triangle zone (=Kambin triangle) of the intervertebral foramen.

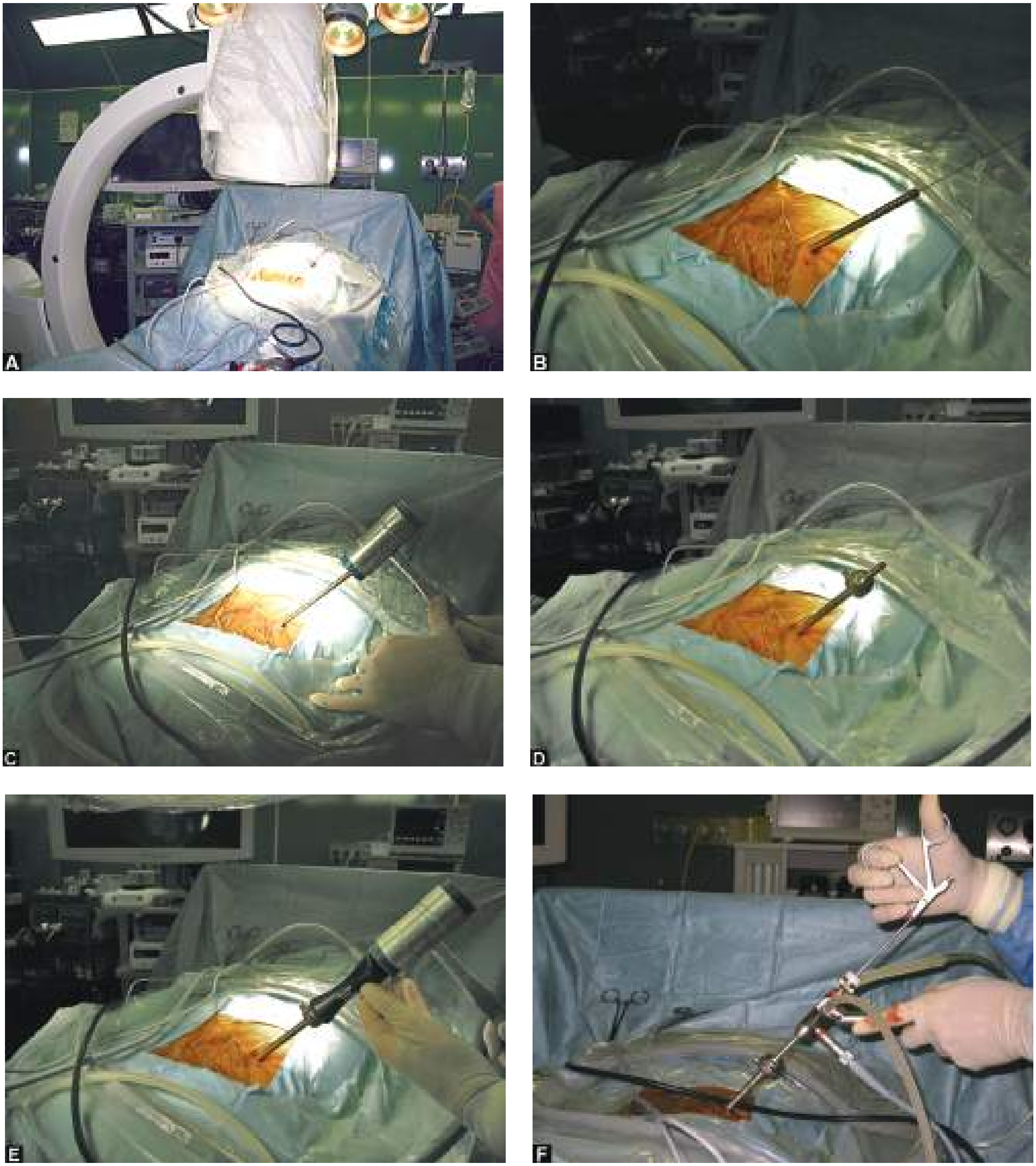
After punctuating the annulus (this is common for all the three types of methods), a guidewire is passed through the punctuation needle and then a dilater and an operating sheath are placed sequentially along the guidewire. At this time, the dilater and the operating sheath need to pass through the annulus fibrosa, where if the patient complains of pain under local anesthesia, local anesthetic is injected around the annulus fibrosa, and furthermore, if resistance is felt at the time of puncturing, it may be tapped gently with a hammer. If the operating sheath is placed appropriately in the intervertebral disc space, the intervertebral disc space should be slightly widened and fixed to the extent that it stands alone even when the scope is taken in and out. When the punctuating needle and dilater are punctured, special care is required to avoid damaging the intra-abdominal organs, and when inserting the final operating sheath, special care is required to avoid damaging the conjoint nerve root and the furcal nerve.

Further careful attention is required while excising the herniated portion and arresting bleeding, should the operating sheath be strongly shifted more than 5° towards the craniocaudal side or the ventrodorsal side, it may damage the exiting nerve root, or postoperative symptoms of dorsal root ganglion (DRG) irritation may occur.

In order to achieve excision of a hernia, firstly the tip of the operating sheath is retracted slowly to the annulus fibrosa and then the nuculeus that is bulging inside the annulus fibrosa is gradually excised, until the pressure of the outside of the annulus fibrosus decreases (nucleotomy). Subsequently, the operating sheath is retracted further, between the posterior edge of the intervertebral disc and the posterior longitudinal ligament, and then the operating sheath is rotated, so that the hernia is invaginated into the sheath.

At this time, it is preferable to confirm the exiting nerve root. The hernia is excised with forceps (Fig. 23.6).

Not all of the herniated mass needs to be excised. The end-point of the excision is the time when excellent pulsation of the dural sac or the exiting nerve root is confirmed. When hemostasis is difficult, the pressure of reflux flow of water is increased, or the



**Figs 23.5A to F:** Steps of PELD operation

**Fig. 23.6:** Endoscopic forceps holding the herniated disc. Exciting nerve root can be seen clearly

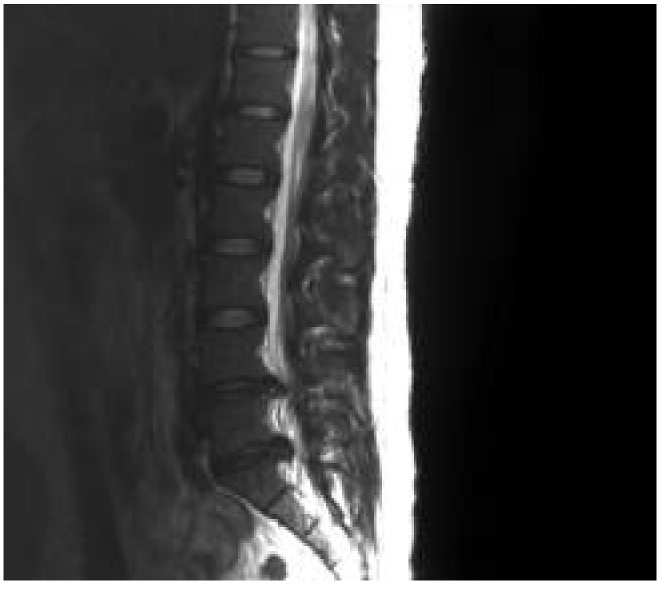


**Fig. 23.7:** L4/5 right disc herniation preoperative MRI

reflux flow is stopped, the water outlet of the operating sheath and the scope are closed, to stop the reflux flow water, followed by a pause for a few minutes.

Even if bleeding cannot be arrested, oxycellulose cotton is inserted by rolling it into a ball, to apply pressure.

Only in cases in which hemostasis is difficult does 4Fr drainage tube is kept in place after the operation.

The operation is completed by taking subcutaneously couple of sutures and applying surgical tape to promote skin alignment (Figs 23.7 and 23.8).

In patients with high iliac crest L4/5 and L5/S levels are not performed because they cannot be approached transforaminally.

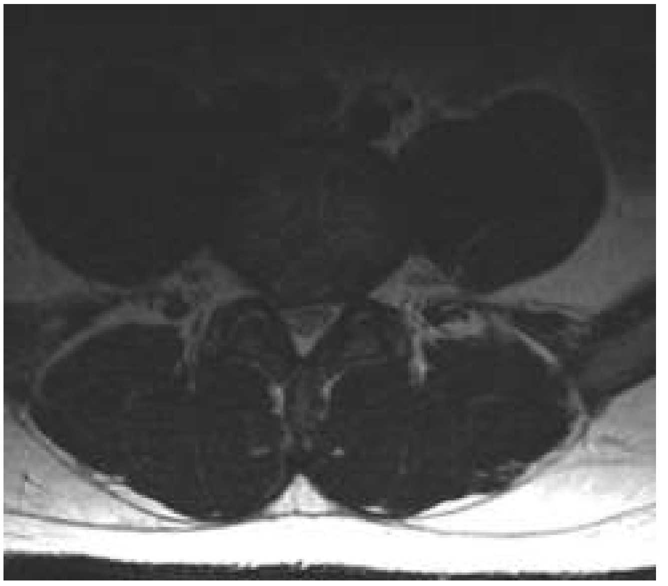


**Fig. 23.8:** L4/5 right disc herniation postoperative MRI

**Fig. 23.9:** Straight cut type

## Posterolateral Approach (Distal Figure of Operating Sheath: Straight Cut Type) (Fig. 23.9)

The patient is placed in a prone position with slight flexion and the procedure is performed, under fluoroscopic control, at 8 to 10 cm from the midline and 30 to 35° externally, oblique to the horizontal plane, reaching the external portion of the canalis vertebralis. This method targets disc herniation and extra-foraminal far lateral type bony stenosis. All the lumbar vertebral levels can be approached by this method.

The landmarks of the intervertebral foramen used when entering the intervertebral disc space are the same as for the transforaminal approach.

This results in passing through the safety triangle zone (=Kambin triangle) of the intervertebral foramen, where decompression of the transversing nerve root inside the inter-vertebral foramen and outside of the intervertebral foramen is a key concept.

It is possible to excise the hernia from the outside of the intervertebral foramen toward the inside of the intervertebral foramen. In cases of bony foraminal stenosis, it is possible to decompress by removing the tip of the superior articular

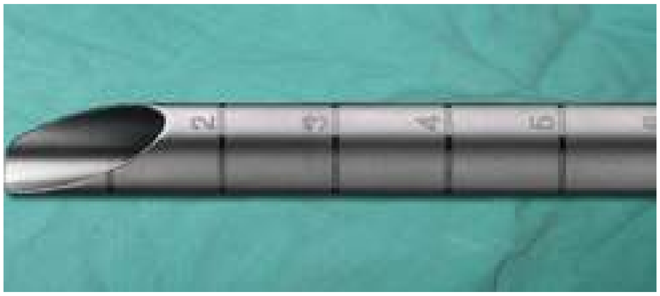


**Fig. 23.10:** Oblique cut type

process and the upper edge of the pedicle of vertebral arch using a trephine or bone punch. Even herniations that project beneath the annulus fibrosa can be excised, with the nucleus pulposus.

### Interlaminal Approach (Distal Figure of Operating Sheath: Oblique Cut Type) (Fig. 23.10)

The applicable cases include medial—mediolateral type hernias at the L5/S1 level and mediolateral type hernias at the L4/5 level in younger patients, in whom the space between vertebral arches is wide.

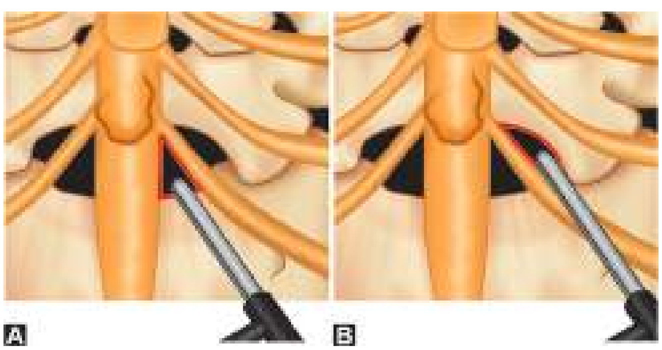
This approach applies an outside-in technique, and the steps to reach the hernia are the same as for MED.

The punctuation point is the intersection between the superior articular process and the superior vertebral arch, and it is invaginated caudally to the root shoulder or the root axilla, internally at an oblique angle of 20° (Figs 23.11A and B).

The puncture needle is slid from the inner caudal edge of the vertebral arch over the yellow ligament, and then the dilation sleeve and operating sheath are fixed sequentially on the dorsal side of the yellow ligament.

This fixation is performed by the surgeon's left hand and it is necessary to fix the scope and operating sheath with the left hand continuously until the herniation is excised (Fig. 23.12).

The yellow ligament is subjected to evaporation until it becomes thin, using bipolar cautery and then ruptured gently with a blunt dissector.




**Figs 23.11A and B:** (A) Trans axilla; (B) Trans shoulder

**Fig. 23.12:** Sheath fixation with flexible arm for surgeon's left hand during interlaminal approach

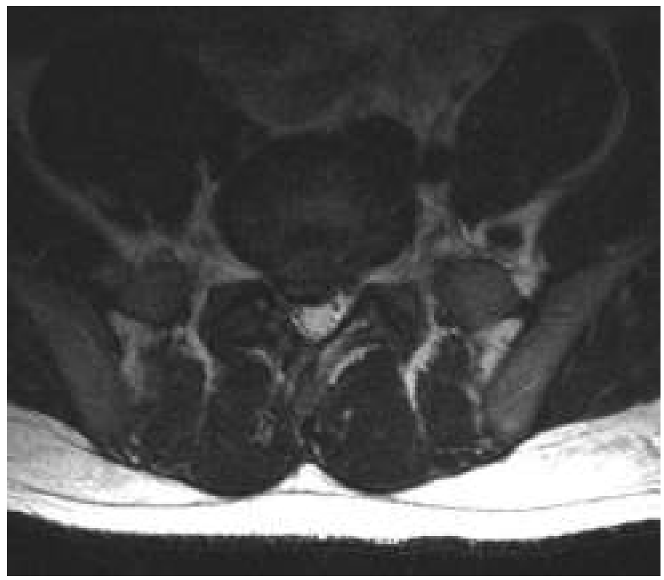


**Fig. 23.13:** Right L5/S1 disc herniation preoperative MRI

Firstly, the opening of the operating sheath is directed inward, causing it to pass through the yellow ligament, the dural sac or the exiting nerve root are confirmed, and the opening is rotated outward to retract them (dural sac or exiting nerve root), inwardly reaching the herniation, which is then excised (Figs 23.13 and 23.14).

## Complications of Surgery

- Damage to intra-abdominal organs—0.4 to 0.9 percent
- Nerve root damage—4 to 13 percent
- Damage to abnormal nerve roots (conjoint nerve root, furcal nerve lesions)

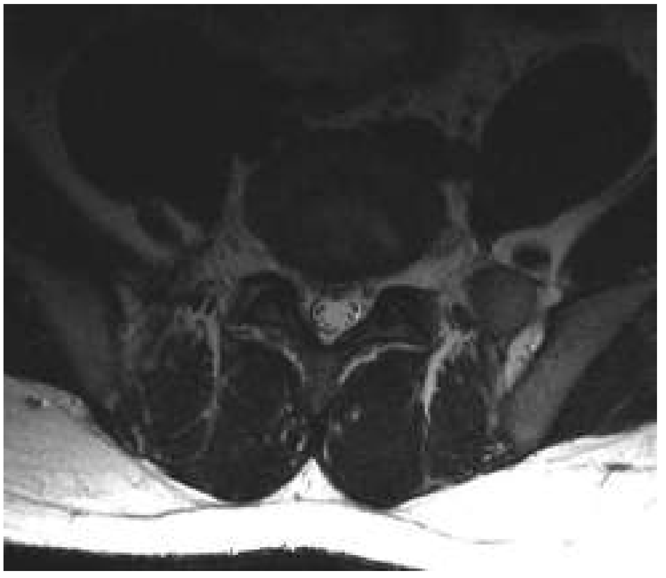


**Fig. 23.14:** Right L5/S1 disc herniation postoperative MRI

- Headache and neck pain due to high reflux flow pressure (only during operations under local anesthesia).

## Conclusion

Percutaneous endoscopic lumbar discectomy (PELD) is a minimally invasive safe procedure and should be practiced by all young spinal surgeons.

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# 24

# Percutaneous Transforaminal Endoscopic Discectomy

*Sushil Patkar*

## Introduction

Relief of severe back and radicular pain continues to remain as the main indication of surgery in prolapsed lumbar intervertebral disc (PVD).

Progress of surgical treatment lies in its self-annihilation. Surgeons continuously struggle to find a less invasive solution to a given surgical problem till ultimately they succeed in a nonsurgical solution. Lumbar disc surgery since the original description by Mixter and Barr has also seen the same course from wide laminectomy to hemilaminectomy to fenestration and finally microlumbar discectomy. All the procedures attempting to decrease the surgical wound, hasten the postoperative convalescence, reduce complications and minimize recurrence.

Cochrane review (2007) for relief of pain in a given case of herniation of lumbar intervertebral disc with surgical and medical management found no difference in the two groups at the end of 4 years and Cochrane review (2009) concluded that surgical treatment can hasten pain relief and return to reproductive life.

Endoscopic discectomy has been attempted since 1975. Its concepts progressed rapidly with the help of MRI imaging, newer technology and progress in microtechniques.

## New Concepts

- MRI examination revealed no correlation between size of prolapse and severity of pain.[1-3] Thus compression of the root is not the only cause of pain in acute PVD. A new chemical theory of root inflammation secondary to exposure of the root to degenerated nucleus pulposus has been widely accepted.
- Provocative discography is a good test to identify the symptomatic disc, especially when the MRI of a patient shows more than one herniation.
- Endoscopic discectomy is performed under local anesthesia, thus giving the surgeon a chance to identify the pain producing structures, confirm pain relief during surgery avoid root injury under vision and avoid general anesthesia.[4,5]

## Indications

- Unilateral contained disc prolapse
- Leg pain more than back pain
- Nucleolus in continuity with the prolapsed component
- Minor neurological deficit
- Unsuccessful completion of an adequate trial of conservative treatment.

## Contraindications

- Sequestrated migrated disc herniation
- Association of lumbar canal stenosis with herniated disc
- Calcified disc
- Osteophytes pressing on the root
- Cauda equina syndrome
- Presence of instability.

## Operative Technique

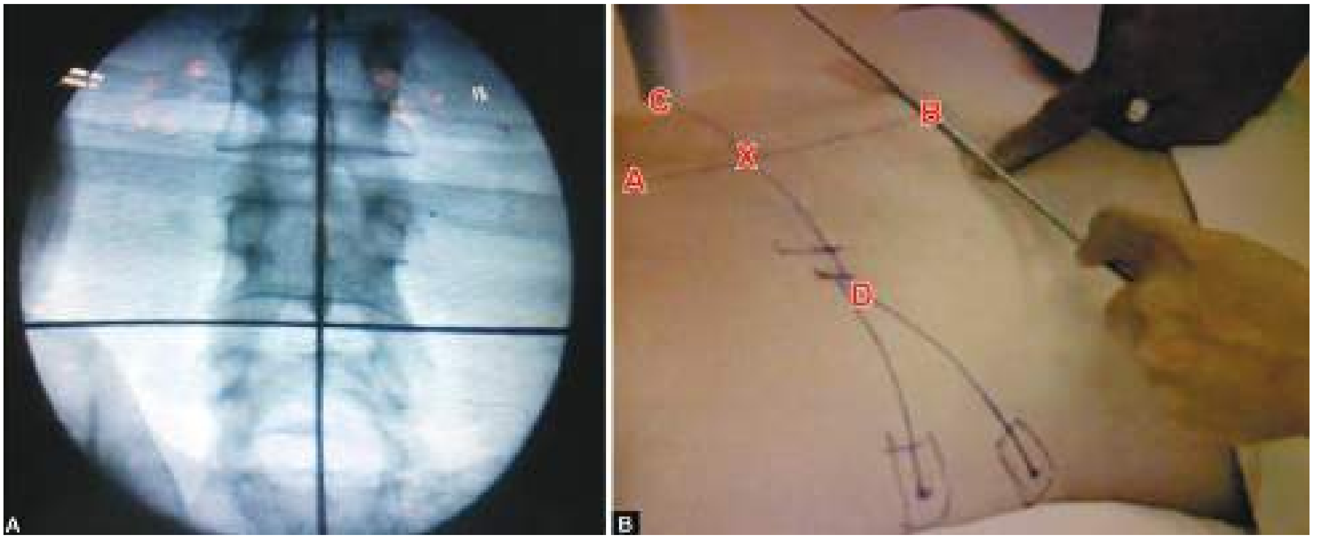
- Operation is performed under local anesthesia in the standard prone position over bolsters with a radiolucent table top.

**Fig. 24.1:** C-arm guidance for correct level is absolutely important

- ‘C’ arm guidance (Fig. 24.1) is used throughout the operation and therefore protective lead apron and thyroid cover has to be used by the theater personnel. Prone position.
- Mild sedation and analgesia
- Continuous dialog with an awaked patient is mandatory to identify and remove the offending pathology.

## Marking Entry Point (Figs 24.2A and B)

- Midline “AB” line is drawn along spinous processes with the pedicles equidistant to midline.
- In AP plane the disc space is identified with end plates parallel to the floor. A horizontal line “CD” perpendicular to AB is then drawn.
- In lateral image the center of disc space is identified and measured upto CD distance –X
- On the line CD, distance X from midline on the side of pain is marked. This is the entry point.




**Figs 24.2A and B:** Technique of marking entry point as explained in the text

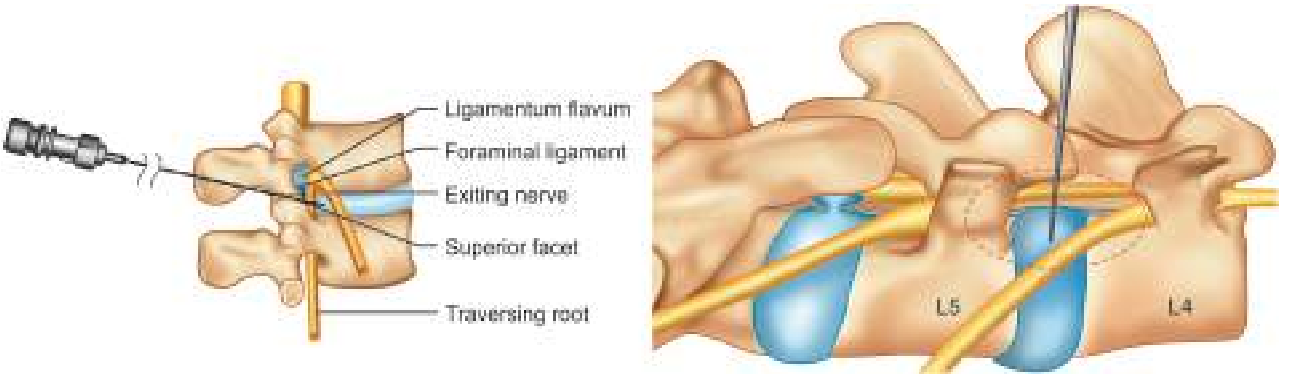



**Fig. 24.3:** Safe zone, triangle of Pervez Kambin

The entry point (Fig. 24.3) is infiltrated with local anesthesia (1% xylocaine) mixed with 1 : 2,00,000 dilution adrenaline in 50:50 proportion. With a long 18 G needle entering the entry point at 45 degrees to the surface. The needle is advanced till the posterior body line is encountered. If nerve root is encountered, one starts getting sciatic pain and the needle should be repositioned. The needle is advanced through the safe zone of Kambin's triangle[6] into the disc space. Using 3 mL of omnipaque in saline discogram is performed (Fig. 24.4) and the provocative pain confirms the level to be correct.

A guidewire is passed into the disc space through the needle which is then removed. Making a small stab incision into the skin dilators are passed over the guidewire sequentially and with twisting movements the dilator is passed into the annulus (Fig. 24.5). The annulus is infiltrated with local anesthetic.

There are different types of sheaths. For foraminal disc herniation, a duckbill type sheath is used with bevel facing dorsally.

The dilator is then removed and trephine is passes through the sheath to cut into the annulus. Using disc rongeur discectomy is performed in the posterolateral quadrant of the intervertebral disc under fluoroscopic guidance.

Endoscope 6.5 mm in width and 30 cm long with 3.5 mm working channel fitted with irrigation and suction channels is passed through the sheath and irrigation (high flow) is started with saline mixed with 1 gm chloromycetin.

The scope is tilted dorsally and nuclear material is excised from within the disc directing the scope all the time dorsally towards the dural sheath.

If there is a defect in the annulus, then it is identified and through it the impulse on coughing is observed. Once the compressing disc fragment is removed patient feels sudden relief of pain. Dural pulsations are then observed through the defect in the annulus.

The scope is then removed and steroids (40 mg methyl prednisolone) are injected through the sheath into the disc space and the sheath is removed.

Two sutures hold the skin edges apposed.

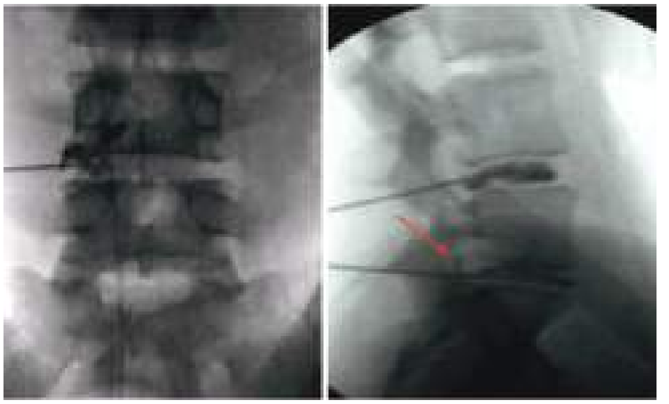


**Fig. 24.4:** Discogram with omnipaque is always performed

## Postoperative Care

Patient is mobilized after 6 hours. He is given 2 doses of antibiotics and analgesics for couple of days.

He is discharged home the same day or the next day with advice to rest at home for 3 to 6 days and resume duties after one week. He can resume sports activities within three days.

## Possible Complications

Following complications can occur in this surgical procedure:

- Disciitis — 1 to 1.5 percent
- Dural tear and CSF leak — 1 to 3 percent
- Nerve root injury — 3 to 5 percent
- Dysesthesia — 8 to 10 percent
- Psoas muscle hematoma — 1 percent
- Incomplete excision — 15 to 20 percent

In our series of 140 patients, there was one patient with mild disciitis controlled with antibiotics for 3 weeks, 2 patients with dysesthesia and one patient with incomplete disc excision. There was no patient with dural tear or nerve root injury.

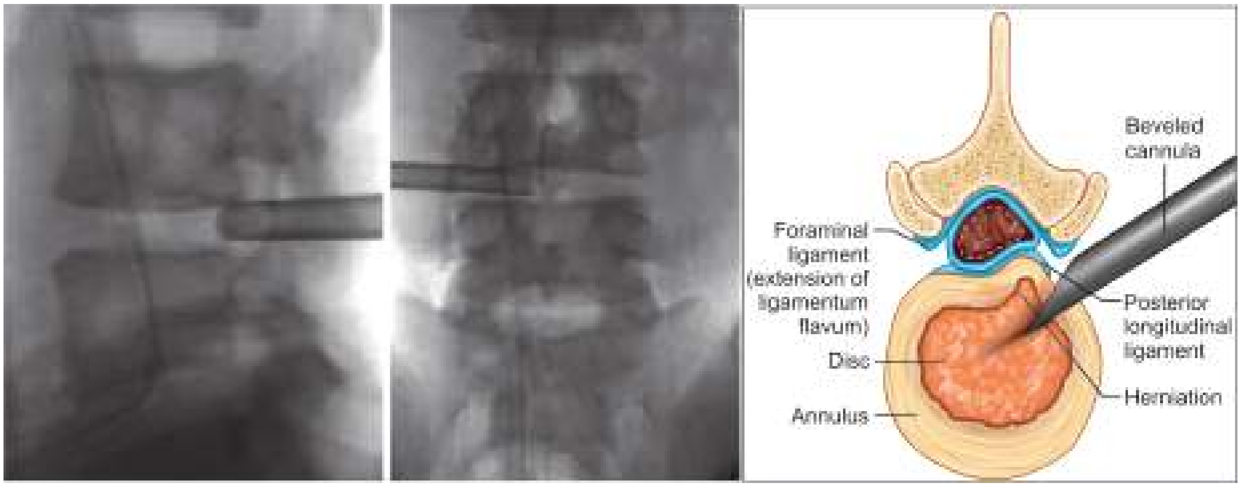



**Fig. 24.5:** The dilator is pressed into the annulus

## Conclusion

Microlumbar discectomy remains the gold standard of surgical treatment in a given case of lumbar PVD which requires surgery.

Percutaneous transforaminal endoscopic discectomy[7-9] is a therapeutic option between open surgery and conservative management. The procedure is performed under local anesthesia providing an opportunity to remove only that which is offending and confirming pain relief on operation table in addition to being minimally invasive and avoiding the access related problems of open surgery. There is no doubt that lesser disc tissue is removed, thus inviting an increased recurrence rate but this is traded off with faster recovery, no added back pain and preserved spinal biomechanics. With improvements in equipment (lasers, radiofrequency and endoscopic drills) surgical outcomes will improve and this procedure may become a standard of care.

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# Percutaneous Endoscopic Lumbar Discectomy (History, Evolution, Surgical Strategy, Outcome and Complications)

*Jin-Sung Kim, Chun-Kun Park*

## History and Evolution

As the remarkable improvements of surgical instruments and techniques in surgical field in last twenty years, this innovation gave birth to the change from conventional open surgery to minimally invasive surgery (Table 25.1). In the field of spine surgery, with recent advancements, this kind of attempt has been also done and minimally invasive spinal surgery (MISS) has gradually replaced conventional open surgery. Since Mixter and Barr first described herniation of disc material as a cause of neural compression in the lumbar spine,[1] Yasargil and Casper have introduced the discectomy procedure for the treatment of lumbar disc herniation.[2,3] There have been numerous articles in the literature in which authors have reported success rates ranging from 70 to 95 percent.[4-6] Open microdiscectomy has been a gold standard procedure for treating the refractory leg or back pain due to lumbar disc herniation and has provided satisfactory outcomes. However, postdiscectomy syndrome, epidural scarring or other deteriorations associated with surgery may develop, and revision surgery is more difficult.[7-9] Epidural scarring develops in more than 10 percent of patients after open microdiscectomy. As surgery has advanced and expectations regarding the surgical outcomes have grown, there has become increasingly greater request for MISS to treat the lumbar disc herniation (LDH). Therefore, surgical approaches using minimally invasive technique including tubular microdiscectomy and microendoscopic discectomy (MED) are becoming more widespread in spine surgeries.[10–12] The introduction of the METRx tubular retractor system (Medtronic Sofamor Danek, Memphis, TN, USA) enabled surgeons to perform muscle-splitting dissections without the traditional extensive subperiosteal stripping of the paraspinal musculature, used in open posterior approaches. However, recent literature revealed that tubular microdiscectomy is equally invasive as conventional microdiscectomy in terms of CPK and multifidus muscle atrophy.[13] Patients treated with tubular microdiscectomy reported more back pain during first year after surgery. Some authors introduced percutaneous lumbar discectomy procedure and its indication has been broadened.[14–19] This kind of percutaneous endoscopic discectomy has been considered as a real minimal invasive procedure because this preserves most of spinal posterior elements such as facet joints, back muscles and ligamentous structure under the local anesthesia. Recently, with the aid of many instruments including laser, videoequipment, endoscopic forceps, drills, etc, this technique has become widely accepted in MISS for the treatment of lumbar disc herniation. In the past decades, many kinds of MISS have been introduced to reduce the complications of conventional surgery. Here, we introduce a history of MISS from Mixter and Barr to recent outstanding surgeons who use percutaneous endoscopic instruments.[1,14–24]

## Rationale for MISS

Minimally invasive spinal surgery (MISS) encompasses surgeons' techniques and innovative specialized devices to reduce approach-related complications by sparing normal functional structures including muscle, ligaments and joints during spine surgery. It also can be performed for treatment of the various kind of spinal diseases, and offer a compelling alternative to conventional open surgeries. Wolfgang Rauschning emphasized, through his the macro- and microanatomic study of degenerative disc disease, the importance of preserving the posterior spinal structures including muscles, ligaments, and facet joints. He

**Table 25.1:** Milestones of MISS

| | | |
|---|---|---|
| 1934 | Mixter and Barr | Exploratory laminectomy for radicular pain in 19 cases of lumbar, thoracic, and cervical spine[1] |
| 1964 | Lyman Smith | Chemonucleolysis using a percutaneous injection in patients who have sciatica to hydrolyze the LDH[25] |
| 1975 | Hijikata | First nonvisualized posterolateral percutaneous nucleotomy[26] |
| 1983 | Kambin and Gellman | 72% success rate for 136 patients by a percutaneous lateral technique[14] |
| 1985 | Onik | Automated percutaneous nucleotomy[27] |
| 1988 | Kambin | The first intraoperative discoscopic view was obtained[28] |
| 1989 | Schreiber | Biportal approach with a discoscope[29] |
| 1990 | Kambin | Safe triangular working zone[30] |
| 1993 | Mayer and Brock | Biportal endoscopic technique using an angled lens scope[15] |
| 1996 | Mathews | Foraminoscopic approach[31] |
| 1998 | Ditsworth | Foraminoscopic approach[32] |
| 2001 | Knight | Endoscopic foraminoplasty technique using a side-firing holmium:yttrium-aluminum-garnet (Ho: YAG) laser[33] |
| 2002 | Maroon | Percutaneous thermal annuloplasty and nucleoplasty[34] |
| 2002 | Yeung and Tsou | Comparison study between endoscopic discectomy and conventional open surgery in 307 patients[16] |
| 2002 | Yeung and Tsou | Transforaminal endoscopic technique for intracanal noncontained lumbar disk herniations with a 91.2% clinical success rate in 219 patients[35] |
| 2003 | Yeung | A standardized method for transforaminal endoscopic surgery, the Yeung Endoscopic Spine System (YESS) was devised |
| 2004 | Ahn Y | Percutaneous endoscopic lumbar discectomy (PELD) for recurrent disc herniation[36] |
| 2005 | Ruetten | Extreme lateral full endoscopic transforaminal approach[17] |
| 2005 | Schubert and Hoogland | Foraminoplastic approach using reamer to remove a sequestrated lumbar disc[22] |
| 2006 | Lee SH | Radiologic analysis for failed cases of percutaneous endoscopic lumbar discectomy[37] |
| 2006 | Hoogland | Transforaminal posterolateral endoscopic discectomy with or without the combination of a low-dose chymopapain: a prospective randomized study in 280 consecutive cases[38] |
| 2007 | Choi G | Percutaneous endoscopic discectomy for extraforaminal lumbar disc herniations: extraforaminal targeted fragmentectomy technique[20] |
| 2007 | Ruetten | Use of newly developed instruments and endoscopes: full-endoscopic resection of lumbar disc herniations via the interlaminar and lateral transforaminal approach[21] |
| 2009 | Choi G and Kim JS | First report of transiliac percutaneous endoscopic discectomy[24] |
| 2011 | Choi KC and Kim JS | Clinical result of percutaneous endoscopic discectomy and annuloplasty[39] |

also has guided the ideal minimal approach in the lumbar spinal surgery. According to his postsurgical cadaveric specimens who had posterior lumbar surgery, there were extensive scar formations of the dorsal column muscles, even with smaller incisions. Not only were the erector trunci muscles affected, but so were the deep short oligosegmental muscles which account for proprioception and fine tuning of segmental mobility. Based on this kind of studies, technical evolution of MISS now gained popularity and it enables the achievement of favorable success rate compared with conventional open surgical procedures. However, even though MISS have gained popularity in spinal treatments, concerning about the evidence based medicine, the effectiveness of MISS is still low because most papers that have been reported do not have well-structured design in the randomization or outcome measures with a relative high-risk of bias. Therefore, highly randomized controlled trials with large sample sizes are essential to advocate the effectiveness of MISS in the future.

Because everything is simply *res ipsa loquitur* (i.e. the thing speaks for itself), we have to not only keep performing MISS but also observe the destination of MISS.

## The Inclusion and Exclusion Criteria

The inclusion criteria for patients were as follows: (1) Unilateral radicular leg pain (main symptom); (2) Clear clinical signs of nerve root irritation without significant axial back pain; (3) A minimum of 6 weeks of unsuccessful conservative treatment; and (4) Initially acute presentation with severe symptoms and a herniated lumbar disc, evidenced by magnetic resonance imaging and computed tomography (study images show central to paracentral herniated discs without significant stenosis in affected level) The exclusion criteria were as follows: (1) Calcified disc herniation; (2) Central stenosis with disc herniation with neurogenic claudication; (3) Pyogenic discitis or other infections; (4) Disc herniation associated with spondylolisthesis; (5) Cauda equine syndrome; and (6) Main symptoms of back pain.

## Surgical Techniques and Strategies

### Positioning and Anesthesia

The patient is placed in the prone position onto a radiolucent table. The surgical approach is made on the affected side. After preparation and draping, the C-arm is positioned for the anteroposterior and lateral views of the affected level. Anesthesia is limited to 1 percent local lidocaine infiltration, supplemented with light sedation. The skin entry point is determined on the shape and location of disc herniation which is seen in preoperative CT scan or the axial view of the MRI. The exact location of this point is different because all patients have different dimensions of the facet joints, and waist. The correct position of the needle tip is confirmed using C-arm images.

### The Insertion of Working Cannula

After the insertion of the needle in epidural space, the anteroposterior and lateral fluoroscopic views are obtained to confirm the proper needle position. A loss-of-resistance technique and an epidurogram are used to identify the epidural space, and the epidurogram revealed target location. After epidurogram and injection of lidocaine to relieve the pain during the procedure, the needle is more inserted into the disc space, discography is performed using a contrast mixture consisting of 6 mL of Telebrix and 1 mL of indigo carmine for the staining of the disc material. A guidewire is gently inserted through the needle channel into the posterior annulus, and a small stab incision by No.11 blade is made at the entry site of the needle. After withdrawing the needle, an obturator is introduced over the guidewire and advanced into the disc space. Mallet is usually used to push the obturator into the disc space. A beveled working cannula is introduced over the obturator with twisting manner, which is then removed, and finally spinal endoscope is inserted. Final location is confirmed using fluoroscopic views.

### Discectomy and Removal of Herniated Fragments

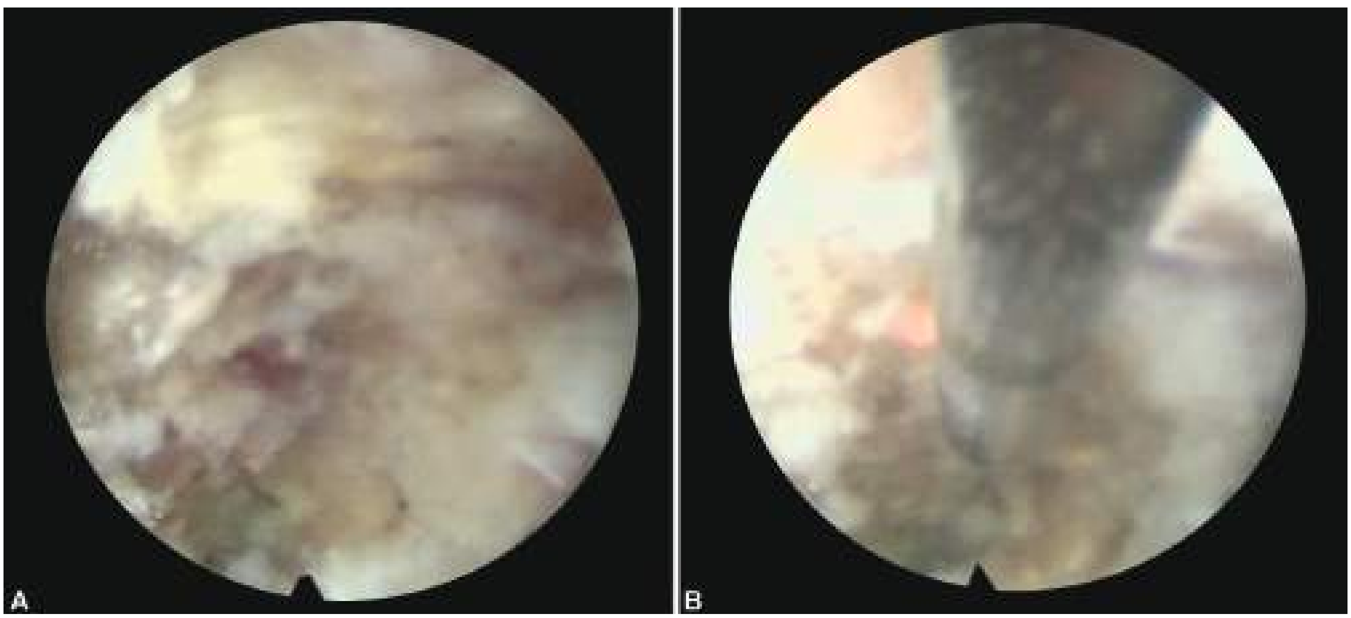
After confirming the position of the working cannula in the disc space, internal decompression of the disc was performed with pituitary forceps. Any epidural bleeding encountered is gently controlled by using a radiofrequency Elliquence probe (Fig. 25.2). Annulus release to remove transligamentous disc fragments are performed by using a Holmium yttrium-aluminum-garnet laser. After confirming the ventral dura and the traversing nerve root, the surgeon usually asks the patient whether the previous radiating leg pain subside or not. Well decompressed traversing nerve root and subsided leg pain are evident, surgeon could stop the surgical procedures and the spinal endoscope is withdrawn. Postoperative MRI is then conducted to confirm the results of procedures.

## Cutting Edge of Percutaneous Endoscopic Lumbar Discectomy (PELD)

### Foraminoplasty Technique

*Foraminoplasty using Ho:YAG Laser (Figs 25.1A and B)*

Since the foraminoscopic approach was introduced by Mathews and Ditsworth,[31,32] transforaminal endoscopic surgery for lumbar disc herniation has evolved. Foraminal ligaments, some fibrotic bands present in the foramen could be easily removed with side firing Holmium: Yttrium-Aluminum-Garnet laser. This may help easy removal of the ruptured disc fragment through the foraminal widening by Ho:YAG laser.




**Figs 25.1A and B:** Endoscopic views showing the foraminoplastic technique with Ho:YAG laser

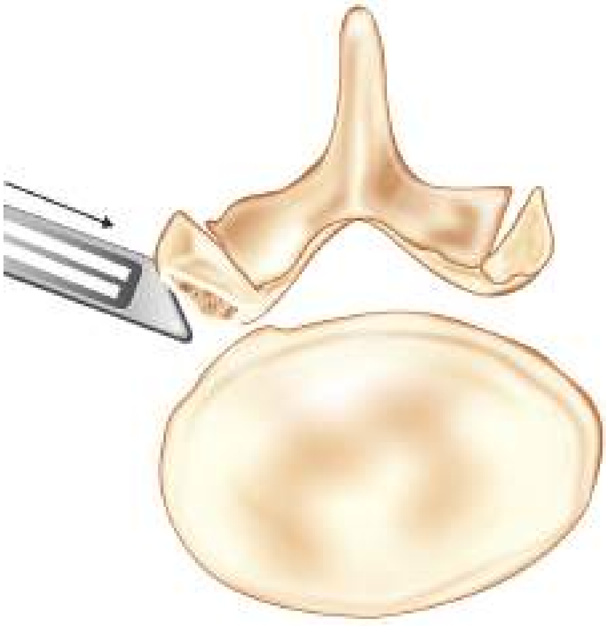


**Fig. 25.2:** After the insertion of the beveled working cannula to the superior facet under the guidance of C-arm, a 5 to 7 mm bone reamer is inserted and then bone cutting is done with a twisting and pushing motion with mallet

### *Foraminoplasty using Reamer (Fig. 25.2)*

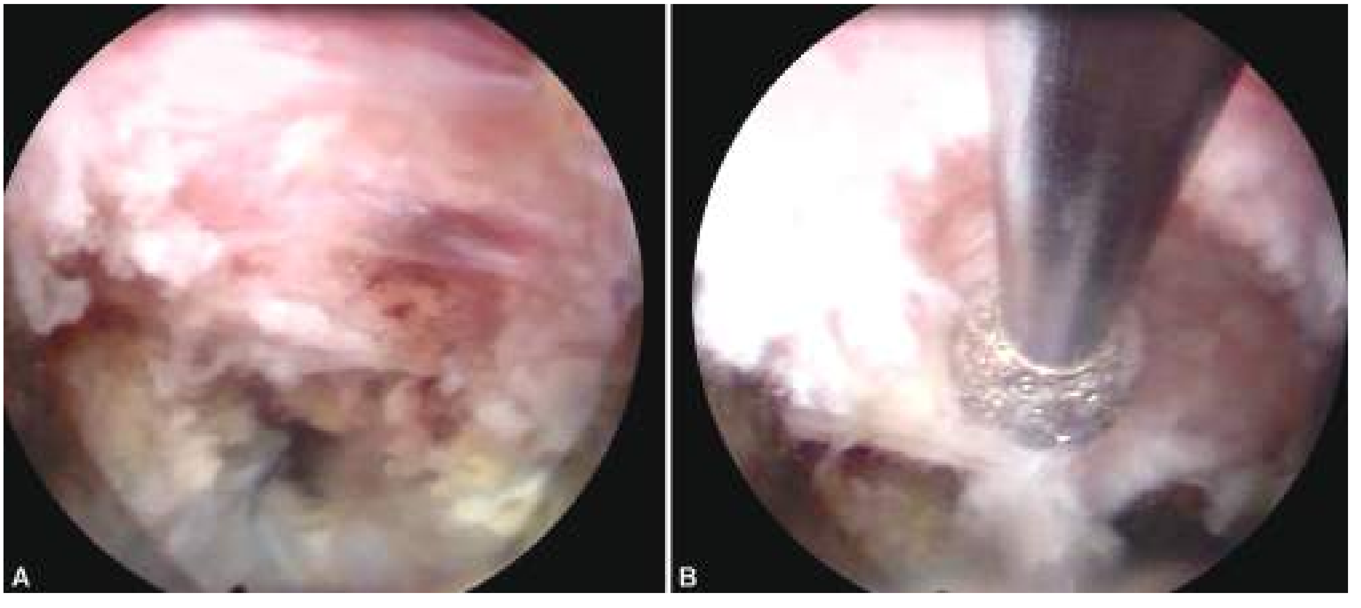
Other foraminoplastic techniques were introduced by some surgeons[40,41] and their techniques were to remove a sequestrated lumbar disc by endoscopic transforaminal approach using reamer. Transforaminal PELD is difficult at L5-S1 level with high ilium, thickened transverse process and a hypertrophied facet joint. Foraminoplasty could be one of the techniques that could overcome the anatomic limitation. The foraminoplasty could be also done using the endoscopic bone reamer. Because the tip of endoscopic bone reamer is located on the undersurface of the superior facet, the facet joint itself does not violated by bone reamer. After foramen is enlarged enough by using the foraminoplasty done with bone reamer, the working cannula could be advanced safely.

### *Foraminoplasty using Endoscopic Drill (Figs 25.3A and B)*

In some cases with hypertrophied facet joint, narrow foramen and highly down-migrated disc herniation, a partial resection of undersurface of facet or partial removal of superior part of pedicle is required to remove ruptured disc fragments. Using an endoscopic drill with a round diamond burr tip, undersurface of hypertrophied facet or upper part of pedicle is undercut, which may allow the working cannula to move in the ventral dural space.[41,42] Recently, many kinds of endoscopic drills are introduced for the effective removal of lumbar disc herniation (Figs 25.4 and 25.5).

## Transiliac Approach

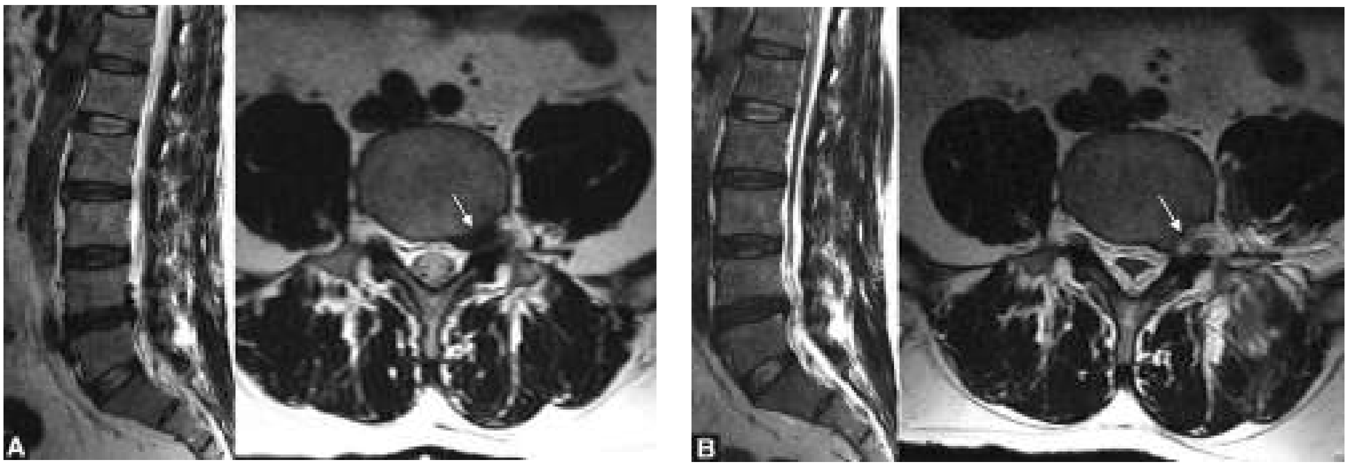
PELD via transforaminal route is difficult at L5-S1 level with high ilium, thickened transverse process and a hypertrophied facet joint. The presence of a high iliac crest may compel a surgeon to choose a more medial skin entry point, medial to the medial border of the iliac crest, which is not effective for removing a central located herniated fragment (Figs 25.6A and B). To overcome these limitations, Choi and Kim et al. introduced a PELD through the small tunnel on ilium to excise herniated fragments in other paper (Fig. 25.7).[24]




**Figs 25.3A and B:** The endoscopic drill in Vertebris System (From Richard Wolf Medical Instruments Corp, Vernon Hills, Illinois)


**Fig. 25.4:** The Joimax® Shrill® shaver blade


**Fig. 25.5:** The Joimax® Shrill® system




**Figs 25.6A and B:** (A) Preoperative T2-weighed MR images in axial view along with topogram show a upward migration of the herniated disc compressing the left L4 nerve root; (B) Postoperative T2-weighed MR images in axial plane along with topogram show that the up-migrated disc fragment has been removed

## Contralateral Approach

The highly down migration of a ruptured disc may compel a surgeon to choose a MISS, which has a more difficulties and anatomic limitation. Moreover, PELD is very difficult in downward migrated disc fragments just along the medial to pedicle because the ipsilateral pedicle blocks view of the target fragments of down-migration. To overcome the limitation, Kim et al introduced PELD via contralateral foramen.[43] This kind of contralateral approach could be considered in the following cases (Figs 25.8 and 25.9):

- Narrow ipsilateral neural foramen with tolerable contralateral neural foramen
- Low position of the exiting nerve root
- Vessels in the foramen in sagittal T2-weighted MRI
- Highly down-migrated disc herniation, especially located between the traversing nerve root and thecal sac
- Recurrent lumbar disc herniation.

**Fig. 25.7:** Postoperative three-dimensional CT scan shows the hole (black arrow) made on the ilium


**Figs 25.8A and B:** (A) Preoperative T2-weighed MR images in axial view along with topogram of the same patient show a downward migration of the herniated disc compressing the left L5 nerve root. Right, postoperative T2-weighed MR images in axial plane along with topogram show that the down-migrated disc fragment has been removed; (B) Fluoroscopic images showing the position of the tip of working cannula anchored in the subannulus in the lateral view, and the slight downward inclination of the working cannular on anterolateral view

## Technique for Recurrent Lumbar Disc Herniation

In some cases with recurrent disc herniation, there are adhesion scar not only in interlaminar space but ventral epidural space, which may hinder the surgeons to approach the interlaminar window. Transforaminal PELD could be only of the surgical option for recurrent lumbar disc herniation.[18,36] A partial resection of undersurface of facet using the endoscopic drill or bone reamer is done to remove ruptured disc fragments (Figs 25.10 and 25.11). This technique may allow the endoscope to move in the ventral target disc herniation.

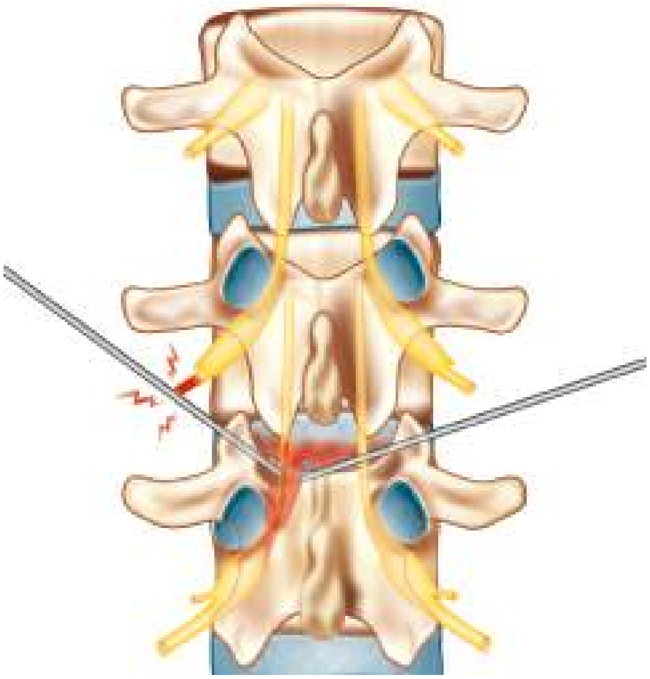


**Fig. 25.9:** Illustration demonstrating the contralateral PELD for highly down-migrated disc fragments. Ipsilateral PELD more than 30 degree may increase the risk of injury to the exiting nerve root

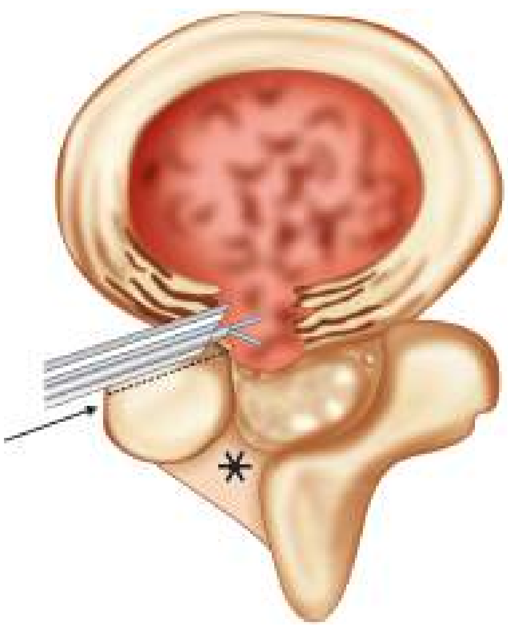
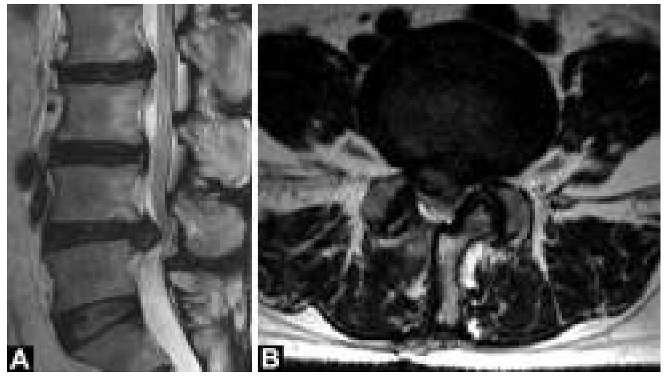


**Fig. 25.10:** The endoscopic working cannula is inserted to the herniated disc and the superior articulate process is removed by endoscopic drill, or reamer, if necessary

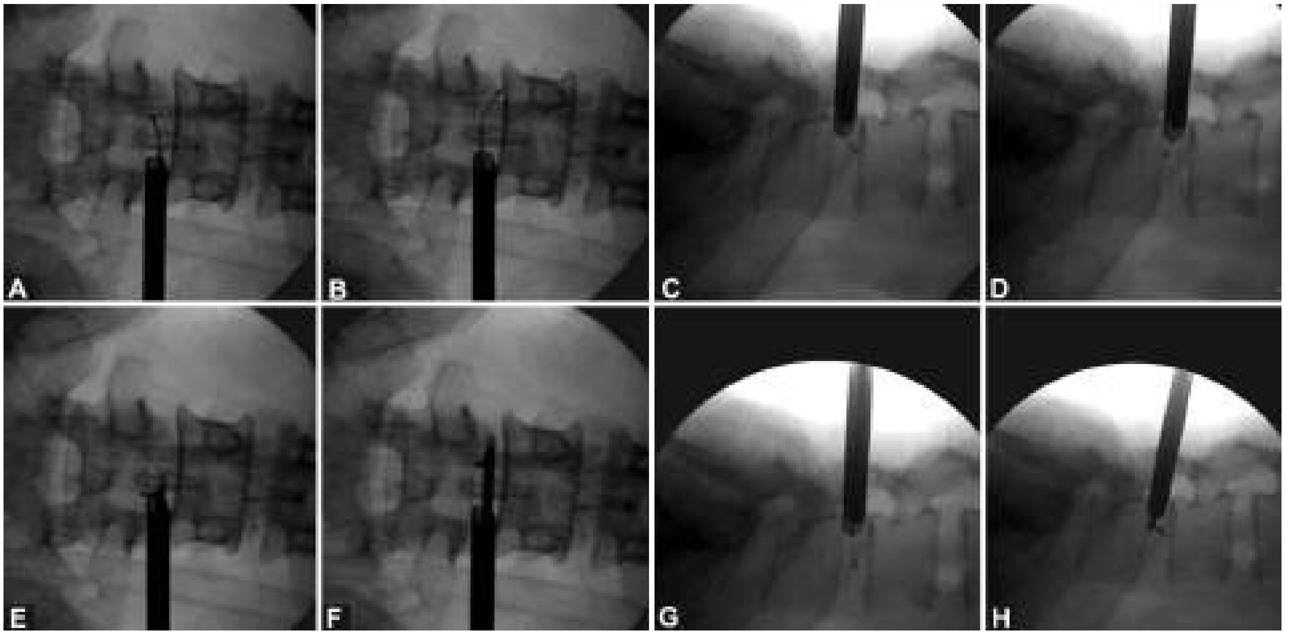


**Figs 25.11A and B:** (A) Preoperative T2-weighed sagittal MR image shows huge disc herniation; (B) Preoperative T2-weighed axial MRI image shows huge disc herniation compressing the nerve root and laminotomy wound at L4-5 level

## Hybrid Technique

Herniated disc that have a main fragments acrossing the midline to the other side of the spinal canal have many surgical risks of spinal cord injury when surgical approach is applied at above conus medullaris. Kim and Cho et al. already reported oblique paraspinal approach (OPA) and its clinical results in another paper.[44,45] However, this approach may not be not well suited for removing calcified disc herniations or osteophytes that extend into the spinal canal. Therefore, to reduce the surgical risk of neural damage, authors present our new surgical experience of treating the herniated intervertebral disc by combining PELD and OPA (Figs 25.12A to H).

Even though transforaminal PELD has been popular in lower lumbar spine, it is still restricted in upper lumbar and thoracic spine. This technique introduces the combined approach of oblique paraspinal approach (OPA) and PELD as a minimally invasive spinal surgery (MISS) for the disc herniation in upper lumbar or T-L junction. The authors present our new surgical experience of treating the herniated intervertebral disc at the upper lumbar and thoracic spine by combining PELD and OPA.
All surgical procedures are performed using the OPA, as previously described. The lateral portion of the pars interarticularis, the facet joint and superior articular process are removed using a high-speed drill and Kerrison punch under the operating microscope. Most epidural vessels in around disc surface is coagulated by bipolar coagulator, and traversing, exiting nerve root and lateral side of thecal sac are exposed. Discography is done, using a mixture of radio opaque dye (Telebrix), the indigo carmine (Carmine) and normal saline mixed in 2:1:2 ratios. By using $CO_2$ laser or blade, surgeons make an annulotomy and subsequent pulled-out disc fragment through this annulotomy site after pushing the disc space by right-angled probe. Then, obturator is gently introduced through the annulotomy site under the microscopic guidance until it is appropriately located. Final location of obturator was confirmed under the C-arm




**Figs 25.12A to H:** Fluoroscopic images showing the position of the tip of working cannula anchored in the subannulus in the anteroposterior and lateral view, and the tip of radiofrequency tip touching the upper endplate of L5 (A, D), the lower endplate of L4 (B, C), the center of nucleus (G), endoscopic forceps in the center (E), contralateral side (F), and the center of nucleus (H)

guidance. Finally, surgeon introduces an endoscope with a working channel into the round end of the cannula over the obturator under the C-arm guidance. All other procedures are performed at affected level according to a previously described percutaneous endoscopic technique.

## Postoperative Care

The patient is encouraged to ambulate immediately 4 hours after surgery. Anti-inflammatory medications, muscle relaxants, and analgesics are prescribed in the immediate postoperative period. The patient is discharged within the postoperative 1 day.

## Limitations of Percutaneous Endoscopic Lumbar Discectomy (Figs 25.13 to 25.18)

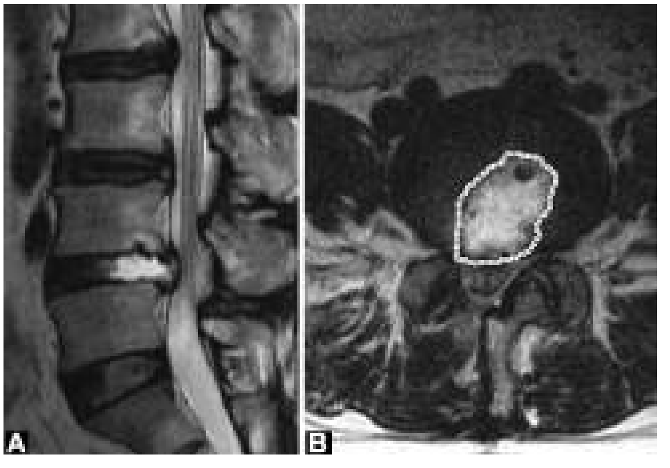
Schaffer and Kambin reported 11 patients after 100 cases of PELD.[46] According to their study, lateral recess stenosis, sequestrated disc herniations, improper position of the working cannula and psychosocial factors such as drug abuse are main causes of failure.

Another study using the "Berlin PELD technique" by Mayer,[47] however, reported low success rate compared with open surgery, so they claimed that PELD could not be alternative surgical option for traditional open lumbar discectomy.[48]

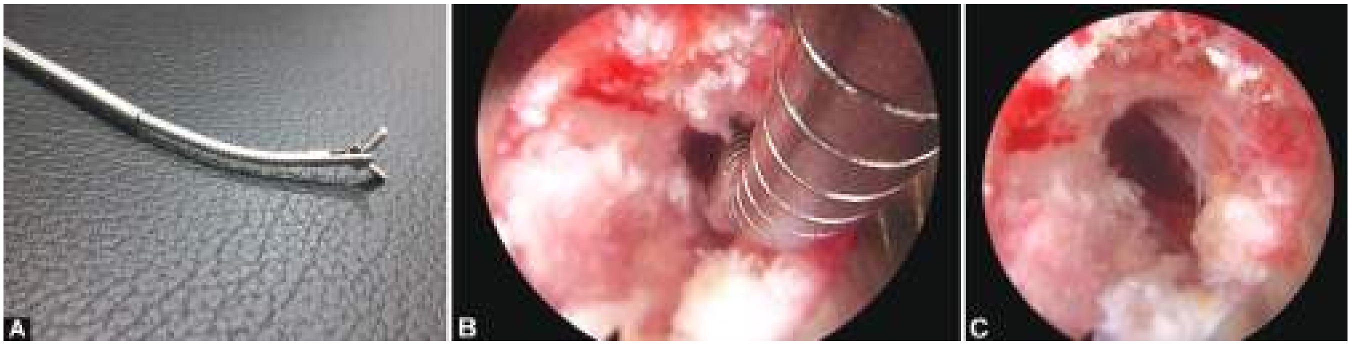
The assumed analysis of this high failure rate after PELD is the surgeons' unfamiliarity with the PELD technique, leading to an inadequate decompression. So, it is very important for surgeon to achieve enough learning curve for enough decompression. Moreover, it is also important to know about exclusion criteria for PELD, which are central stenosis, lateral recess stenosis or ipsilateral foraminal stenosis that hinder the introduction of working cannula, and joint hypertrophy.

## Complications

Although PELD has the advantages of avoiding complications related to the open discectomy (e.g. epidural adhesion, facet

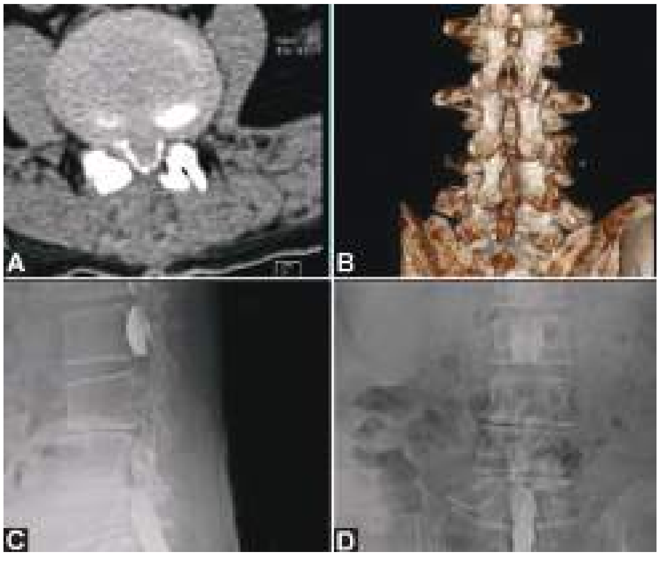



**Figs 25.13A and B:** (A) Postoperative T2-weighed sagittal MR image shows huge disc herniation removed well; (B) Postoperative T2-weighed axial MRI image shows huge disc herniation has been well removed and small boxels mark the boundary of decompression




**Figs 25.14A to C:** (A) Semiflexible grasper forceps is easily accessible to transligamentous lumbar disc herniation in central location; (B) Endoscopic view of semiflexible grasper forceps approaching to lumbar disc herniation; and (C) Endoscopic view after removal of herniated disc fragments


**Figs 25.15A to D:** Preoperative T2-weighed MR images in sagittal (A), T1-weighed enhanced sagittal (B), T2-weighed axial (C), and T1-weighed enhanced axial view (D) show a huge central disc herniation at L2-3 level



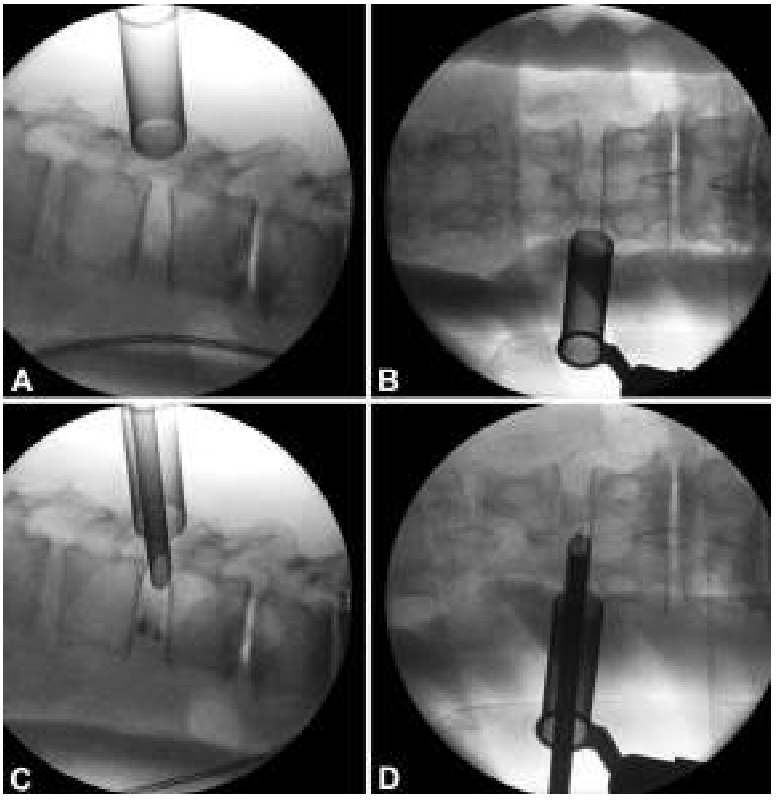

**Figs 25.16A to D:** Axial CT scan (A), three-dimensional CT (B), and myelographies (C, D) also show severe thecal sac compression

violation, back muscle damage, aggressive discectomy, and general anesthesia-related complications), it still has some drawbacks, even though there are relatively low risk procedures, including limited surgical indications,[37] stiff learning curve,[49] missed fragments, postoperative dysesthesia,[50] intraoperative injury to neural structure, etc. The usual risks of complications including nerve root injury, dural tear,[51] hematoma,[52] and discütis[53] are also present as with conventional microdiscectomy.

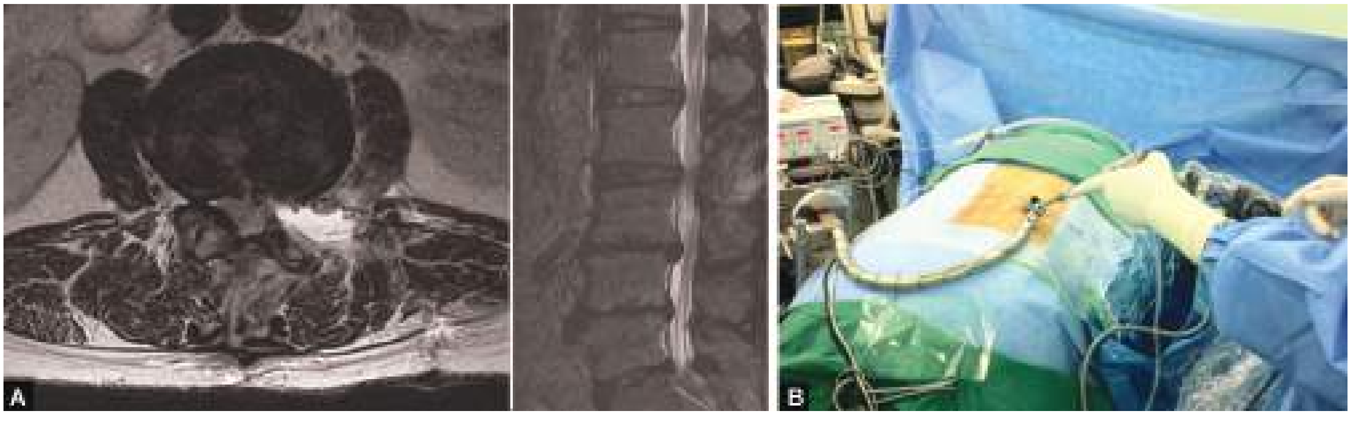
## Procedure-related Complications

- Direct injury to neural structure
  - Inappropriate needle positioning
  - Injury to exiting nerve root by obturator or working cannula
  - Mechanical injury to nerve root or ventral dura by endoscopic forceps or laser
- Direct injury to vascular structures
- Direct injury to peritoneal sac
- Thermal injury to nerve root
  - Postoperative dysesthesia and allodynia
- Psoas hematoma
- Iatrogenic cystic formation
- Postoperative infection
- Remnant disc fragments
- Recurrent disc herniation.

The exiting nerve root at the affected level is most common neural structure that is injured by the 18G needle, obturator and working cannula. To avoid the exiting nerve root injury, needle approach to the target point should be done gradually and step by




**Figs 25.17A to D:** Fluoroscopic images (A, B, C and D) showing the positions of the tubular retractor and the tip of working cannula anchored in the subannulus




**Figs 25.18A and B:** Postoperative T2-weighed MR images in axial (A) shows a well-decompressed thecal sac and postoperative change on L2-3 extraforaminal area; (B) Photograph showing the operation field including the patient, tubular retractor and spinal endoscope

step under the C-arm guidance and surgeon have to know about the intervertebral foraminal structure and Kambin triangle. For beginners, it is recommended that the 18G needle should touch the facet first, and it is slightly withdrawn and glides under the facet into the foramen.

Although cerebrospinal fluid leakage and nerve root injury could develop during the procedures, the risk is very low.

To prevent this complication, surgeons must exercise great caution while performing the surgical procedures. If the main pathologies are located at ventral areas, such as with calcified disc herniation and bony spurs, open discectomy and fusion may be preferable.

Spine surgeons have to try their all best to decrease the rate of complication, although there are inevitable in some cases.

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# 26

# Minimally Invasive Surgical Management of Lumbar Disc Herniation by Anterior Epidural Endoscopy: Epiduroscopy

*Marcos Masini, Aldo Calaça*

## Introduction

Chronic low back pain (CLP) is a very common symptom and an important marker of a clinical and social problem that affects practically every human being at some time or the other.[1,2] Approximately 70 percent of adults will suffer from back pain in varying. About 1.6 to 43 percent of these patients will have associated sciatica.[3] In around 5 to 15 percent of cases, the origin of low back pain is generally related to facet joint degeneration and disc disease.[4]

As ten percent of the patients suffering from low back pain will have no improvement after 6 to 8 weeks of conservative treatment,[5] several options have been included in the treatment of the patient's pain. In some cases, the clinical picture, the image diagnosis, the patient's decision and treating physician's experience will define the next treatment of choice. It is not an easy decision. Clinical and imaging picture can be puzzling. Sometimes there is no clear explanation for patient's symptoms or are rather contradictory mainly in elder patients and patients that had submitted themselves to a previous surgical procedure in the spine.[6]

Anterior epidural endoscopy is an option among minimal invasive modalities in the management of the lumbar pain and disc herniation. It can be used both for diagnosis and treatment and was included in the armamentarium in 1966 by Saberski and Kitahata.[7,8] This technique allows you to navigate, diagnose and treat the exact place of lesion without any morbidity.

The treating physician accepts the concept of presence of inflammatory mediators in the genesis of the low back and radicular pain[9-11] and several options considered by him include anesthetics, corticosteroids, clonidine, and $O_2/O_3$ mixture.[12,13] The purpose of this chapter is to evaluate retrospectively the effectiveness of the treatment of CBP targeted by anterior epidural endoscopy.

## Material and Methods

This retrospective study evaluated the results of the procedures performed in 75 consecutive patients with lumbar disc herniation with magnetic resonance imaging (MRI) or computed tomography (CT) and EMG/NC studies of lower extremities. The patients included were those who failed to show significant response to at least 6 weeks or longer from treatments that included anti-inflammatory and analgesic drugs and physiotherapy. The procedure was performed during a 6-year period from 2006 to 2011. Patients with facet joint pain or sacroiliac joint pain as major causative factors of disability were excluded. Data of age, gender, time of onset, cause, duration of pain, history of previous surgical interventions was collected. All patients had image study with plain X-rays in anteroposterior and lateral/oblique positions, Magnetic resonance and/or computerized tomography (or both) of the lumbar spine. Pain in pre- and post-procedure evaluation was measured using a visual analogical scale (VAS) and the patients graded in percentage improvement immediately, at 1, 3, 6, 12 and 24 months postprocedure so that all the patients had the minimum follow-up of 2 years. The work ability was evaluated using Oswestry Disability Scale before and after 3 months of the procedure. The microsoft excel statistical pack was used to analyze the data. The charts of all patients were reviewed by a third person who was not evolved in their treatment.

Fig. 26.1: The steering video guided catheter is introduced through the sacral hiatus using the spinal endoscopy access kit

## Procedure Technique

The procedure was performed under light sedation by an anesthesiologist and in a conventional surgical theater with monitoring systems. The procedure was carried out under sterile conditions The patients were positioned in prone and the lumbosacral area prepared and draped as a sterile field. The epidural space was entered through the sacral hiatus using a spinal endoscopy access kit (Myelotec) (Fig. 26.1). A Touhy 18-gauge 90-mm needle is inserted after local anesthesia with 5 cc of Lidocaine 2 percent without vasoconstrictors. A 0.9 mm wire was inserted through the needle and advanced with fluoroscopic control to L5/S1 level. The needle was taken out and followed by a 3-mm incision around the wire with the advancement of a 3.8-mm × 17.8-cm dilator over the guide wire. The internal part of the dilatators was then taken out and the two working channels video guided catheter with 3.0-mm × 30 cm (Myelotec) was introduced with video endoscopic (0.8-mm fiberoptic spinal endoscopy) (Fig. 26.2) and fluoroscopic guidance to the level of suspected pathology (Fig. 26.3). The catheter and fiberoptics were manipulated and rotated in multiple directions with visualization of the nerve roots at various levels (Figs 26.4A to C). The widening of the epidural space was carried out by slow injection of normal saline (maximum of 120 mL) (hydrodissection) and manipulation of the catheter under the endoscope and fluoroscopic visualization (mechanical dissection). We avoided the injection of contrast materials for correct positioning the catheter. Upon confirmation, the procedure was accomplished with the application of Clonidine (0.5 micrograms/kg); Marcaine 0.5 percent 4 mL; Solumedrol (steroid) 2 mL (80 mg); Fentanila 0.5 mL (25 micrograms per mL). Ozone ($O_2/O_3$ mixture) 10 mL with a concentration of 10 micrograms per mL which is injected at the end. The catheter was taken out and an absorbable suture applied to the wound.

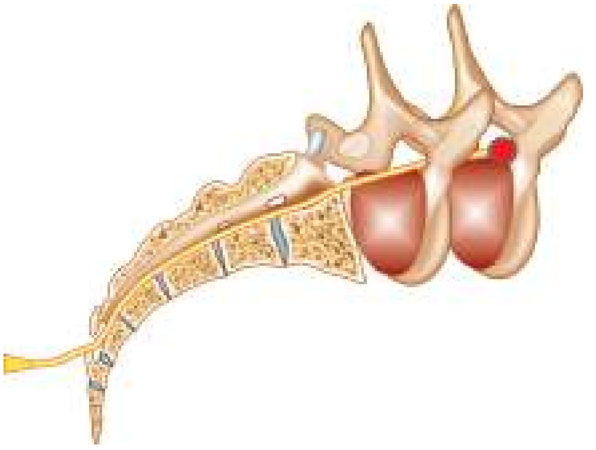


Fig. 26.2: Illustration of the trajectory of the steering video guided catheter anteriorly to the dural sac

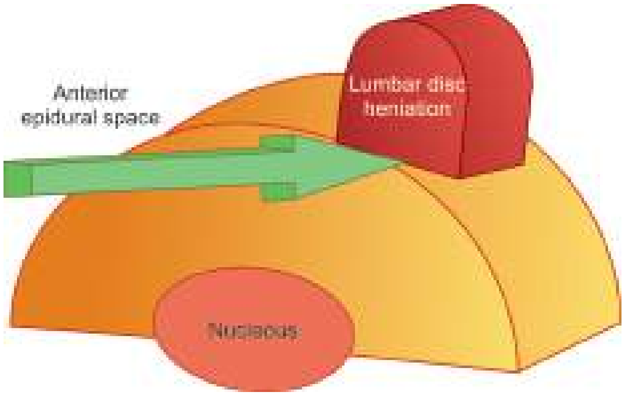
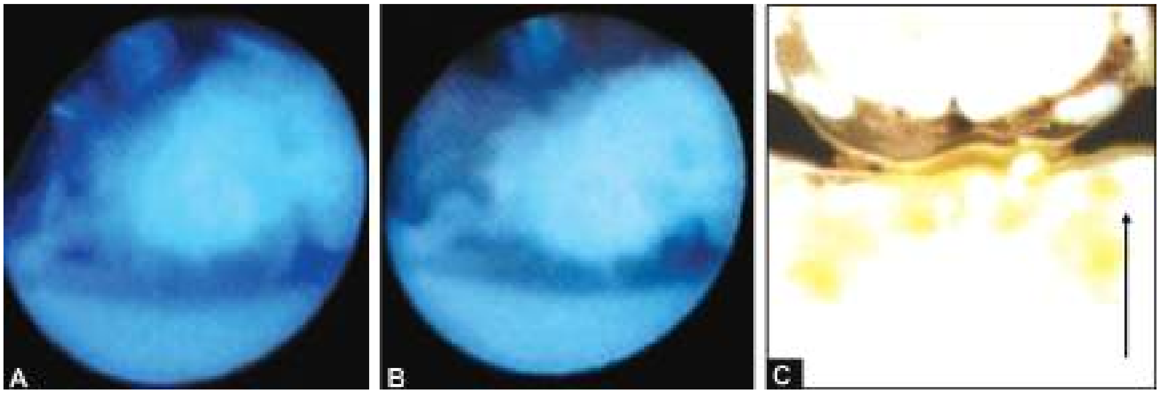



Fig. 26.3: With the steering guided catheter in the anterior epidural space one can access the disc herniation

The patients were evaluated by the physiotherapist and discharged at the end of the same day. They were given anti-inflammatory/analgesics for 10 days, antidepressant drugs for 2 months or as long as necessary and submitted to hydrotherapy from 10 to 20 sessions.

## Results

The 74 patients with 75 procedures (one was repeated due to technical difficulties) which included 44 females and 30 males with maximum patients in the third, fourth and fifth decades of life (Figs 26.5 and 26.6). All these patients failed to show any significant response to at least 6 weeks or longer from treatments that included anti-inflammatory and analgesic drugs, physiotherapy and posterior epidural steroids and/or facet joint injections. Clinically the patients had untreatable low back pain and sciatica without progressive neurological signs and with no indication for open surgical procedure. Plain X-rays, magnetic resonance and/or computerized tomography of the spine demonstrated that 46 (61%) patients had previous surgical




**Figs 26.4A to C:** (A and B) Corresponds to extruded lumbar disc identified by an anterior epidural endoscopy. (C) There a small disc herniation is identified in an anatomical section at the cervical spine. It is a finding without any clinical symptom very similar to those found in lumbar region

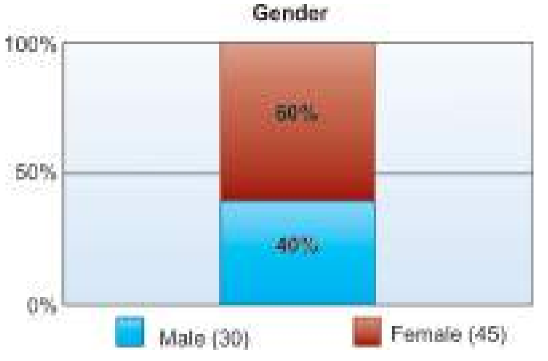



**Fig. 26.5:** Gender


**Fig. 26.6:** Age in decades

procedure with instrumentation of the spine. In these cases, the posterior approach to the epidural space was practically impossible due to the scar and instrumentation. The anterior epidural approach was a feasible solution.

Patients were evaluated by VAS scale pre and immediately postprocedure showed a mean improvement of 84 percent of their previous pain status. Follow-up evaluation at one, three, six, twelve and twenty-four months showed persistent improvement at mean of 68 percent. Figure 26.7 shows a fall of 15 percent between the moment of the procedure and after one month evaluation which is regained during the next 3 and 6 months. Patients that have improvement detected in the first month will not lose it during the next few months allowing a wide window to complete the treatment utilizing other modalities options. Data also suggest a better improvement in females than in males probably related to the life style. During the follow-up of 6 years, 3 patients (4.1%) had a surgical procedure with the intention to reduce pain. Most of the cases with persistent pain were diagnosed as having a neuropathic pain.

The Oswestry disability index applied after 3 months showed improvement of the status pre- and postprocedure with XX (70%) of the patients with better work capacity (Fig. 26.8). This index follows the pain reduction analysis. All patients were classified as group 5 initially due to the excruciating pain, meaning that they were unable to work or assume responsibilities. After 3 months analysis, 70 percent were classified as group 1 showing good capacity to work. The lower index was 3 which means patients are still in rehabilitation program with expectation of improvement. Worthy to mention that in other treatments the time between the procedure and the recovery takes longer than 3 months. No serious complications were related to the procedure. There were no adverse effect of drugs and there was no infection. No motor deficit or sphincter disturbance.

## Discussion

Saberski[7] in 1995 mentioned that epidural endoscopy is not limited to injections but also it can be used as an instrument to diagnose many conditions such as hematomas, abscess, tumors, inflammations and adhesions. It can help in the treatment to drain cists, to make biopsies and remove scars. It is known that adhesions develop after extrusion of nucleus pulposus causing a chronic chemical radiculitis[9,14] which explains the persistence of pain in many patients. The mechanical movements of the disc associated to a fissure of the annulus releases proteoglycans, which causes an autoimmune reaction next to the root maintaining the inflammatory process. The inflammatory reaction

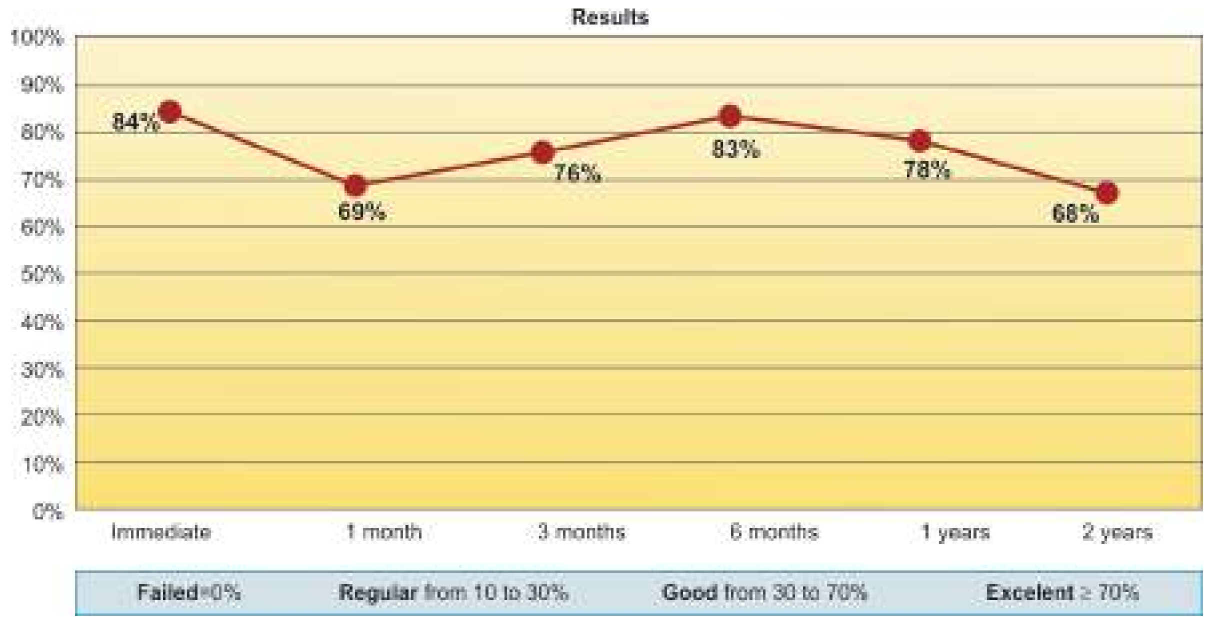



**Fig. 26.7:** Results—evaluation of the patients along 2 years

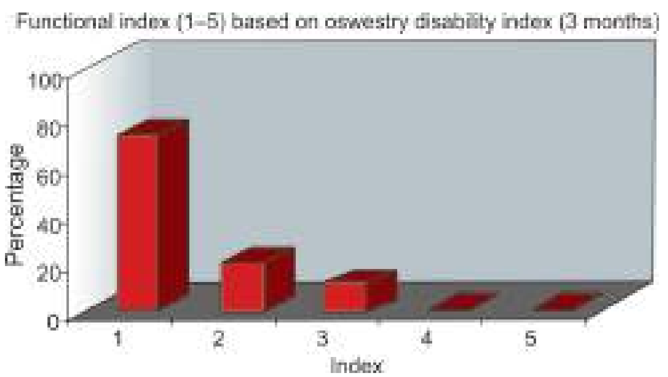



**Fig. 26.8:** Graph showing the improvement in Oswestry disability index after 3 months of the treatment. All patients were out of work before the treatment

is evoked consecutively through histamine, bradykinins or prostaglandins which sensitize the nerve root and the ganglion stimulating the biochemical pain.[15,16] Distortions caused by the disc fragment or the scar process do not allow adequate blood supply to the root and the ganglion stimulating biomechanical pain. Drugs given orally or by venous injection will not reach the place to stop or reverse the inflammatory process. Catabolites will not easily leave the region due to scar isolation and impaired vascular drainage. Kayama[17] suggested that the intraneural vascular compromise is probably the cause of nerve conduction distortion and pain generation which can be alleviated by reducing radicular edema and the local inflammatory process.

Sakai et al.[13] showed that after contrast injection in the epidural space in patients with previous surgical procedure that all of them presented some kind of a block in the diffusion around the roots which did not happen in places not submitted to procedure. They also confirmed that patients submitted to epidural endoscopy, application of steroids and anesthetics had reduction in their pain and dysfunction of fibers Aβ and Aδ associated to chronic sciatica.

Geurts[18] described their experience using clonidine with analgesic and antineuropathic properties at the dorsal ganglion and antinociceptive property at the posterior horn of the spinal cord. They describe a good clinical response with the use of clonidine associated to hyaluronidase in epidural endoscopy for incapacitating low back and sciatica pain. They confirmed that among 20 patients with normal magnetic resonance 8 patients had some epidural scars and adhesions due to very tiny discs rupture that are not clearly visible on CT or MRI. The intradiscal effect of ozone is based on its direct effect on proteoglycans under the release of water molecules, which is followed by cell degeneration and shrinkage of tissue. The activation of fibroblasts causes additional scarring and a subsequent reduction in the herniated disc tissue under strain. Around the root ganglion space, ozone improves the tissue oxygenation and through the immunomodulating effect, reduces the release and activation of cytokines, bradykinins and prostaglandins and other pain stimulators.[2,3,20] After localizing the pain source, epiduroscopy allows direct injection in the targeted place, mainly in the cases where the imaging test is not evident. The 3D capability of the myeloscope allows improved targeting. Some inflammatory mediators of pain are theorized to be "washed away" or diluted within the saline perfusion.[7,8,13]

Manchikanti et al.[19] used steroids and anesthetics through epidural endoscopy with 50 percent of initial pain reduction but no significant lasting result after 6 months. The association with ozone injection is probably the explanation for our long lasting results after 2 years follow-up.

Oder et al.[12] studied the nucleolysis with ozone combination with steroids and analgesics in 620 patients with lumbar pain. They also confirm the sustainable results with significant pain relieve mainly in patients with bulging discs. Muto et al.[20] in 2008 reported their experience with 2,900 cases of patients treated by discolysis with $O_2/O_3$ intradiscal, periganglionic and periradicular injection. They relate an initial success of 80 percent for substantial pain relief in disc protrusions and no major complications related to this method. We too have concurred with this decision.[21,22]

Igarashi et al.[23] relates the effect of epidural endoscopy and injection in the treatment of 58 patients with lumbar stenosis relating the improvement of the patients to sympathetic block and better blood supply in the compressed roots. Heavner et al.[24] relates two cases of intravenous injections of contrast during epidural endoscopic procedures and relates to vein lesions and absence of wall collapse associate to fibrotic adhesions. Gill et al.[25] in 2005, reviewed 12 cases of retinal venous hemorrhagic complication associated to epidural endoscopic injection and concluded that it could be associated to the speed of volume injection. He stated that the injection speed should not exceed 1 mL per second.

Buric[26] reports that after intra discal injection, ozone can accelerate the degradation of proteoglicans in the herniated degenerated nucleus pulpous leading to resorption and dehydration with the consequent reduction of herniated material responsible for nerve root compression.[27] The natural history of the evolution of an herniated disc points in the same direction in clinical treated patients with a progressive reduction of its volume shown by image follow up with the reduction of the bumping mechanism with associated to internal fibrosis of the disc and consequent reduction of the root compression. After 10 or more years, the clinical history is similar for those operated and those clinically treated for their lumbar disc herniation. The report of Alexandre[28] points out that the progressive physiological reduction that occurs to the disc material is speed up by ozone therapy.

## Conclusion

We see large amounts of small disc ruptures not identified in image examinations. The scar caused by chemical lesion will limit the washing out mechanism of the pain stimulating factors.[29,30] Anterior epiduroscopic approach localizes and releases the scars accelerate the chemical washing out mechanism. Highly recommended for treating lumbar disc recurrence.

With the development and association of the mechanical and washing dissector allowed by the steering guide needle associated with laser, radio frequency and or other kinds of chemical substances, among them the ozone will increase the power of this technique.[31,32] Targeted epidural anterior endoscopy associated with injection of ozone and steroids is a safe and efficient minimal invasive procedure.

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# 27

# Lumbar Microendoscopic Discectomy

*Mehmet Zileli, Vehbi Gülmen*

## Introduction

Microendoscopic discectomy (MED) system was first introduced in 1997 by Foley and Smith.[1] METRx system is the next generation of MED system. It allowes surgeon to perform discectomy in a minimally invasive fashion.[1,2] It also offers some advantages over other minimally invasive techniques.[3] Thanks to this system, nevre roots are exposed directly, even far sequestred disc fragments may be decompressed effectively, while minimally affecting the surrounding tissues. Interlaminer space is approached by splitting paravertebral muscles with a small incision, approximately 1.5 to 2 cm long. By using tubular retractor system, contained lumbar disc herniations even sequestered disc fragments can be removed unlike other percutaneous approaches. The root that is compressed by lateral recess stenosis can also be decompressed by this system. A lateral approach may also be used so far lateral disc herniations can be removed effectively. A prospective clinical study has shown that treatment of lumbar disc herniation is effective by using microendoscopic technique.[4]

## Indications

Lumbar disc herniation with or without sequestration is the most common indication of endoscopic discectomy. If the pain from one nevre root compression by disc herniation is not relieved by conservative treatment, endoscopic discectomy can be considered. Absolute indication for lumbar disc herniation is progressive muscle weakness. The common indication of discectomy is to obtain quick relief of pain and disability.[5] Endoscopic discectomy provides both rapid recovery and returning routine life as soon as possible. One level lumbar stenosis and lateral recess stenosis can be decompressed by the surgeon who is experienced in microendoscopic discectomy.[6] High speed drill must be available to challange for hypertrophied facet joints. MED system can also be used for foraminal or extraforaminal sequestration.[5] We preferred to set the tubular retraction system lateral to the spinal channel between transverse prosesses. Isthmic part of lamina must be shaved to expose the foraminal sequestrations. The lateral and upper part of facet joint which is caudal from sequestration must be removed for exposing the extraforaminal disc herniations. MED system can be used for central, mediolateral, foraminal and extraforaminal disc herniations from L2-3 level to the L5-S1 level. MED system has also been used for posterior cervical foraminotomy, discectomy and thoracic discectomy and also for recurrent lumbar disc herniations.[6-8]

## Contraindications

Contraindications are similar to standard discectomy. Coagulation disorders, using antiaggregant and anticoagulant drugs are main contraindications.

Lumbar spinal stenosis is relatively contraindicated. Transverse and anteroposterior length of the spinal canal must be measured preoperatively. Diameter of spinal canel lower than 15 mm is considered a contraindication for using tubular retraction system.

## Surgical Procedures

### Surgical Equipment

Surgical equipment can be classified according to their functions (Figs 27.1A to F):

- Visualization and illumination equipment
- Tissue retraction equipment
- Laminotomy and discectomy equipment

Visualization is obtained by endoscopic assembly of METRx system. Camera head and light cable is connected to endoscope via clockwise rotation. Camera head is connected to the video recorder and monitor. Light cable is connected to the cold light source. After connection is completed, white balance must be performed. For white-balancing, a white object is placed 1 cm apart from the lens of endoscope while pressing white balance button on video recorder. Now endoscopic system is ready to visualization.

Tissue retraction equipment include Kirshner wire, 5 muscle splitting tubes, one working tube and one flexible arm which can be fixed to the operating table. Diameters of the splitting tubes increases to the diameter of the working tube. Working tube has two accessory processes. One process is for connection to the flexible arm, the other one is for attachment of endoscopic system. If operating microscope is preferred for visualization, second process is not necessay. Flexible arm can be fixed by turning the circle clockwise for tube to be positioned. Circle is turned counter clockwise to release the arm and then positioning of the working tube. Endoscopic system is placed into the tube via a plastic ring tightened by an arm. This plastic ring has an aspiration part to remove the blood from operation field. Aspiration port can be used as an irrigation port to clean endoscopic eye.

Surgical instruments are similar to standard discectomy. Instruments used in MED are longer, thinner, bayonet design and nonreflecting dark. However, surgeon has lost the skill of 3-D visualization while performing discectomy by MED system. That is why the disc remover has numbers which show the depth of disc remover tip. This is very important nuance to avoid injuring paravertebral tissues. Kerrison punch must have a 3 mm footplate. Both Kerrison punches oblique and straight must be available on the operation table. High speed drill is helpful for medial facetectomy. Drill handle must be angled and must be the longest choice.

### Operating Room Set-up

Operating room is arranged for surgeon to view both video monitor and fluoroscopy monitor. Surgeon stands on the same side of disc herniation. C-arm of fluoroscopy is placed under operation table. This allows fluoroscopic visualization in whole operation. C-arm is placed not to discomfort the surgeon.

Anesthesia is placed at the head side of the patient.

### Patient Positioning

Operation can be performed under general or spinal anesthesia. Patient is positioned in prone with lumbar flexion. Silicon rolls or frames are advised to put on the anterior crista iliaca. Rolls must not compress both left and right femoral arteries. Silicon-made rolls help to prevent meralgia paresthetica. Care must be taken not to compress the abdomen by rolls to prevent epidural bleeding which can make the operation discomfortable.

### Surgical Technique (Figs 27.1G to S)

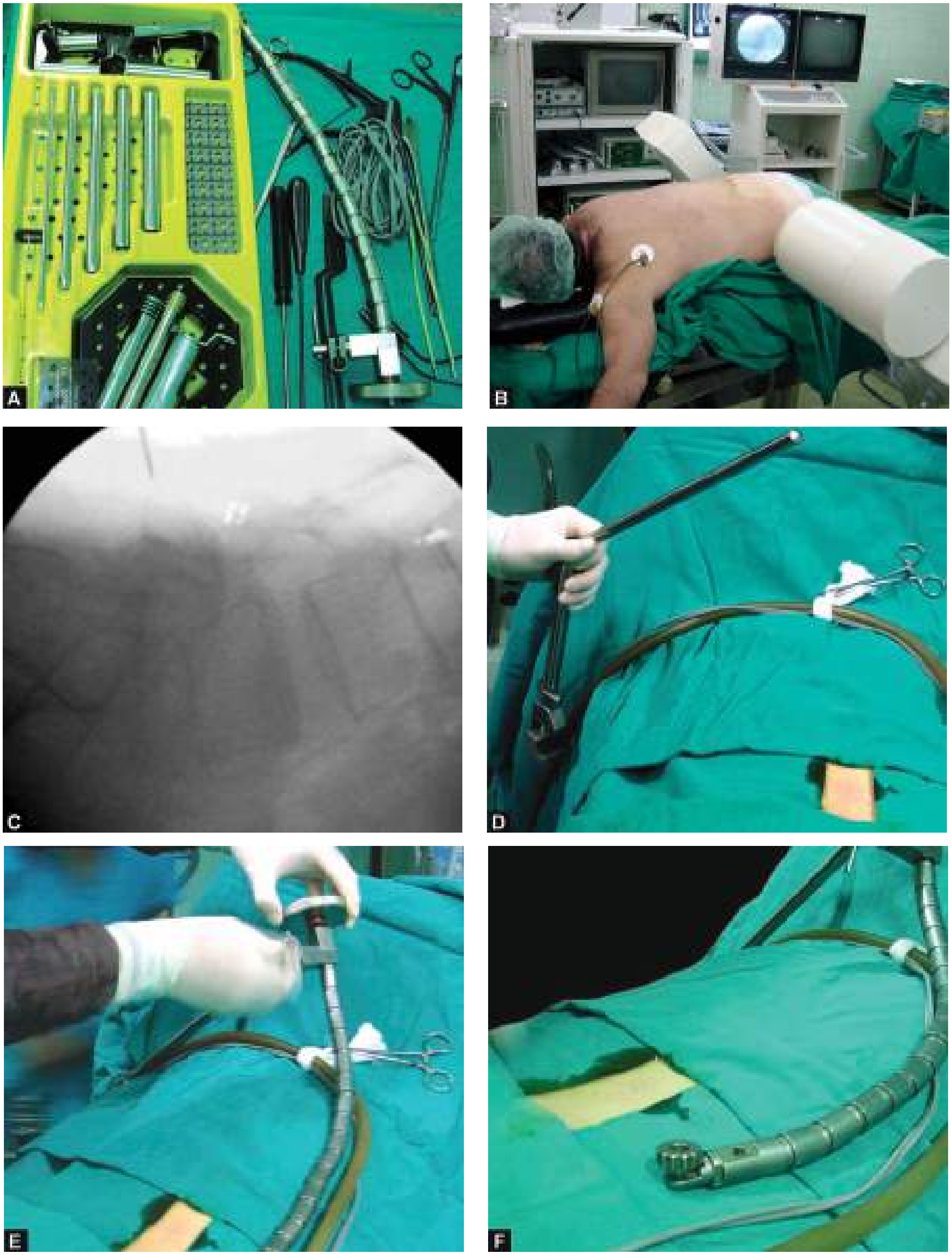
After surgical field is prepared by antisepsis rules, it is dried and draped. A 20-gauge needle is inserted into aimed level, just 1.5 cm lateral to the midline. The level is confirmed by fluoroscopic imaging. If the level is correct, then a K-wire is inserted after the needle is removed. K-wire must be aimed to the intervertebral disc space. Care must be taken not to enter the K-wire into the interlaminer space and then penetrate the spinal canal. Skin is incised 1.6 cm for 1.6 m working tube. Fascia can then be incised. Fascial incision makes it easy for dilator tubes to insert into the paravertebral muscles. Initial tube is inserted over the K-wire. Surgeon feels the bone tissue through the muscles. Sequential insertion of dilator tubes splits muscles. Tip of dilator tubes dissect muscle which cover the lamina by medial to lateral, rostral to caudal movements. Finally, working tube is inserted over the dilator tubes. After confirming the level by fluoroscopy, working tube is connected to flexible arm which is fixed to operating table. When appopriate position is obtained, flexible arm is tightened.

Endoscope which was connected to the light source and camera cable before, is secured to the working tube with a plastic ring. Arm of plastic ring is tightened for endoscope not to turn. Now it is ready to watch the operation from the monitor.

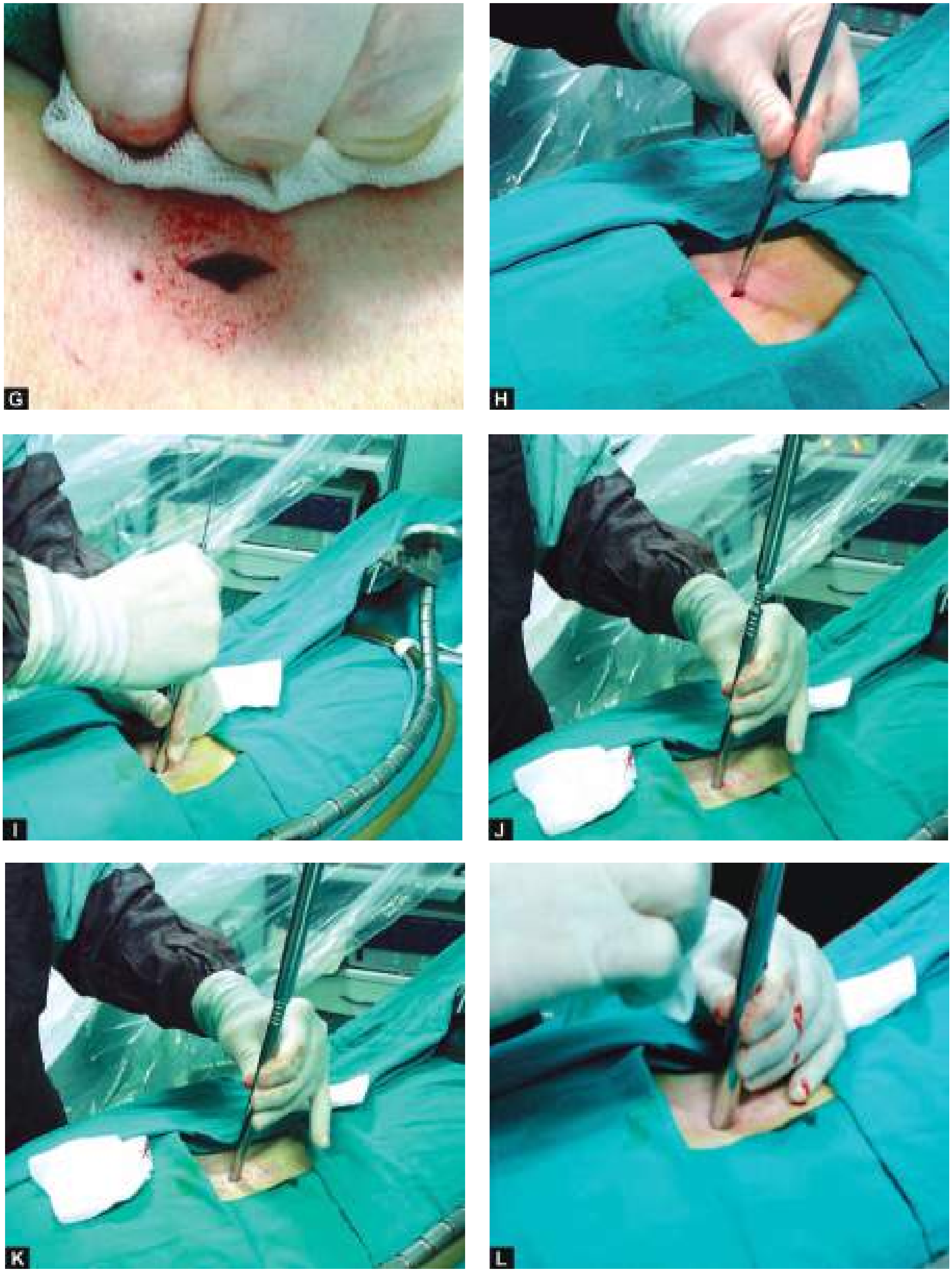
Endoscopic view is focused by turning black ring on the MED endoscope. Yellow ring on the endoscope turns the image on video monitor. It is advised to arrange the view as in the standard discectomy. Lateral side is positioned in 6 o'clock, medial side is positioned in 12 o'clock on the monitor. A 'V' shaped recess is observed in the monitor. This recess shows the position of the endoscopic eye within the working channel. Orientation is confirmed with a curette. The curette must be observed in 12 o'clock position when it is directed to the midline. If it is correct, discectomy can be performed like as standard discectomy.

Muscles overlaying lamina, facet and interlaminar space must be removed. Bipolar cautery and scissors are used for this purpose. First, muscles are cauterized by bipolar, then dissected by scissors in Kerrison shape which is available in METRx endoscopic set. Using this method reduces bleeding. Lamina, facet and ligamentum flavum are exposed to maximize the visualization.

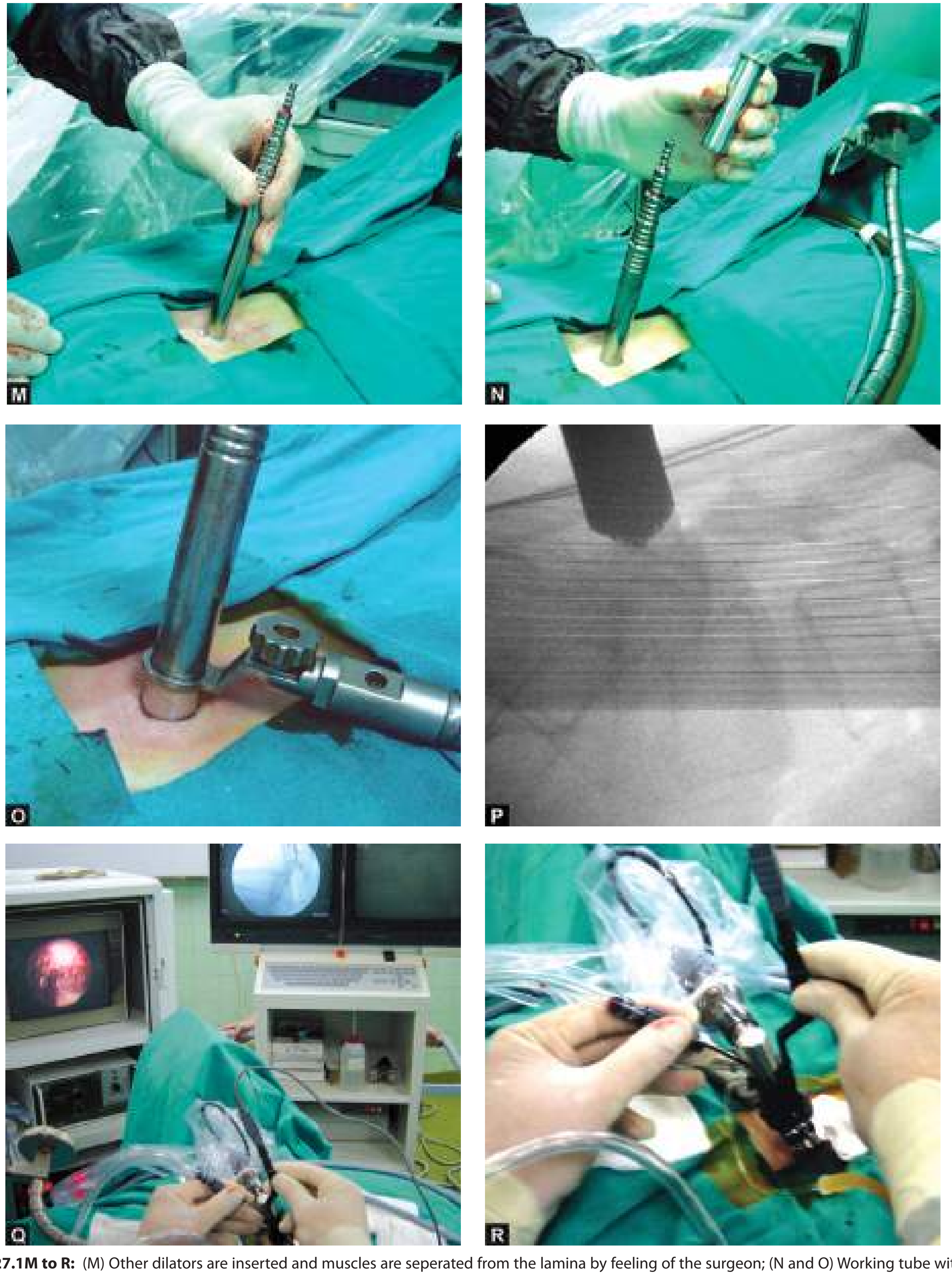
Laminectomy and medial facetectomy are performed. Laminectomy must not be enlarged up to the ligamentum flavum ending. If it is performed to the end of the ligamentum flavum, removing free ligamentum flavum will be difficult. Ligamentum flavum is removed in layers. A curette or No. 15 scalpel may used for this purpose. Each layer is removed by Kerrison punch. Dura and root are exposed. If it is needed to angle the working tube, flexible arm can be released. At that time, working tube must be kept underpressure not to miss the muscles that were retracted before. Root is retracted by a hook to search the disc herniation. When the herniation or fragment is visualized, suction is performed by a especially designed




**Figs 27.1A to F:** Stages of the endoscopic discectomy using METRx system. (A) METRx instruments set; (B) Set-up of the surgical room must be prepared so that the surgeon can look the C-arm and monitor at the same time; (C) A needle will help to learn the proper level; (D) After sterile covers, retractor arm is fixed to the table; (E and F) The flexible arm is placed on the tip of the arm and fixed




**Figs 27.1G to L:** (G) A 1.5 cm incision is done; (H) The first dilator is inserted onto the K-wire; (I to L) Other dilators are inserted and muscles are seperated from the lamina by feeling of the surgeon



**Figs 27.1M to R:** (M) Other dilators are inserted and muscles are seperated from the lamina by feeling of the surgeon; (N and O) Working tube with 1.6 cm diameter is inserted around the last dilator; (P) The proper position is observed on the C-arm image; (Q and R) Endoscope is placed and the surgeon works with instruments

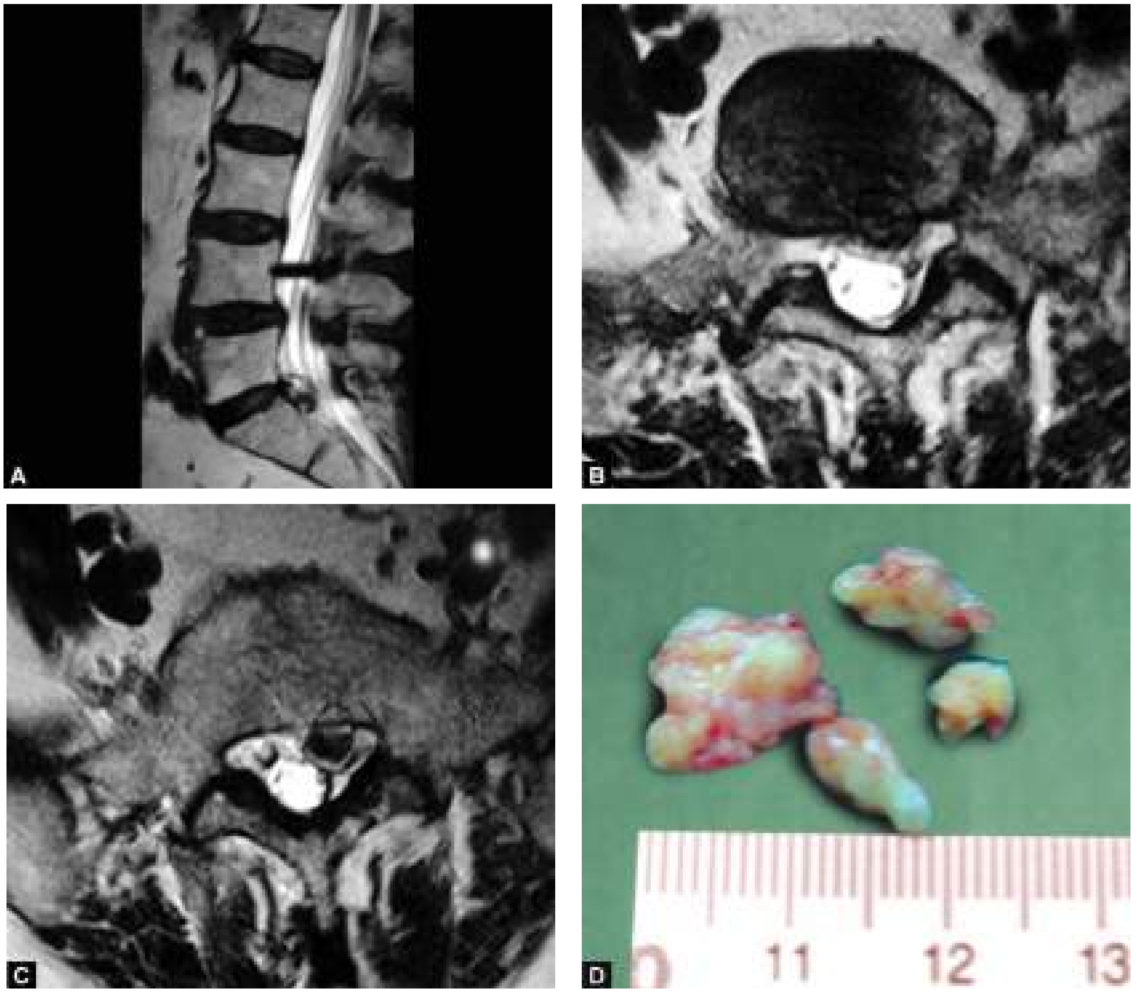
Fig. 27.1S: Endoscope is placed and the surgeon works with instruments

retractor-suction tip. If posterior longitudinal ligament is intact, it is incised with a No. 15 scalpel. Then discectomy is performed, up to root is well decompressed. If there is a free fragment, other free fragments must be searched. The root is moved by hook for searching other fragments. Disc space may be irrigated by saline solution. Sometimes disc tissue is found by this maneuver. We prefer using local antibiotics to the disc space at the end of discectomy and never faced a discitis after irrigating the disc space with rifampiscin. Bleeding is controlled by bipolar cautery or application of spongostan.

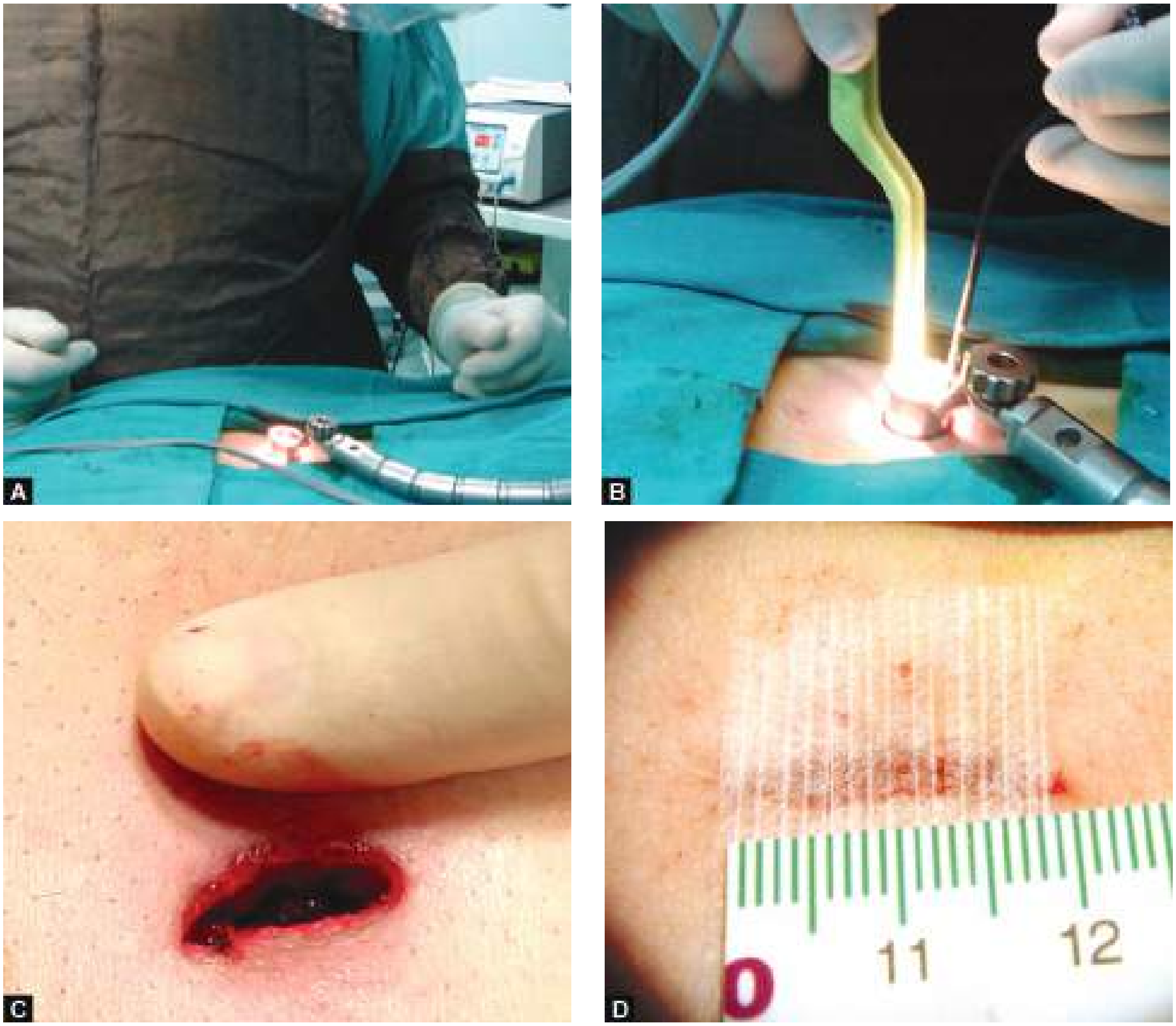
Flexible arm is released, working tube is withdrawn. Fascia is closed by interrupted one or two absorbable sutures. Skin is reapproximated with subcutaneous sutures or sterile skin adhesives (Figs 27.2A to D).

### *Tubular Retraction System with Microscope (Figs 27.3A to D)*

The METRx tubular retraction system can also be combined with an operation microscope, so a three-dimensional imagination can be obtained. Microscopic visualization in tubular retraction



**Figs 27.2A to D:** (A to C) MR images of a patient with extruded fragment on L5-S1 level; (D) The picture of the removed fragments

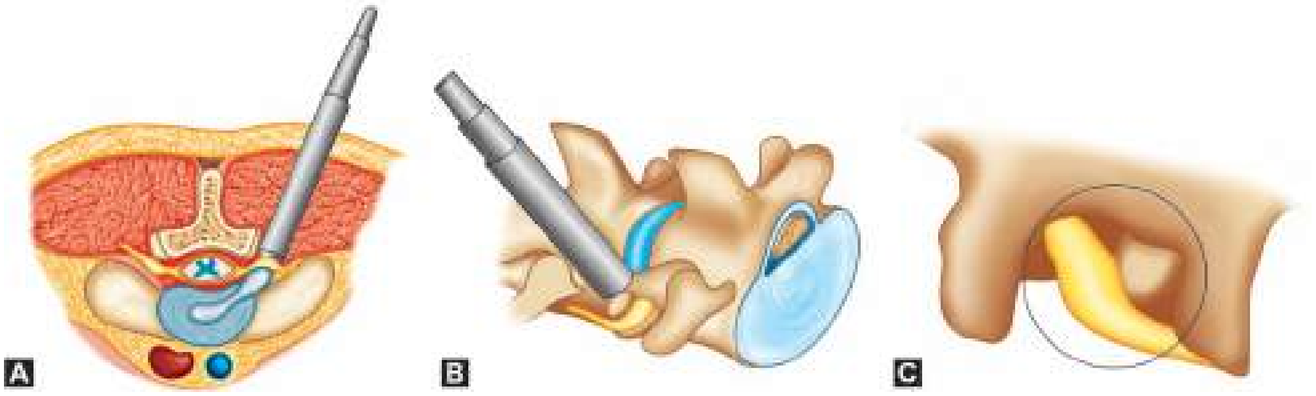



**Figs 27.3A to D:** (A and B) Set-up for microendoscopic discectomy using microscope and METRx tube; (C) The incision line after surgery; (D) After closure

system gives a 90 degree working angle. On the other hand, endoscopic discectomy is performed by a 30 degree angle. Some surgeons believe that 30 degree angle has advantages.[9] It is useful for decompressing to contralateral recess stenosis from an ipsilateral approach. However, it is possible to decompress contralateral recess stenosis by using microscopic discectomy with giving angle to the tubular retractions. Main disadvantage of using a microscope is reflection from tubular system. Arrangement of light source of microscope to the diameter lower than 1.5 cm can solve this problem. Another disadvantage of using the microscope is touching the surgical instruments to the microscope's lens apparatus. The lens focussed more than 350 mm must be preferred when performing microscopic discectomy. Optic lens of endoscopic system sometimes becomes dirty with blood and with smoke from bipolar coagulation. In that instance, removing and cleaning the optic system is necessary. This increases the duration of the surgery and causes a disorientation in operation field.

## Postoperative Care

After operation, patient is followed at postoperative care unit. If the vital functions are stable, patient is sent to his or her room. Family members are allowed to stay with patient at the room.




**Figs 27.4A to C:** Approach to far lateral disc herniations using METRx tube

Patient is informed about the operative findings and what he or she must do. We advise the patient to lay in the bed for six hours in supine position. After the patient has wakened spontaneously and effect of spinal anesthesia has resolved, he or she is ambulated at postoperative eight hours. If there is no problem, patient is discharged with a family member or a friend or with a vehicle.

## Complications and Avoidance

Complications of endoscopic microdiscectomy are similar to those of standard discectomy. Dura laceration, root injury, epidural venous bleeding, injury to the paravertebral vessels and abdominal tissue, infections and neurological deterioration are the complications that may be seen.

Although it is not easy to repair dural tear via 16 mm tube, it may be performed using a microneedle holder. Atraumatic suture with maximum 12 mm round needle is advised for repairing. Dural graft matrix like Dura Gen can also be used for covering dural tears. Fibrin glue can be placed on dural graft matrix. In that instance, fascia must also be approximated in a watertight fashion. In spite of all these measures, if CSF leakage occurs, lumbar external drainage must be considered for 3 to 4 days.

Microendoscopic discectomy is an instrument dependent operation. These instruments are fragile and must be handled with care. Angle of the working tube must not be changed unless flexible arm is fully released. Flexible arms and cables of light and endoscope must be placed away from surgeon's working corridor. Tip of the endoscope is cleaned with a soft and wet sponge. Handling of the tip of the endoscope must be very careful and crashing the endoscope tip to the metal faces should be avoided. While illumination, temperatures may exceed 41°C at the tip of the endoscope and 8 mm beyond. To avoid tissue burning, irrigation of the operation field must be done in intervals.

Compared to open techniques, minimally invasive lumbar discectomies do not decrease the rate of complication.[3,10] Instead, more dural tears and related complicatioons may be observed during the early learning period of this surgery.

In general, many of these procedures have a steep learning curves and require additional training to master, such as fellowship training, cadaveric workshops, and animal lab study.[11,12] However, once mastered, these techniques may result in a significant reduction of complications and postoperative pain and discomfort and return patients to their activities of daily living sooner than standard open, more conventional procedures.

## Conclusion

Endoscopic microdiscectomy is an effective and safe choice for surgical treatment of lumbar disc herniation. It is not superior to the microdiscectomy in terms of clinical results. But it is not inferior, either. Endoscope provides the surgeon working with a 30 degree angle. But it does not have three-dimensional imaging. Learning curve is longer for the surgeon who used to use operating microscope in the other spinal operations. Experienced surgeons can also overstep recurrent disc herniations, lumbar stenosis, cervical foraminotomy, discectomy for lateral lumbar disc herniation (Figs 27.4A to C), thoracic discectomy by using METRx endoscopic system. Surgeon has a chance to unite tubular retractor system with operating microscope which provides a three-dimensional visualization in a minimally invasive fashion as we perform nowadays.

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# 28

# Minimally Invasive Lumbar Microdiscectomy

*Richard Kim, Pulak Ray, Christopher M Loftus, Bong-Soo Kim*

## Introduction

Minimally invasive spinal surgery is gaining an increasing amount of popularity amongst surgeons and the general public. Classically, traditional surgical options were considered the treatment of last resort except in cases of neurologic deterioration due to concern for significant morbidity. As such, patients prefer minimally invasive surgery (MIS) to open surgery because it affords less pain and a shorter recovery period. However, there is a large variation in the definition and technique of minimally invasive surgery among surgeons.

The lumbar hemilaminotomy for microdiscectomy is by far the most commonly performed MIS spine surgery. The combination of localized pathology and the minimal bone window and nerve root retraction necessary for access to these lesions makes it an ideal surgery to be performed by MIS methods. Unique retractors applied via muscle splitting or dilating approaches allows for smaller incisions without compromising visualization, as well as minimizing nerve root retraction. These factors add up to less morbidity for the patient, a faster recovery, and decreased cost.

Another advantage of MIS microdiscectomy is the ease with which this procedure can be carried out in obese patients. Tubular retractors are able to retract soft tissue completely with excellent visualization of the pathology without the need of an extended incision. Adipose tissue is often not even seen during the procedure. In addition, the potential space created is minimal when compared to the traditional open method. This minimizes fluid collections and infections in this patient population with traditionally high morbidity rates.

## History

The technique for minimally invasive lumbar discectomy has been evolving ever since Poole described an endoscopic approach to the lumbar disc in 1938.[1] Since then numerous surgeons documented the feasibility of similar minimally invasive procedures such as chymopapain injections,[2] intradiscal electrothermy,[3] percutaneous lumbar nucleotomy,[4] and laser discectomy.[5] In the 1970s, Hijikata[4] and Kambin[6] independently approached the posterolateral spine to decompress nerve roots. Kambin later used arthroscopic techniques to prospectively validate the value of minimally invasive approaches for the lumbar spine.[7] He was able to demonstrate that not only were the outcomes similar to the standard open microdiscectomy, the morbidity was lower.

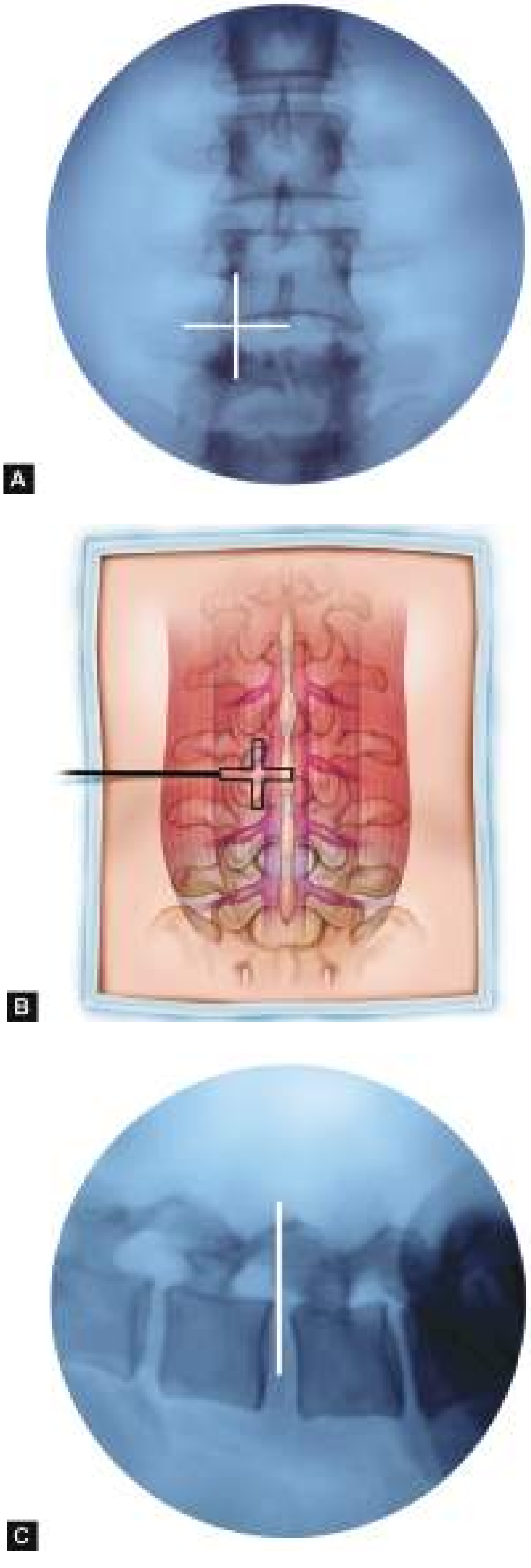
The continued evolution of endoscopic techniques allowed a biportal endoscopic approach by Schreiber and Suezawa,[8] a far lateral approach by Smith,[9] and a transforaminal uniportal approach by Mathews[10] and Ditsworth.[11] Smith and Foley described the microendoscopic technique in 1999[12] and a tubular retractor system soon followed. Concurrent with Hijikata and Kambin, Yasargil,[13] Caspar,[14] and Williams[15] described initial efforts in applying microsurgical techniques to the lumbar discectomy. Improvements in operating microscopes and microsurgical instruments have made the operation safer and faster and it is now the preferred method of removing the herniated lumbar disc. Now, with the tubular retractor systems widely available, the muscle splitting approach is quickly becoming popular with surgeons.

**Fig. 28.1:** Prone positioning on a Wilson frame on a Jackson table allows the spinous process of the levels of interest to splay, thus providing a corridor for the microdiscectomy. The Jackson table allows for ideal fluoroscopic access

## Surgical Technique

After the patient is intubated and access obtained, a Foley catheter is inserted. We find that although most cases do not last more than an hour, sometimes due to equipment problems or unexpectedly difficult approach/discectomy, a case may last longer than expected. The patient is positioned prone on a Jackson table with a Wilson frame (Mizuho OSI, Union City, CA) which allows the posterior elements to splay open, and allow easier access to the disc space. The Jackson table also allows for effortless mobility for fluoroscopy (Fig. 28.1). Compression stockings and compression devices are applied to the legs. The patient is secured to the table and all pressure points are padded. At this point, prophylactic antibiotics covering gram positive flora are given. C-arm fluoroscopy is utilized in planning the incision to center over the disc space of the proper level to be operated on (Figs 28.2A to C). A paramedian longitudinal incision slightly larger than the desired port diameter is made 1.5 cm or approximately 1 finger breadth from midline. In the case of an obese patient, the incision may need to be moved more laterally in order to obtain the optimal placement of the retractors. The incision is usually made through skin only, since the dilators will pierce and dilate the fascia.

The first dilator is inserted into the incision, bluntly piercing the fascia to dilate the paravertebral muscle tissue down to the inferior lamina, just medial to the facet joint being careful not to pass the level of the lamina (Fig. 28.3). Failure to do so could result in injury to the nerve root or a dural tear if too medial. After the first dilator's position is confirmed fluoroscopically, with careful tactile sensation, the paravertebral muscles are swept free from the lamina, the base of the spinous process, and over the facet joint with a gentle wanding motion to facilitate visualization and ensure the subsequent dilators and retraction ports are fully seated against the laminar bone (Fig. 28.4). Sequential dilation is performed by passing the next largest dilator over the previously inserted dilator until the desired diameter is achieved (Fig. 28.5). The depth should be taken at the point where the skin contacts the dilator. Once final serial dilation is complete and the proper retraction port's diameter and length have been determined, the retraction port can be inserted and should be centered over the



**Figs 28.2A to C:** The planned incision for microdiscectomy lies approximately 1.5 cm off the midline (A). An anteroposterior and lateral X-ray help guide the trajectory towards the disc space of interest, just medial to the facet joint and interlaminar space (B and C)

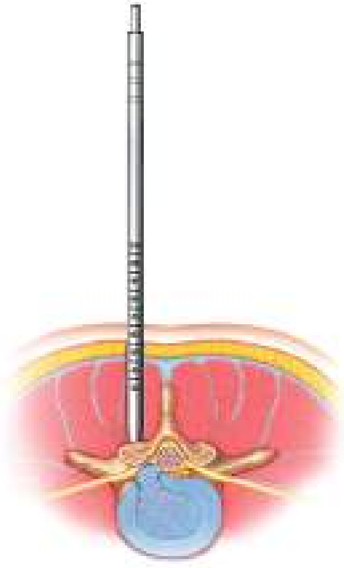


**Fig. 28.3:** The first dilator is guided down to the inferior lamina, medial to the facet

**Fig. 28.5:** The final dilator is measured and seated on the lamina

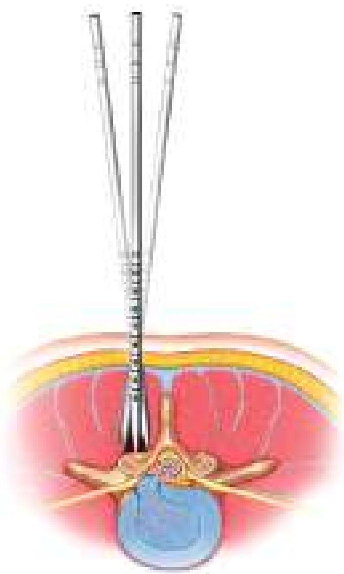
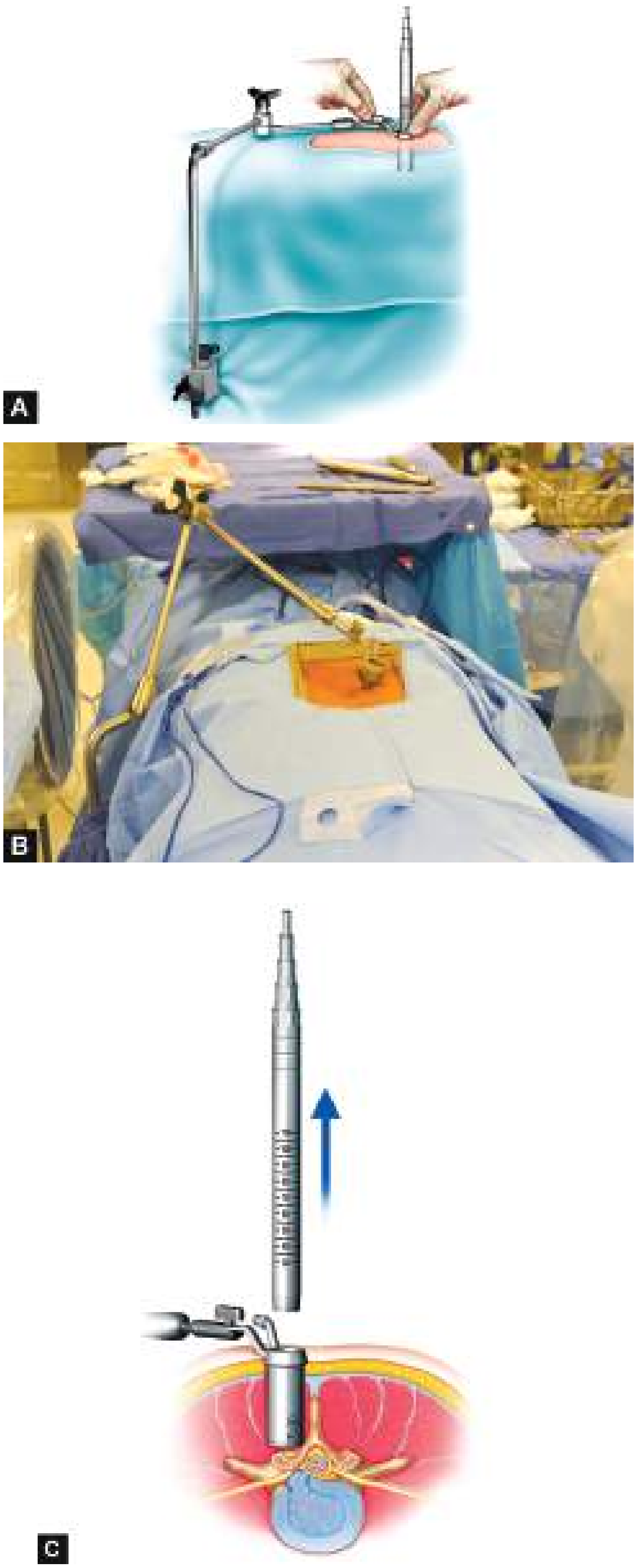


**Fig. 28.4:** Sequential dilators then help dissect paravertebral muscles away from the lamina

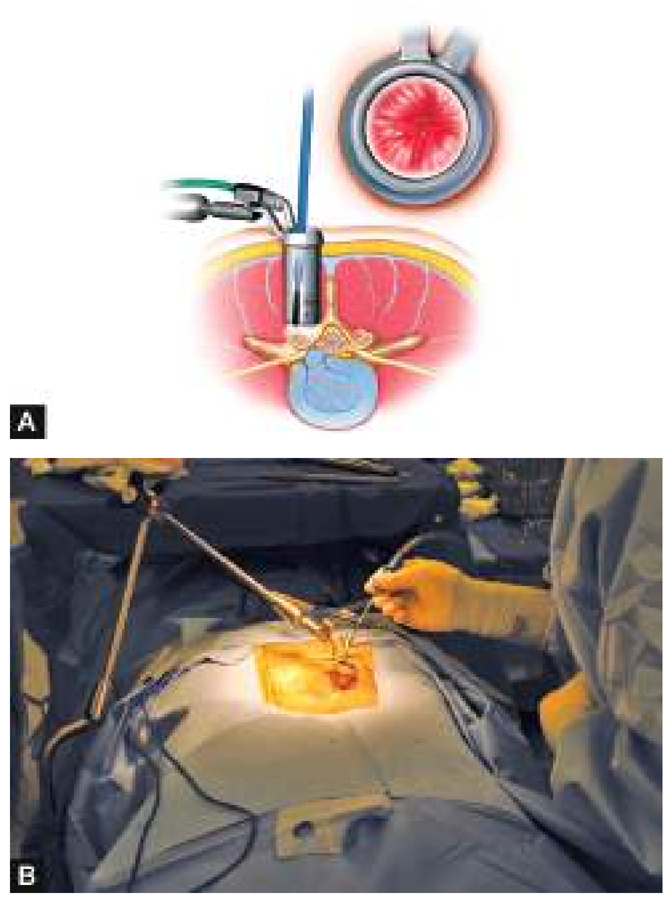
**Fig. 28.6:** The retraction port is placed with attention paid to maintaining relaxed skin edges

interlaminar space (Fig. 28.6). Once the position is verified, the retractor is secured in place with a rigid arm assembly which is attached to the surgical table. The mount must be kept out of the way of the surgeon and fluoroscopy. Care should be taken to ensure the retraction port remains fully seated during the procedure (Figs 28.7A to C). At this point, the surgical microscope or the port mounted endoscope is brought into the field. The view through the microscope should be centered over the interlaminar space and include the inferior edge of the superior lamina, the superior edge of the inferior lamina, and the medial edge of the facet.

Remnant muscle is then removed from the bone using electrocautery inside the retraction port. This prevents bleeding or oozing from the tissues (Figs 28.8A and B). Gentle palpation using an inactive, extended length Bovie tip ensures anatomic borders. A pituitary Rongeur can be used to remove tissue



**Figs 28.7A to C:** The rigid arm is secured to the port (A and B). The sequential dilators are removed after the port is firmly seated (C)



**Figs 28.8A and B:** The muscle is dissected free in a circumferential manner, paying attention to the interlaminar spaces. The surgical microscope is brought into the field for the remainder of the procedure

fragments as well. Irrigation can be used routinely to ensure adequate visualization during these maneuvers. The lamina, ligamentum flavum, and lateral border of the canal can easily be identified (Fig. 28.9). A hemilaminotomy is performed using a high speed drill until the bone is thinned. Kerrison Rongeurs can then help complete the laminotomy. If necessary, a high-speed burr can be easily and safely used to remove hypertrophic bone or medial facet. Until the thecal sac is identified directly, the ligamentum flavum will act as protection to the dura during hemilaminotomy. An up-angled curette is ideal to elevate the ligamentum flavum from the lamina and sweep it from midline laterally. Then the ligamentum flavum can be resected with Kerrison Rongeurs (Fig. 28.10). Once the dura is visualized, the nerve root is identified and the dura can be retracted with a nerve root retractor to expose the disc. Epidural bleeding can be controlled with bipolar electrocautery or if very brisk, gel foam can be applied for tamponade. Once bleeding is controlled, the discectomy can proceed in the same manner as in the open variation of this operation. The annulotomy is made sharply with a scalpel and nucleus pulposus is removed with a combination of pituitary and Kerrison Rongeurs.

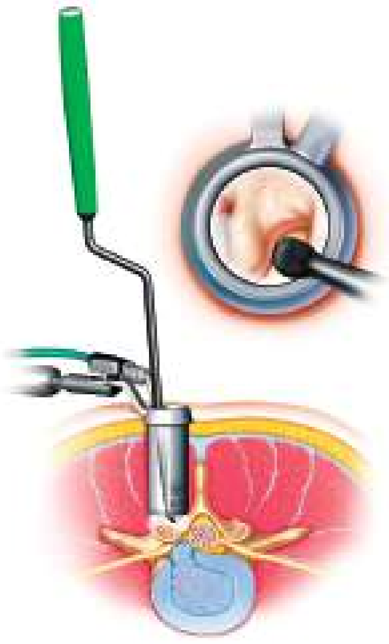


**Fig. 28.9:** The superior and inferior lamina, ligamentum flavum, and medial facet are identified and the laminotomy is performed with a drill

The use of bayoneted instruments has improved the efficiency and visualization through tubular retractors.

Once hemostasis is obtained, the muscle is inspected circumferentially for any bleeding. This is usually easily controlled with bipolar electrocautery. The wound is copiously irrigated with antibiotic irrigation. The lumbodorsal fascia is approximated with a single interrupted absorbable sutures followed by a subcuticular layer closure. The skin is closed according to the surgeon's preference. Many practices choose to discharge patients on the day of surgery.

## Complications

Complications can undermine the benefit given to a patient by an otherwise technically sound operation. In a recent systematic review of literature, Fourney compared complication rates between open and MIS tubular access versions of standard spine operations.[16] Several complications were examined in this study. Blood loss was found to be variable across groups however, there was a trend towards less blood loss with experience and fewer transfusions with tubular discectomies versus the open version. Revision surgeries were required in a slightly higher percentage of tubular cases (9.2%) versus open cases (7.7%) when only RCTs were considered. However, results were variable across cohort studies.

These percentages also applied to rates of dural tears, however, corresponding rates of cerebrospinal fluid (CSF) leaks were much lower. Overall, CSF leaks were less frequent with MIS procedures compared to their open counterparts. Nerve injury during single level discectomy was rare for both groups at 1.8 percent vs 1.9 percent (MIS and open, respectively). Other rare events recorded included wound hematoma, exploration starting at the wrong level, vascular injury, and death. Importantly, Wu et al. found that complications tend to occur early in the learning curve.[17]

**Fig. 28.10:** View after the ligamentum flavum is resected with Kerrison Rongeurs

Overall complication rates were 6.8 percent in the first 220 cases compared to 3.6 percent in the last 653 cases and this difference was statistically significant. Specifically for dural tears, the rates were 3.6 percent and 0.9 percent for first and last cases respectively. There was no difference in infection rates (0.5% for both groups).

## Review of Results

### Outcomes

The outcomes data for minimally invasive lumbar microdiscectomy is accumulating. Certain patient populations may benefit additionally from the MIS approach. In one recent retrospective review, Lee et al. showed that the tubular approach afforded a small but statistically significant decrease in the length of stay while maintaining the similar rates of complications.[18] Similarly, Harrington et al. found in his retrospective review that the MIS approach significantly decreased the length of stay and narcotic use while maintaining the low surgical times and blood loss.[19] The leading theory behind why the length of stay is shorter posits that the muscle splitting approach leads to less muscle damage and therefore pain. However, Arts et al. argue that in fact the tubular discectomy increases postoperative back pain and causes similar levels of CPK release and multifidus muscle size on follow-up imaging.[20] Despite this report, the advantage of the tubular retractor system in obese patients seems to be more apparent.

Open spine surgery in obese patients is associated with higher rates of complications, longer incisions, and more blood loss.[21,22] Tomasino demonstrated that the perioperative complication rates for infection, dural tears, DVT, as well as reoperations, as well as patient outcomes, were not different in obese and non-obese patients with the tubular discectomy.[23]

### Cost Analysis

The cost of spine care in the United States totaled over $86 billion in 2005 which is a 65 percent increase from 1997.[24] Considering these significant costs, Allen et al. suggest developing technologies that are cost effective and show clinical benefit.[25] While outcomes from microendoscopic approach to the herniated lumbar disc seem to be as good as the open approach, the cost effectiveness is unknown. Intuitively, it seems that the MIS approach would decrease costs through decreased length of stay in hospital, decreased requirement of pain medications. There are several studies showing MIS lumbar discectomies may have potential in lowering the overall cost of care for this patient population however, there is scant data addressing this issue specifically. Palmer reports that initial savings of 18 percent per case can be achieved with a microendoscopic discectomy versus the standard open discectomy.[26]

One of the issues hindering a high quality study is the lack of consistent cost measurement and methods of costing.[25] In two studies comparing the cost benefits of an MIS approach to PLIF versus the standard open procedure, there were short term benefits to the MIS approach due to fewer infections, complications, shorter LOS, less narcotics usage, more rapid return to work, and shorter recovery periods. Upfront costs were higher, but were more than balanced out by the factors mentioned above.[27,28] Whether or not these cost benefits apply to the MIS lumbar discectomy population remains to be seen through future studies.

## Conclusion

The minimally invasive approach to the lumbar disc is becoming an invaluable tool in the treatment of the lumbar disc herniation. While MIS microsurgical approaches have its advantages and disadvantages, recent data suggests that this technique is at least as effective as the open procedure in patient outcomes and complication rates. However, it is clear that MIS technique is associated with higher complication rates early on due to the learning curve. Careful application of minimally invasive technique can produce excellent clinical results while potentially decreasing the overall cost of care for this patient population.

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# Tubular Microsurgical Discectomy for the Treatment of Lumbar Disc Herniation

*Marcos Masini, Wellingson Silva Paiva, Rogério Safatle Barros*

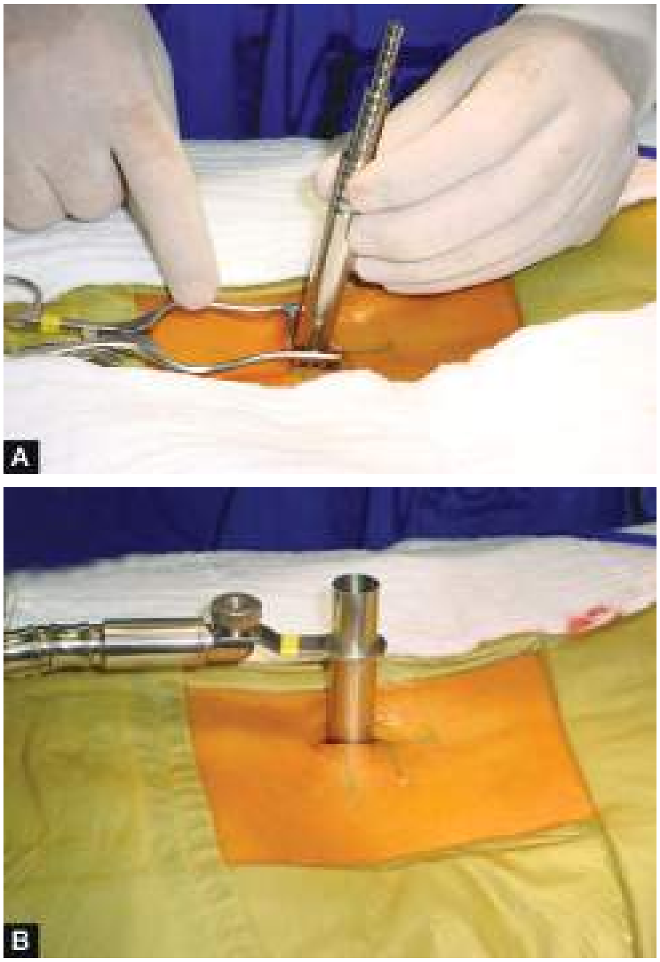
## Introduction

Sciatica or lumbosacral radicular syndrome affects millions of people worldwide and is most frequently caused by lumbar disc herniation (LDH).[1] The natural course of these signs and symptoms are usually favorable. Surgery is offered to patients with persistent pain and refractory to conservative treatment[2-5] or to patients with neurological deterioration. Surgery for lumbar disc herniation is one of the most frequently performed procedures in neurosurgery. Since the first successful lumbar disc operation, described by Mixter and Barr,[6] in 1934, a variety of less invasive techniques have been developed. Many techniques are available, highlighting the microsurgical discectomy (MDC) as the most widely used in neurosurgical practice and, in many studies, with results comparable to conventional discectomy.[7-16] Stand out as advantages of microsurgery the illumination and magnification provided by the microscope.[17,18] However, many techniques have been proposed in recent years, mostly by percutaneous methods such as chemonucleolysis, laser vaporization, endoscopic foraminotomy, endoscopic nucleotomy, they have not shown comparable results to those of microsurgical discectomy or discectomy with regard to conventional decompression of roots and removal of herniated disc.[19-21] Moreover, these new techniques have limited indications and longer learning curve.

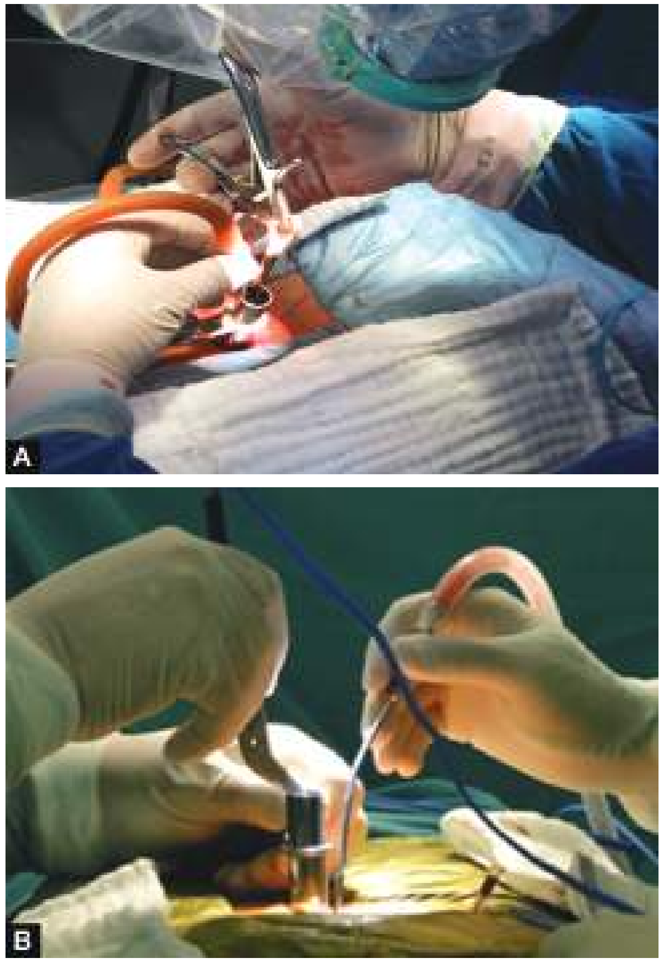
Following this trend, the technique of tubular microendoscopic discectomy (MED) was developed by Foley and Smith in 1997, for the treatment of lumbar disc disease and has been presented as a new option for those surgeons looking for less invasive surgical techniques.[22] The method may combine microsurgical techniques with conventional endoscopic devices, such as tubular retractor, fiber optic lighting and may also include ancillary endoscopic visualization.[23,24] In the recent years, thousands of procedures were performed by this technique in more than 500 institutions in the US.[25] The rationale behind is that replacing the conventional subperiosteal muscle dissection by the muscle-splitting approach with tubular discectomy causes less tissue damage, thus resulting in a reduction of operative trauma, less postoperative pain and a faster rate of recovery but with similar long-term outcomes. Patients are expected to have also reduced postoperative back pain, thus allowing quicker mobilization and contributing to faster resumption of work and daily activities. The objective of this chapter to compare two groups of patients with LDH, one treated by the microsurgical discectomy (MDC) and another with a tubular retractor of MED, associated with surgical microscope: modified microendoscopic discectomy (MEDm) which modified from the basic Foley and Smith technique.

## Patients and Methods

In 2001, we developed a prospective and comparative study.[26] Forty patients who had undergone LDH surgery were assessed for this study. The volunteers had been divided randomly into two groups: 20 operated on by the MDC (conventional) technique and a second group operated on by the MEDm (modified) (Figs 29.1 and 29.2). Forty consecutive operations in patients with lumbar disc herniation were performed from October 2001 to May 2002; only patients with larger herniated discs and distinct nerve root compression were included. The sample of patients consisted in 26 men and 14 women, aged 27 to 72 years (mean 42 years). The volunteers were randomly divided, according to order of entry into the study,




**Figs 29.1A and B:** Positioning of the tubular dissectors and retractor with installation of the working channel




**Figs 29.2A and B:** Application of tubular system in modified microendoscopic discectomy and the association with surgical microscope (Modified Microendoscopic Discectomy)



a group of 20 patients operated on by microsurgical discectomy technique (MDC) and a second group of 20 patients operated on by modified microendoscopic discectomy (MEDm). In all cases, the instructions and method of removal of disc material were similar. The groups were matched for age, sex and professional activity. Cases of reoperations were excluded. The average follow-up was of 10 years for both groups.

The outpatient revisions occurred with 10 days, 1, 3, 6 and 12 months after the procedure and continuing annually thereafter. The average follow-up was 10 years. The item pain is assessed using the visual analog scale (VAS)[27] before and immediately after the procedure and in the 1, 3, 6, 12 and 24 following months. The difference between VAS1-VAS2 is considered an index of analgesic effect. This difference was calculated as a percentage to allow direct visualization of the results. For this analysis, we used the Statistical System of Excel. The results were also assessed using the Functional Scale and Economic Prolo (Prolo, 1986).[28] Statistical analysis was performed using Sigma Stat® 8.0-sigma plot (Jandel Inc., CA, USA) and graphical development with SPSS® 10.0 (SPSS Inc., IL, USA).[29-31] In both techniques, the operation was performed with the patient prone, under general anesthesia, with access unilateral posterior lumbar spine. In the technique MEDm, the initial location of the tubular retractor was confirmed by lateral fluoroscopy or radiography. We use the progressive tubular retractors system associated with surgical microscope focused at 350 mm, and implementation of material extended to microsurgical endoscopy instruments, maintaining the three-dimensional binocular vision.

## Results

No complications of surgical procedures were observed during the study. With reference to the vertebral segment operated we used the MEDm in the L5-S1 segment in eleven cases, L4-L5 in seven patients and in segment L3-L4 in three cases. With microsurgical discectomy, were operated ten patients with herniation in L5-S1 segment, seven cases in L4-L5 and three patients in L3-L4. The mean operation time was less than 90 minutes (average of 88 minutes, 69 minutes minimum

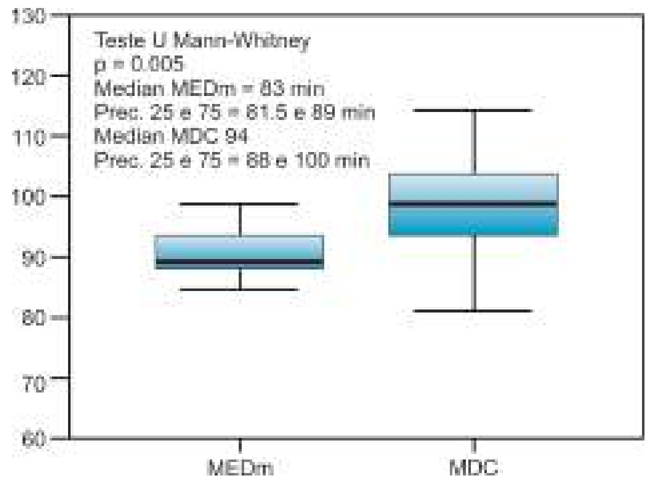



**Fig. 29.3:** Duration of the procedures in minutes. Comparison between tubular (MEDm) and MDC referring to the duration of the procedure, in minutes

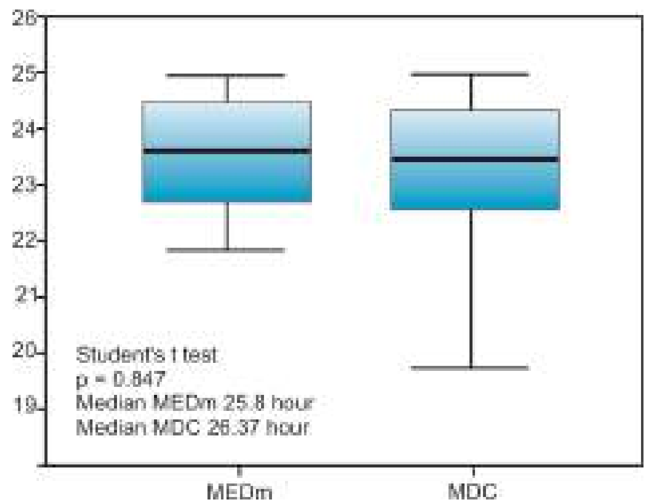



**Fig. 29.4:** Hospital stay in hours. Comparison between tubular (MEDm) and MDC referring to the duration of the hospital stay

and 112 maximum). We noted that the operative time was significantly shorter in the MEDm (Test U Mann-Whitney; p=0.005) (Fig. 29.3). The hospital stay was not statistically different (Student's t test; p = 0.847) and was close to 24 hours (one day stay) (Fig. 29.4). Referring to the outcomes evaluation, no difference was noted between the two groups of patients (Q square; p = 0.33) (Fig. 29.5). The recurrence surgeries occurred in 2 patients, one of each group along the 10 years follow-up, corresponding to an incidence of 5 percent. One patient of the first group needed a wide procedure and fusion of the spine. Also in this first group we had 3 patients that underwent facet denervation by radiofrequency due to back pain during the follow-up period.

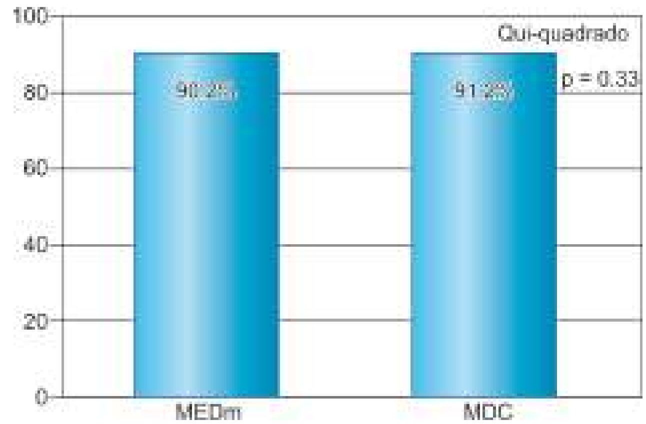



**Fig. 29.5:** Results in percentage of excellent and good among patients treated by tubular (MEDm) and MDC technique

## Discussion

The minimal access technology has evolved rapidly with tubular and percutaneous approaches for decompression and stabilization of the lumbar spine. The potential benefits are smaller scars, diminished local pain, reduced blood loss, reduced postoperative wound pain, shorter hospital stays which have to be weighed against possible drawbacks like reduced orientation, steep learning curve, increased radiation exposure for patient and staff, dependency on technology and cost.[32] This could be significant in the first hundred cases and explains why comparative papers do not find great differences in results comparing the conventional and tubular approach.

Righesso and Ryang[33,34] refer that tubular discectomy is equally invasive as conventional microsurgical discectomy in terms of creatine phosphokinase (CPK) and multifidus muscle atrophy. In their experience, patients treated with tubular discectomy reported more low-back pain during the first year after surgery when compared to those who underwent conventional microdiscectomy although the differences were small and not clinically relevant. Arts et al.[35] reported that tubular discectomy and conventional microdiscectomy resulted in similar functional and clinical outcomes. In a second study made by the same authors, patients treated with tubular discectomy reported more leg pain and low-back pain, although the differences, again, were small and not clinically relevant.[36] Muramatsu et al.[37] showed no difference in postoperative contrast enhancement as a marker of tissue damage between tubular discectomy and microdiscectomy confirming that the skin incision was equally small in both procedures. Brock et al.[38] demonstrated similar results; however postoperative analgesic consumption was less in patients treated with tubular discectomy. The heterogeneity of participants' authors in the papers may explain these unexpected and contradictory results.

It has been demonstrated that those patients treated with aggressive discectomy are reported to have more back and leg pains, although the incidence of recurrent disc herniation is lower than in those treated with limited discectomy.[39] In our experience the disc approach was similar in both groups of patients what explains the same long term results. Christie et al.[40] reported success and safety in using the MED technique for recurrent disc herniation. We have also use tubular approach in disc recurrences. This situation is risky due to the loss of protection of the yellow ligament taken out in the previous surgical procedure. Care should be taken to localize precisely the lamina above and below and define the surgical planes to protect the root and dural sac. The identification of the disc protrusion or extrusion with the microscope is certainly easier and safety.

It is worthy to mention that this approach is the least difficult of the minimal invasive techniques and provides a forum to master the "learning curve" of young surgeons for more complex procedures. Once achieved this first step, the surgeon can then expand its indications and applications. In our 10 years experience, the use of tubular retractors for microsurgical decompression of degenerative spinal disease is a safe and effective treatment. With surgeons becoming more acquainted with the procedure, its applications can be expanded to include, e.g. spinal instrumentation and deformity correction in association to image guided technology.[41] Finally, MED can be associated with endoscopy that will allow the experienced surgeon to move to the full endoscopic technique, which reportedly provides the same clinical results.[42-46]

## Conclusion

Minimally invasive techniques such as tubular microsurgical discectomy have been introduced to speed-up recovery. Our experience confirm these assumptions and prove that there are no additional complications. Ten years follow-up demonstrated the same recurrence rate in our study groups.

This system offers great advantages when compared with other techniques of minimally invasive discectomy[13] because it ensures direct visualization of the root and the disc, easy bone decompression, resulting in reduced surgical trauma of surrounding tissues. You can still get an inverted cone on the working area by moving the distal tubular retractor tip in the skin and lumbar fascia. This technique allows a smaller incision with visualization of nerve structures similar to microsurgical conventional discectomy. Moreover, it is not a costly approach. It depends on a low learning curve for a microsurgical trained surgeon; it can be applied to a virgin disc herniation, to the recurrent discs herniation and many other degenerative diseases of the spine.

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# Endoscopic Spine Surgery as Treatment for Lumbar Disc Herniation and Foraminal Stenosis

*Enrique Osorio-Fonseca, Jorge Felipe Ramírez, José Gabriel Rugeles, Gabriel Oswaldo Alonso*

Minimally invasive spine surgery, particularly lumbar endoscopy, has fully compiled with the philosophy of nowadays surgery. It establishes a new way of thinking, which aims to reduce to the minimum, the surgical procedure that would still allow the preservation of function and natural structure of the body and which also prevents iatrogenic processes, without forgetting the main objective of the treatment, in this case, relief for low back pain. Due to this, low back endoscopy is at its very peak, not only regarding implementation, but also to the number of publications and interest in training. For example, the National Library of Medicine has almost 2,000 publications related to endoscopic spine surgery, and more than 650 of them have been published in the last five years.[1] There is also a growing interest of spine specialists to train in these new techniques, along with the worldwide emergence of institutes and training programs focusing on lumbar endoscopy.[2]

However, it is important to deeply understand the basic, but underlying aspects, regarding its evolution, guidelines and most relevant present techniques that may be developed with endoscopic surgery in the lumbar segment. Hence, this chapter will deal with endoscopic techniques for the treatment of low back pain such as percutaneous endoscopic discectomy (using transforaminal and extraforaminal approaches), endoscopic foraminoplasty and endoscopic interlaminar approach, and the required tools to perform them.

## Historical Perspective of Low Back Endoscopy

The development of spinal endoscopic techniques has been at its peak for the last 30 years. However, its evolution has had a longer development. In 1931, Burman performed the first myeloscopy,[3] making it the first step for the technological and scientific race until what we now know as spinal endoscopic surgery. In 1937, Pool[4] performed the first intraspinal endoscopy with an arthroscope to evaluate the root in a disc hernia and yellow ligament hypertrophy. In the early 1940s, Lindblom[5] observed the distribution of the contrast medium in radial tearing and disc protrusions, defining discography as part of a new diagnostic method. In 1955, in Argentina, Ottolenghi published the first posterolateral uniportal approach[6] and, in 1964, Smith[7] was the first one to describe the use of chymopapain in treating low back hernias, even though nowadays its use is limited due to postoperative complications. Recently, in 1975, Hijikata described percutaneous nucleotomy, which allowed the partial resection of the intervertebral disc using the aforementioned posterolateral approach; that was the most relevant occurrence for this technique used by this Japanese physician. One of the standards for spinal endoscopic techniques at the present time is performing the procedure using local anesthesia.[8] In 1983, Kambin and Gellman practiced a dorsolateral discectomy inserting a Craig's cannula and some forceps in the disc space,[9] and two years later, Onik[10] practiced the first nucleus aspiration. In the next year, Kambin and Sampson implemented the use of the fluoroscope, a very important device for increasing safety during the procedures.[11]

A new era began during the 90s, when technological development allowed patients to get better and safer clinical results. Developments ranging from thermal energy use for intradiscal and facet use (e.g. laser and radiofrequency) to endoscopic procedures allowed broadening the indications of minimal access surgery along the different spinal segments.

Regarding all this, it is important to highlight the evolution of the technique and the experience of the most relevant authors. The pioneer in low back endoscopy is Kambin,[12] who, in 1991, described the famous 'safety triangle.' After this, in 1994, and while in their own cities, Knight in England, Siebert in Kassel and Hoogland in Munich (Germany), and Yeung in the United States, performed the first low back percutaneous endoscopic discectomy using laser.[13] This technique was implemented for the first time in Latin America, in 1996, by Ramírez and Rugeles.[14] In this moment, lumbar percutaneous endoscopic discectomy has had so much approval that it is being performed in Europe, the United Kingdom, Latin America, Japan, China, India, Korea and the United States, having in May 2003 more than 35,000 reported cases.[15-18]

Endoscopic lumbar foraminoplasty was developed by Martin Knight in 1994,[19] in Manchester (England), and his first report, which had 219 procedures, was published in 1998.[20] The system developed by Knight used Holmium's laser fiber with a lateral shot and protection with saline solution irrigation. Recently, it is done by drilling the foraminal zone, assuring the integrity of the nervous root, taking into account that this procedure is performed using local anesthesia and sedation.

The most recent endoscopic approach is called 'interlaminar approach' and was developed by Ruetten in Germany. It was the answer to the difficulty of performing percutaneous approaches in the L5-S1 segment in patients with high iliac crests. It was reported for the first time in 2007, in 153 patients, of which 98 were in the L5-S1 segment,[21] evidencing its efficacy compared, a year later, to open microdiscectomy.[22]

**Fig. 30.1:** Endoscopic tower (Richard Wolf GmbH, Germany)

## Low Back Endoscopic Equipment

Given its characteristics, endoscopic spine surgery requires special devices to be implemented. The endoscopic video tower is vital and, in general terms, a standard tower comprises a screen, a video processor, a light source and a camera (Fig. 30.1). It can also have a shaver console and an irrigation pump.[2]

To perform a thermal discoplasty, there are several thermal therapy devices like the laser (now outdated due to its limited security margin) and radiofrequency (Fig. 30.2). Thus, it is essential to have an energy source designed for this. Thermal therapy is applied using fibers that percutaneously or through the endoscope's work channel get to the inner part of the disc, and being bipolar, guarantee even and safe heat transmission.

**Fig. 30.2:** Radiofrequency and fiber console (Elliquence$^{TM}$)

Regarding specialized instruments for spinal endoscopy, commercially we can access various sets that allow carrying out every process from insertion, discectomy and root freeing to foraminoplasty.

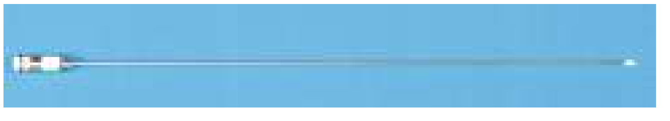


**Fig. 30.3:** Spinal 18 needle set with guidewire (Richard Wolf GmbH, Germany)

For access tools we have a spinal 1.25 mm needle set (Fig. 30.3); dilators with diameters ranging from 5.9 to 6.9 mm (Fig. 30.4), which help to create a way through the muscle to insert the cannulas; and the cannulas, with diameters ranging from 7 to 8 mm and lengths that vary from 145 to 185 mm (Fig. 30.5) that function as the sleeves in which we introduce the cutting instruments and the endoscope.

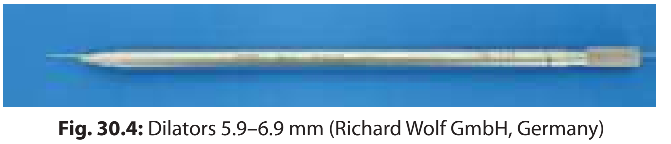


**Fig. 30.4:** Dilators 5.9–6.9 mm (Richard Wolf GmbH, Germany)

Dissection and cutting sets of instruments have a great variety of devices to perform various procedures from annulotomy and

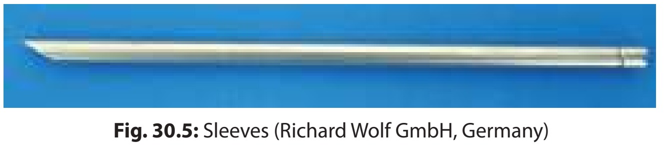


**Fig. 30.5:** Sleeves (Richard Wolf GmbH, Germany)

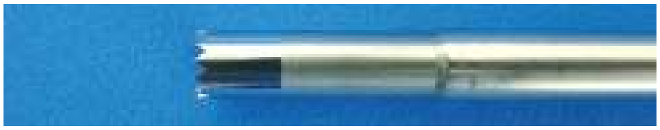
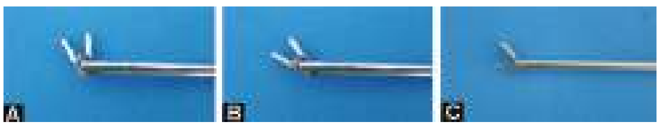


**Fig. 30.6:** Trephine (Richard Wolf GmbH, Germany)

**Fig. 30.7:** Shaver, hand piece and pedal, and drill tips (Richard Wolf GmbH, Germany)



**Figs 30.8A to C:** Articulated forceps in different positions (Richard Wolf GmbH, Germany)

manual discectomy, to those used in endoscopic foraminoplasty. Among these, we can find trephines, drills and forceps, which let us remove annulus and nucleus tissues and to broaden the foramen. According to the technique, trephines are available in several diameters from 3.0 to 6.3 mm (Fig. 30.6).

For drills, some of them may have a cap, used to protect important structures (e.g. the dural sac or the root) around the drilling zone. They are used together with the shaver, which reaches a speed of 6,000 to 16,000 rpm (Fig. 30.7).

There are articulated and not-articulated forceps, with 5.2 to 210 mm lengths and different tips (Figs 30.8A to C).

Endoscopic systems for spinal surgery vary, being Vertebris Spine Endoscope™ one of the most widely used (Richard Wolf GmbH, Germany).[23] It was developed by Sebastian Ruetten and uses a 207 mm long lens, 20° and 25°, 5.8 to 5.9 mm diameter and a 3.1 mm working channel (Fig. 30.9).

## Disc Herniation and Low Back Foraminal Stenosis Treatment via Endoscope

### Lumbar Percutaneous Endoscopic Discectomy

#### *Transforaminal Approach*

This technique is linked to the development of intradiscal thermal therapies and mainly to the use of laser. Its pioneers

**Fig. 30.9:** Vertebris® spine system with its articulated forceps inside the working channel (Richard Wolf GmbH, Germany)[23]

in spine surgery were Ascher and Heppner in 1984,[24] who used $CO_2$ and Nd laser. They stated that the removal of some of the disc's volume causes a decrease in intradiscal pressure, and thus, reduces inflammation and pain. The procedure, performed percutaneously with a laser, received the approval of the Food and Drug Administration (FDA) in 1991, which in turn enabled the first report of the technique in 1992. It was published by Daniel Choy (Presbyterian Hospital, Columbia University, New York) and it was used in 333 patients who were treated for low back pain.[17] Later, other studies evidenced the high temperatures the laser could reach and the risks associated to this phenomenon.[25,26] Given this, we have been implementing thermal discoplasty using radiofrequency as a heat source, which has proven to be more secure and effective.[27-31] For more information on this, see the chapter on thermodiscoplasty.

Lumbar percutaneous endoscopic discectomy is recommended in contained hernias diagnoses by MRI, failure in conservative therapies (6-week physical therapy, NSAID, analgesics and lumbosacral support showing no improvement), low back-radicular persistent pain, epidural or radicular blockage with partial improvement, in agreement with the discography and a positive discogenic test before the procedure done by the attending surgeon. Nevertheless, it is contraindicated when there is anatomical abnormality, segment instability, narrow lumbar canal, extruded and migrated hernia and *cauda equina* syndrome.

#### *Surgical Technique*

The patient lies prone on a radiolucent table and two cylindrical pillows are placed, one in the thoracic zone and the other in the pelvic zone, flexing the hip from 60° to 90° (Fig. 30.10). The place of the surgeon is on the ipsilateral side of the affected disc, with the assistant surgeon next to him.

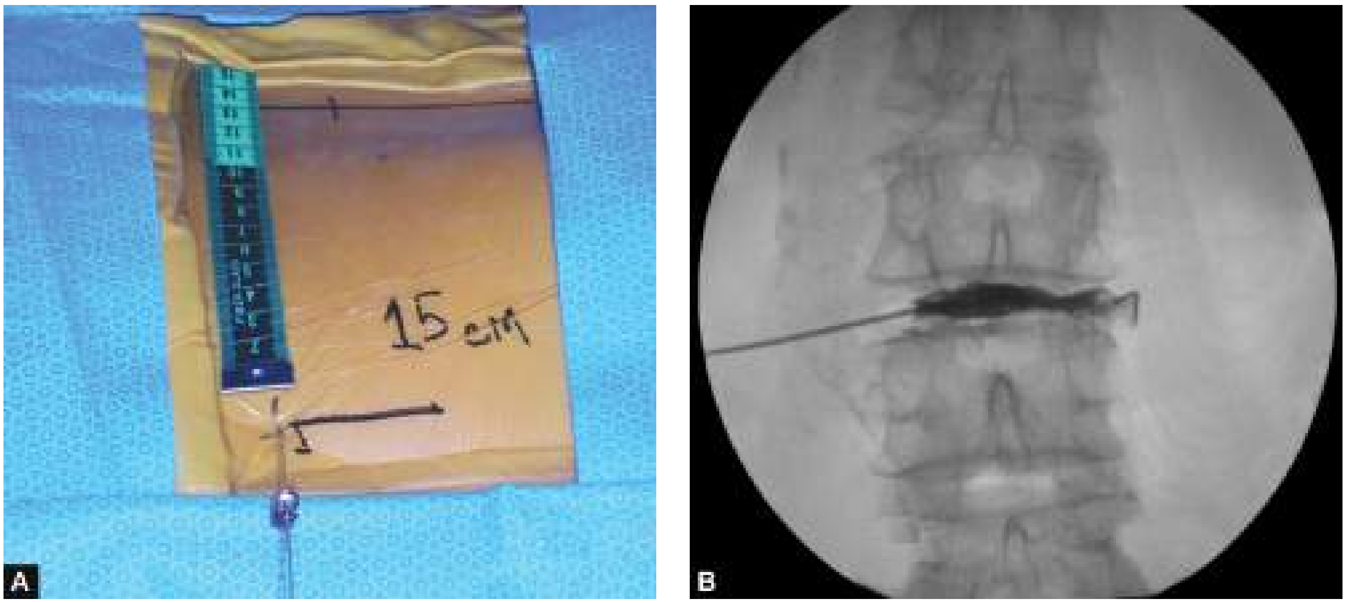
We use a posterolateral approach with an entry point 8 to 12 cm from the midline. Under fluoroscopic vision, we insert the spinal needle with a 45° to 60° angle from the X-axis, which is directed to the posterior-third of the disc. Once its position is located and verified, the contrast medium and methylene blue are injected to perform the discography and the discogenic test (Figs 30.11A and B). The objective of these two procedures is to evaluate the radiological pattern of the hernia and the pain

**Fig. 30.10:** Patient position

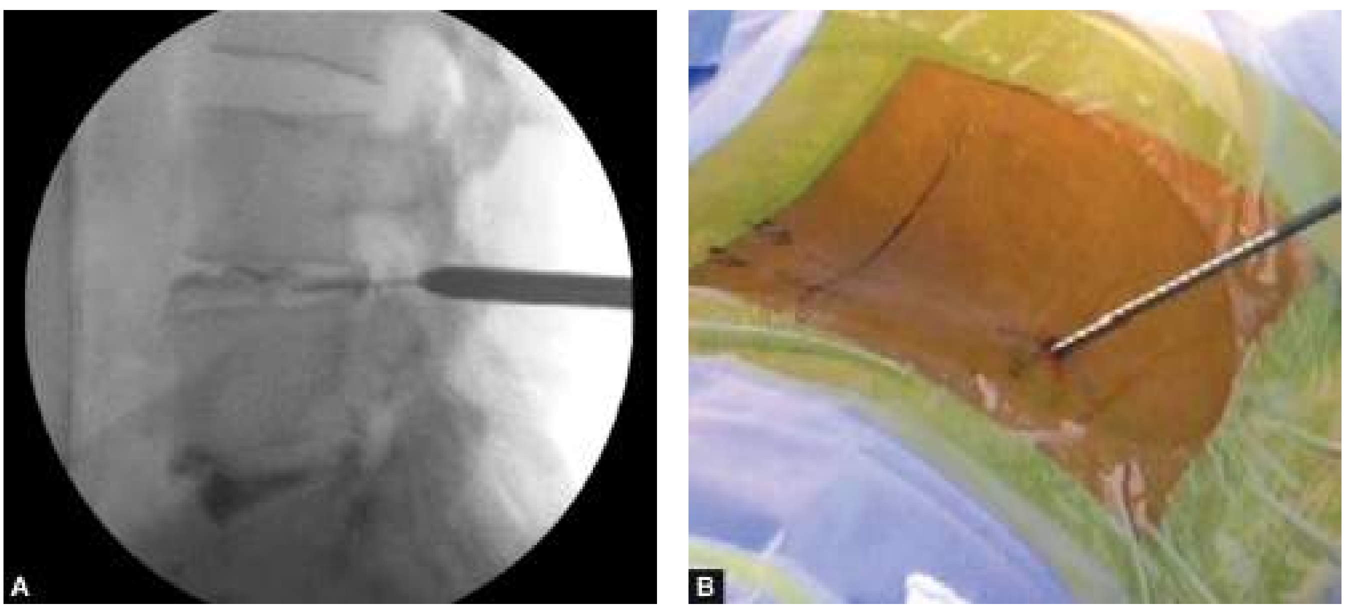
scale of the patient, respectively. Likewise, dying with methylene blue shows the degenerated disc that will be removed using the grasping forceps during the endoscopy. The needle is replaced by the guide wire, over which we will pass the dilator.

The dilator is passed over the guide to separate the tissue. With a scalpel we make a 1 cm incision that lets the working cannulas pass for the endoscope (Figs 30.12A and B).

We introduce the endoscope along with the irrigation-suction system, which has been previously connected to the endoscopy video tower through the camera and video processor system (Fig. 30.13).




**Figs 30.11A and B:** Needle position and fluoroscopic vision of the discography




**Figs 30.12A and B:** Dilator position

**Fig. 30.13:** Insertion of the endoscope

**Fig. 30.15:** Mechanized discectomy

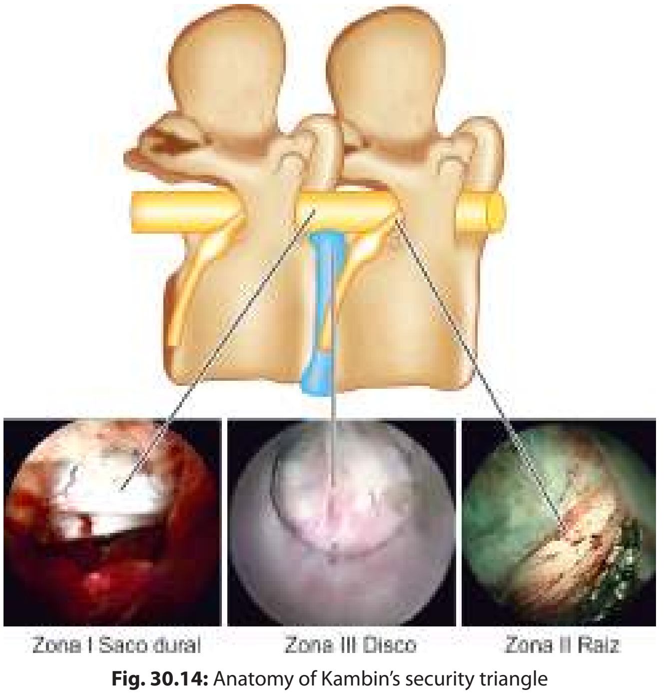



**Fig. 30.14:** Anatomy of Kambin's security triangle

Having the endoscope in position, we proceed to identify Kambin's safety triangle (Fig. 30.14). This lets us visualize the defined structures, i.e. the dural sac (zone 1), the nerve root (zone 2), the annulus and the nucleus (zone 3).

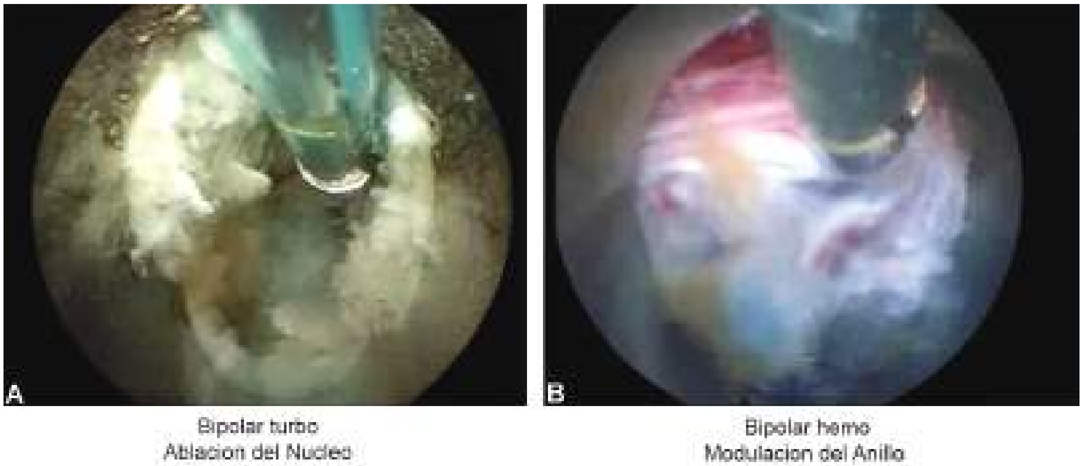
To initially decompress and clean the hernia, a mechanized discectomy is done. It consists in using grasping forceps to remove the extruded disc material, thus freeing the hernia. The ideal scenario is to achieve the removal of an important volume of the disc that has been previously dyed using methylene blue (Fig. 30.15).

For this stage we have two options for the thermodiscoplasty: laser or radiofrequency. Because of the great security margin given by radiofrequency (due to temperatures being more controlled and energy traveling only between two poles), the authors prefer implementing annuloplasty and nucleoplasty using this option (Figs 30.16A and B).[25-27] Thermal discoplasty can cause the following effects on the disc and the bone tissue: tensioning collagen from 60° to 70°C, cauterizing vessels from 70° to 85°C, and lastly, evaporating over 100°C. These effects let us stabilize the disc tissue and, in this way, correct the hernia and relieve pain.

### *Extraforaminal Approach*

Traditionally, techniques for the resection of low back extraforaminal hernias have been open through midline approaches. Among these we have laminectomy and hemilaminectomy, which have very limited access to the hernia and very poor postoperative results. Another option is partial or total facetectomy, which even with the resection of *pars interarticularis* causes instability and the corresponding segment movement problems. These both give origin to low back pain and spondylolisthesis.[31] On the other hand, paraspinal and transmuscular techniques that improve the results have been used, but due to the fact that they require moving the dorsal branch of the spinal nerve (dorsal root ganglion) it may cause radiculitis and postoperative neuropathic pain.

Searching for an alternative, in 2002, Yeung[32] published his experience in 30 patients with extraforaminal and foraminal low back hernias, showing positive results in more than 90 percent using the posterolateral and transforaminal endoscopic approach. In 2007, Choi, et al.[33,34] published their endoscopic approach for extraforaminal hernias called 'fragmentectomy'. These authors used a more median approach than the posterolateral one, between 5 and 8 cm from the midline on the X-axis, exclusively aimed to remove the extraforaminal fragment, preventing the manipulation of the dorsal root ganglion and without the need to reduce the center of the disc. It is vital to take into account that most extraforaminal hernias are sequestrations, and thus, only in some cases it would be necessary to remove the posterolateral portion of the discal annulus.




**Figs 30.16A and B:** Endoscopic image of the radiofrequency fiber while performing the annulotomy and nucleotomy

In the authors' experience, with a casuistry of 20 cases, they obtained a 95 percent success rate without any complications related to radiculitis or postoperative neuropathic pain.

### *Surgical Technique*

With the patient in prone position, we perform a posterolateral insertion where the tip of the needle is more medial than in low back percutaneous endoscopic discectomy, 5 to 8 cm from the midline. It is directed to the pedicular midline close to the top vertebral end plate of the caudal vertebra. This positioning allows having the tip of the needle in the middle of Kambin's triangle.

To achieve this positioning, the angle of the needle must be between 10° and 50°, depending on the level and location of the hernia. In the case of L5-S1, the entry point of the needle is barely medial to the iliac crest and it is aligned with the intervertebral disc with a 10° to 30° angle.

Once the position of the needle is achieved and confirmed with the fluoroscope, we pass the guide through the needle and, over it, the dilators that let us open the muscle tissue and push the prominent nerve root, away from the working channel. Over the dilator, we pass the working cannulas, which are the entryways for the endoscope.

After inserting the endoscope, we find an adipose layer covering the annulus. This cover can be removed and coagulated using the radiofrequency system, which lets us see the previously dyed herniated disc. We have to remove it using grasping forceps until we free the nerve root. It is important to know that we should look for and remove all free fragments of the hernia.[31] Lastly, we recommend inspecting the nerve root to visually confirm its freeing all along the way. We remove the instruments and close the incision in the skin using non-absorbable sutures.

### *Endoscopic Lumbar Foraminoplasty*

Knight developed the endoscopic option for treating foraminal stenosis, called 'endoscopic laser foraminoplasty'. This technique allows decompressing the foramen, mobilization and neurolysis of the nerve root, ablation of the osteophytes, tensing the collagen fibers of the disc, liberating the epidural scar tissue and removing sequestered and extruded disc protrusions with minimal invasion and under endoscopic visualization, tolerating a good exploration of the foramen, the extraforaminal zone, and the epidural and intradiscal space.

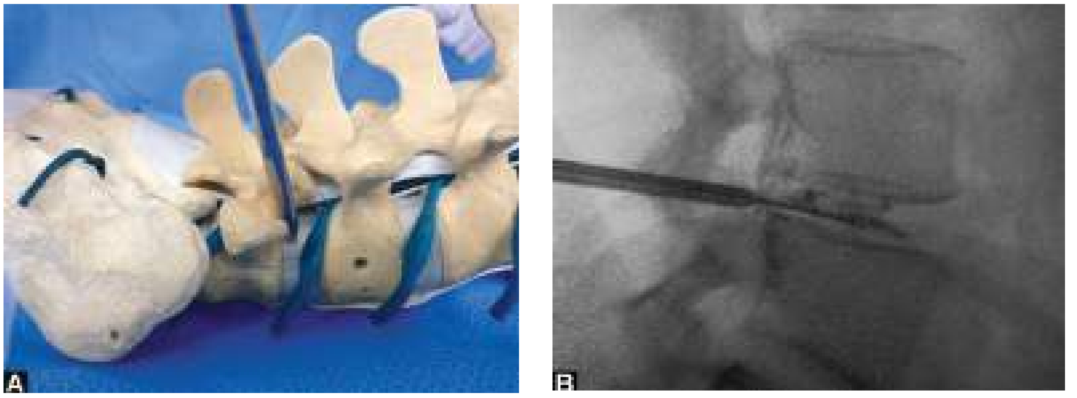
Endoscopic lumbar foraminoplasty is indicated for lateral recess stenosis, epidural fibrosis, osteophytosis, fixed listhesis, disc extrusion and sequestering, failed back syndrome and failed back surgery syndrome. It is not recommended for extruded and central migrated hernias, segment instability, *cauda equina* syndrome, painless motor deficit or tumors.

### *Surgical Technique*

It uses a posterolateral approach like low back percutaneous endoscopic discectomy. The entry point on the skin is approximately 8 to 12 cm from the midline. We insert the needle with the guide towards the annulus. After verifying its position with the fluoroscope, we perform the discography and discogenic testing. After removing the needle and leaving just the guide, we make a small incision with the scalpel to insert the dilator over the guide proceeding to the foramen (Figs 30.17A and B).

Over the dilator, we insert the working cannula. After removing the dilator, we insert the endoscope, which lets us visualize the working zone. Along the endoscope, through its internal working channel, we perform the mechanized discectomy to remove the tissue using the grasping forceps and to modulate the collagen using radiofrequency.

Nowadays, authors prefer foraminoplasty and drilling of the bone (this was previously done using laser) (Fig. 30.18). The procedure is performed irrigating with saline solution for a clear image of the foramen structures; these are: the intervertebral disc, the articulation surfaces, the flavum ligament, the superior foraminal ligament and the nerve roots. It also prevents any excessive increase in local temperature. This security aspect is




**Figs 30.17A and B:** A dilator over the annulus

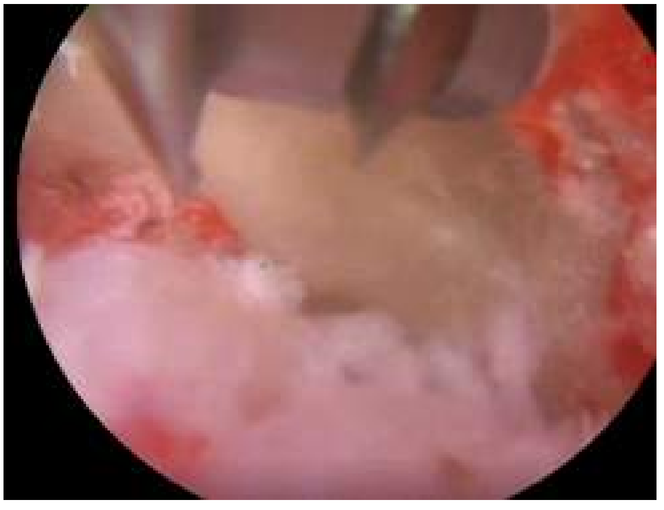


**Fig. 30.18:** A shaver drilling the foramen

essential for developing the technique and is complemented by using the image intensifier for monitoring the correct positioning of the endoscope and the drill tip.[35]

The concept of endoscopic foraminoplasty is surgical expansion of the foraminal volume, mobilization and cleansing of the contents and ablation of the irritant factors for the nerve inside the foraminal zone. The elements causing nerve compression, traction or irritation are removed. The descending and exiting nerve roots are mobilized and decompressed until the exiting nerve root is freed in the apex of the distorted foraminal zone. Subsequently, a thorough cleansing of the root is done by removing any kind of perineural fibrosis. This cleansing is performed by thermal ablation[36-38] and starts in the extraforaminal zone until it reaches the foramen. We perform a digging of the ascending and descending surfaces of the facet articulation until the endoscope passes through into the foramen isthmus inside the epidural space. Then two things occur: ablation of the osteophytes in the epidural space and the facet articulation, and freeing of perineural and epidural fibroses until seeing the fibrous annulus. If the latter is bloated or herniated, we complement it with mechanized decompression.

### *Endoscopic Interlaminar Approach*

One of the complications in endoscopic approaches is the access to intervertebral space L5-S1, especially when trying to decompress central hernias. Due to this, Ruetten developed this technique, which allows the resection of herniated tissue after cutting the yellow ligament through a posterior approach.

Among its indications, we can name the treatment of extruded nonmigrated hernias, sequestered migrated hernias, secondary reherniation after a traditional or endoscopic procedure, lateral or medial canal stenosis, facet articulation cyst, intervertebral monosegment fusions with expansion loads combined with transpedicular or translaminar stabilization. On the other hand, this approach is not recommended when there is extensive central canal stenosis or in patients with a history of posterior fusion or segment instability that does not reduce with position or remains in listhesis.[21]

### *Surgical Technique*

We identify the entry site of the posterior approach, approximately 1 cm from the midline and in the low part of the interlaminar window L5-S1, and make a 1 cm incision. This will allow the insertion of the dilator towards the yellow ligament.

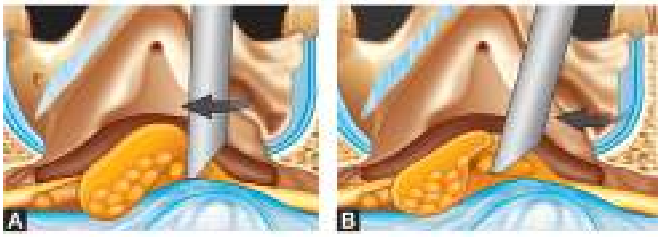
Over the dilator, we pass the 6.4 mm working channel needed for the insertion of the endoscope and visualization of the yellow ligament (Fig. 30.19).

Once the yellow ligament is identified, we proceed to cut it using either radiofrequency or forceps, to be able to visualize the previously dyed herniated annulus and disc. The content is removed with forceps until the nerve root is completely free.[35]

It is vital to know that the working channel serves as a retractor for the nerve, putting thecal sac medially and the S1 root laterally (Figs 30.20A and B).

Using twist movements the working channel is taken towards the vertebral body and the sequestered fragments in the axillar part may be seen immediately after inserting the endoscope. This facilitates its removal using forceps. Epidural veins can be cauterized using radiofrequency. Afterwards, the working channel is put in the intervertebral space, through an opening done in the annulus or the posterior longitudinal ligament using

**Fig. 30.19:** Endoscopic view of the yellow ligament




**Figs 30.20A and B:** Diagram of the protection to the nerve working channel (*Source:* Richard Wolf[23])

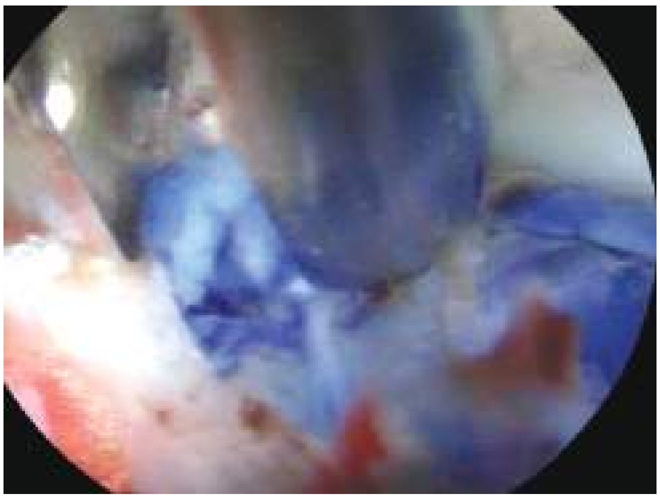


**Fig. 30.21:** Endoscopic view of the yellow ligament opening, and discectomy

the tip of the bipolar, we remove any disc rupture using forceps (Fig. 30.21).

We ablate the remaining bloated disc and annulus fragments using radiofrequency. After confirming that the root is intact and has been freed, we remove the cannula and the endoscope (Fig. 30.22).

**Fig. 30.22:** Interlaminar annulotomy using radiofrequency

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# 31

# Minimally Invasive Technique for Lumbar Disc Herniation

*A Bambang Darwono*

## Introduction

In the past decade, the trend in medicine has been away from traditional surgical procedures and towards less invasive ones. This trend has had profound effects on the practice of medicine. Some examples are arthroscopy, laparoscopy and peripheral as well as coronary angioplasty.

This trend is also evident in the treatment of patient with lumbar disc herniation. Earlier the use of chymopapain and now the performance of automated percutaneous lumbar discectomy (APLD) attest to the move toward less invasive procedures.

Automated percutaneous lumbar discectomy by mechanical decompression of the disc is an attempt to achieve the benefits of chymopapain injection without its associated risks.

Unlike with laminectomy or microdiscectomy, patients undergoing automated percutaneous lumbar discectomy do not require general anesthesia.

### History

In 1975, Hijikata in Japan published his results with a series of patients who underwent percutaneous lumbar discectomy. He designed special instruments placed through a 5 mm cannula inserted against the posterolateral annulus.

Using annulus cutter placed through the cannula, a fenestration or circular incision was made in the annulus and the herniated nucleus material was grasped and removed with special small straight or curve-tipped punch forceps.

Fenestration of the posterolateral annulus away from spinal canal and partial resection of the nuclear substance plus suction considerably reduced the intradiscal pressure (Fig. 31.1).

Although the extraction of the herniated portion of the disc is not achieved, however, the disc decompression by the procedure reduced the intradiscal pressure and relief of mechanical irritation of the nerve root or pain receptors around the disc is obtained.

In this initial published findings, Hijikata reported that approximately 80 percent of his patients experienced improvement after this procedure.

Variation on this method have been subsequently popularized by Kambin in Philadelphia, Suezawa in Switzerland, Shepperd in United Kingdom, Monteiro in Belgium, Graham in Australia, and Brock in Germany.

Onik (1984) working with engineers of Surgical Dynamics Inc. designed instruments for lumbar discectomy. Using a 2 mm blunt-tipped probe with a single-side port he automated the aspiration and evacuation of contained disc herniation.

The automated percutaneous lumbar discectomy probe contained a guillotine-like cutting knife that passed across the side port 160 times per minute.

### Patient Selection

The success of automated percutaneous lumbar discectomy depends on the proper patient selection. The most favorable results were obtained in patients who were properly diagnosed and properly motivated.

The only indication for using APLD is contained disc herniation or protrusion stage according to Mcnab classification.

In the 63 cases presented here, the major symptomatic complaints of the patients were sciatica and/or back pain. While the multi-institutional study excluded patients with workmen's

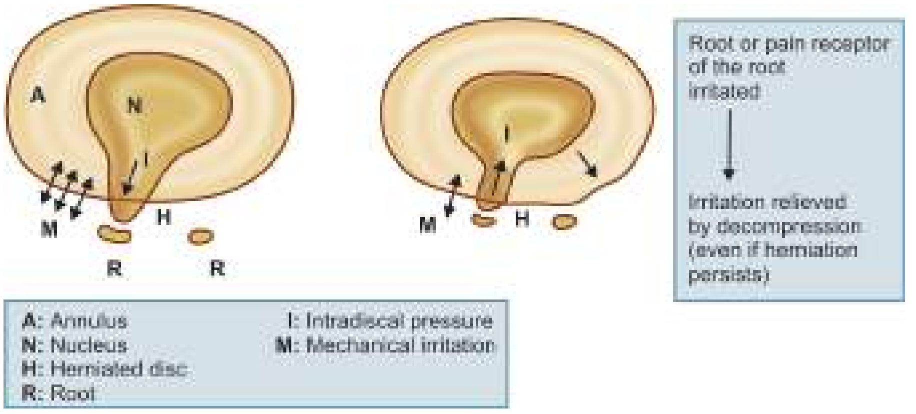



**Fig. 31.1:** Mechanism of reducing intradiscal pressure as proposed by Dr Hijikata

compensation claims and patients with previous surgery, those patients were not excluded from having the procedure in my clinical practice as long as they met the clinical and radiographic criteria for a contained disc herniation.

In my current experience, discography followed by CT is of great value in properly identifying the painful disc space, contained disc herniation and selecting patients who will benefit from the procedure (Figs 31.2A to C).

CT discography is used as a diagnostic procedure prior to percutaneous discectomy to show the internal morphology of the disc and is usually performed at the operating table a few days before surgery. A CT discogram can give a carbon copy of the patient's clinical syndrome and in the author's current opinion a disc protrusion combined with degeneration less than 25 percent according to dallas discogram discription (DDD) is predicted to respond successfully to this treatment.

The CT discogram can also be extremely useful in ruling out those patients whose pain is not organic. This nonorganic patient is not advisable for any surgical procedure including automated percutaneous lumbar discectomy.

Plain X-ray of the lumbar spine is helpful in detecting anomaly like lumbosacral transitional vertebra (LSTV) and severely degenerated disc which are contraindicated for the procedure.

Myelography, CT scan and MRI are useful in selecting the pathological disc levels to be further evaluated with CT discography and in ruling out other nondiscogenic pathology.

## Position of Patient

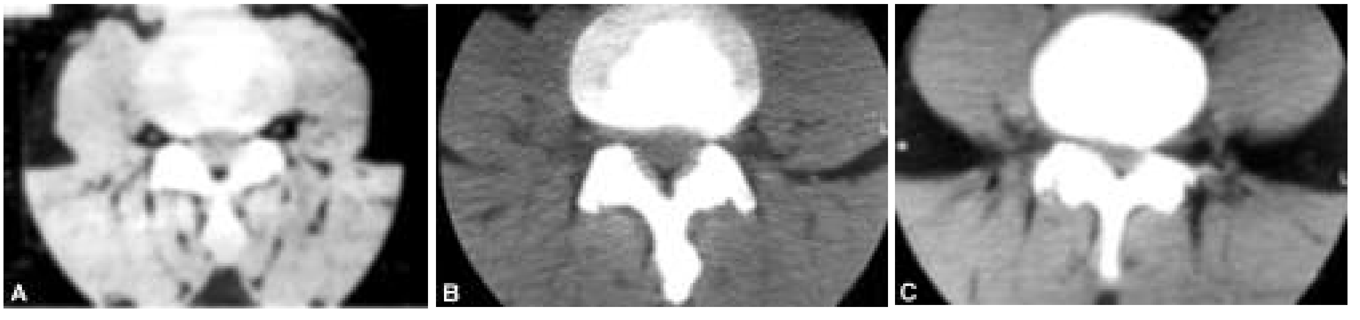
The procedure can be performed with the patient in either prone or lateral decubitus position. When the patient is in prone position, we use a Collis table and place bolsters under the patient's abdomen to open the disc spaces posteriorly. When the patient is in the lateral decubitus position, in making sure that the patient is flexed, we take great care to ensure that the patient is not rotated out of a straight lateral position.

Theoretically, if there exists a so-called laterality of symptoms or root signs, the patient should be laid on the symptom-free side. The painful side should be uppermost and will be the side of entry for APLD. However, in practice, the side of entry should facilitate the instrument to reach as close as possible to the location of herniation as show in Table 31.1.

Hyperflexed position, as is usually done for the lumbar tap, is unnecessary for this procedure. A slightly flexed position

**Table 31.1:** Location of herniation and side of entry of instrument

| Location of herniation | Side of entry |
|---|---|
| • Far lateral | Same side as herniation |
| • Posterolateral | Opposite side from herniation |
| • Central | Either side or both side biportally |




**Figs 31.2A to C:** (A) Normal CT discogram; (B) CT discogram showing disc degeneration and less than 25% disc protrusion; (C) CT discogram showing disc degeneration and protrusion more than 50%

is good enough and relaxes the patient both physically and psychologically, pillows or towel rolls are placed on the operating table to ensure a convexity of the patient's lumbar column at the site of puncture.

The straight lateral position can be confirmed by noting the spinous process to be midway between the pedicles in the anteroposterior fluoroscopic view. While positioning the fluoroscope for the procedure in the lateral view, the sacrum should first be identified and then, using continuous fluoroscopy, the unit is moved up to the concerned disc space.

## Determining the Entry Point

After the lower lumbar region and buttocks are widely sterilized, using a lateral fluoroscopic control an entry point is chosen.

The plane of the center of the disc can be easily detected in cases where the L3-4 and/or L4-5 disc levels are involved. In cases of the L5-S1 disc level, it is somewhat more complex. Three dimensional consideration is required.

According to the inclination of the desired disc, an entry point is chosen at the cross-point of the disc plane on the skin. The entry point on the skin of the L5-S1 disc is near that of the L4-5 disc, which is located approximately 8 to 12 cm lateral from midline.

## Anesthesia

General anesthesia is contraindicated and the procedure is performed under local anesthesia. Local anesthesia with 0.5 percent xylocaine or lidocaine plus adrenaline 1 in 100,000 is injected into the skin all the way down to the paradiscal structure.

The 20 to 30 mL of 0.5 percent xylocaine/lidocaine is needed for a successful and painless procedure.

Intradermal and subcutaneous anesthesia is given in a 1 $cm^2$ area around the entry point. The 19 gauge discography needle is directed toward the appropriate disc by the posterolateral approach.

Advancement is at an angle of $50^o$ to $60^o$ from the sagittal plane and anesthesia is applied from the skin until the tissue around the facet joint.

Due to the course of the nerve root, no anesthesia drug is injected in between the facet joint and the outer layer of the annulus to keep its chance producing radicular pain when the nerve root is touched or approached by the APLDs instrument.

## Placement of Nucleotome

Through a 3 mm skin incision at the entry point, 18 gauge flex-trocar is inserted at an angle of $50^o$ to $60^o$ from the sagittal plane until the outer layer of the annulus fibrosus is touched.

When the gritty sensation is felt while the tip of flex-trocar is touching the outer layer of the annulus, the tip should be at the posterior vertebral body line (PVBL) (Fig. 31.3) in the lateral fluoroscopic view. When the trocar's tip is high in the foramen or anterior to the PVBL, the chance of producing radicular pain is great.

The radicular pain is the only warning when the trocar's tip is approaching or touching the nerve root.

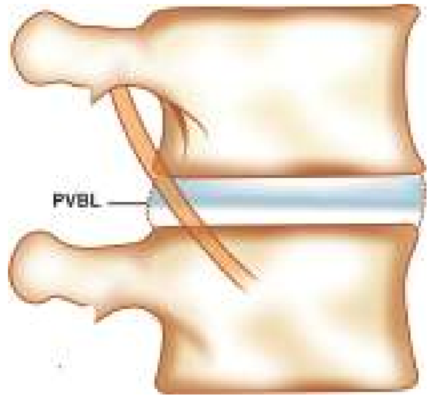



**Fig. 31.3:** The course of the nerve. At the upper end of the foramen it is under the pedicle and course anteroinferiorly. PVBL: Posterior vertebral body line

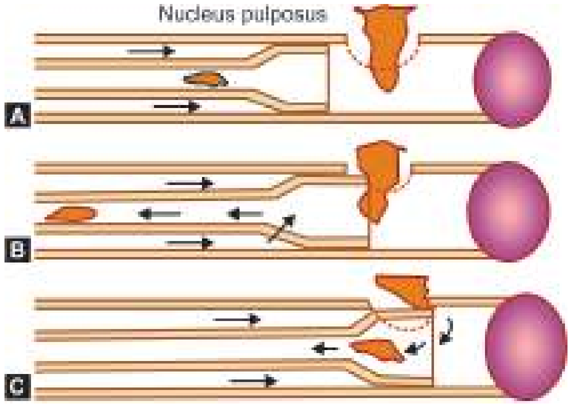
The flex-trocar should be withdrawn and redirected or a correction of the patient's position is made. The possibility of rotation in lateral decubitus position produces a false image of the PVBL.

The position of the flex-trocar is confirmed in both AP and lateral views. In the AP view, the tip of the flex-trocar should be lateral to the line that connects the medial borders of the pedicles, since the thecal sac lies medial to this line (Fig. 31.4).

When the tip of the flex-trocar is in the correct position, it is advanced to the center of the disc, the position of the flex-trocar is again confirmed in both AP and lateral views.

The cannula with tapered dilator is passed over the flex-trocar and inserted down to the wall of the annulus. The tapered dilator is removed from the cannula, leaving the flex-trocar cannula in place. Because the dilator extends 2 mm beyond the cannula,

**Fig. 31.4:** The position of the tip of flex-trocar as seen in AP view




**Figs 31.5A to C:** Cross-sectional view of the distal end of the probe. (A) Vacuum draws the nucleus material into the cutting port; (B) Reciprocating cutting guillotine action ensures maximum safety with optimum cutting; (C) Irrigation removed aspirated disc material from the probe

therefore the cannula should be advanced until it rests against the annulus.

The trephine is placed over the flex-trocar and passed through the cannula. The trephine is rotated in a clock-wise motion with slight pressure to incise the annulus. After incision has been made, the trephine and the flex-trocar are removed from the cannula.

The nucleotome probe with cannula seal nut, is inserted into the cannula and the nut is locked into the place.

At the beginning of the procedure, the maximum cutting rate should be used to cut smaller pieces of disc and prevent the instrument from clogging. Later in the procedure, when the amount of disc material being aspirated decreases, the cutting rate can be slowed to allow more time for disc material to enter the port before it is cut (Figs 31.5A to C).

The port of the instrument is first turned toward the area of the herniation and as much disc material as possible is aspirated from this region before the port is turned to other areas. Slowly move the probe back and forth the full length of the disc while keeping the port in the direction of the herniation.

## Results

Sixty-three patients were treated by APLD over the last three years. All the patients were strictly selected using CT discography and were diagnosed as lumbar disc herniation protrusion stage with degeneration less than 25 percent according to Dallas discogram discription.

The number of cases, mean age, age distribution, clinical diagnosis, levels of disc pathology, site of herniation are shown in Tables 31.2 to 31.4.

The mean age of the 45 males and 18 females was 40. The eldest was 64 years and the youngest was 17 years (Table 31.2).

Only protrusion stage of herniation whether primary or recurrent were treated by this procedure (Table 31.3).

L4-5 discs were most commonly and easily treated. L5-S1 discs were less common and L3-4 disc were rare.

**Table 31.2:** Sex distribution and diagnosis of herniation

| Male/Female | No. of patients |
|---|---|
| **Patients** | |
| Male | 45 |
| Female | 18 |
| Total | 63 cases |
| **Diagnosis** | |
| Primary herniation | 59 |
| Recurrent herniation | 4 |
| Total | 63 cases |

**Table 31.3:** Level and frequency of disc herniation

| Level of prolapse | No. of patients |
|---|---|
| **Single** | |
| • L3/4 | 2 |
| • L4/5 | 34 |
| • L5/S1 | 18 |
| Total | 54 discs |
| **Double** | |
| • L3/4, L4/5 | 1 |
| • L4/5, L5/S1 | 8 |
| Total | 9 |

**Table 31.4:** Clinical presentation and age distribution of disc herniation

| Clinical pattern | No. of patients |
|---|---|
| **Site** | |
| • Lateral far lateral | 40 |
| • Central | 32 |
| Total | 72 discs |
| **Age distribution** | |
| • Less than 20 years | 3 |
| • 21–30 years | 5 |
| • 31–40 years | 30 |
| • 41–50 years | 13 |
| • 51–60 years | 10 |
| • 61–70 years | 2 |
| Total | 63 patients |

The clinical evaluation was done according to Japan Orthopedic Association's Score (JOA's score) before the operation. The total score for a normal person is 26 and an increasing clinical score toward the normal score means an improvement in the clinical condition of patient.

Changes in symptoms and signs are observed immediately after the procedure, one day, one week, two weeks, one month after the procedure and followed every month until six months after the procedure.

For the purpose of observation, patient stayed in hospital for one day after the procedure and re-evaluated at outpatient clinic according to the schedule.

Within the first week after the procedure patients were not allowed to bend forward, lift objects or work. After one week patients were allowed to do light work and the workload was increased until 6 to 12 weeks after the procedure.

Recovery rate was calculated according to the formula proposed by Satomi in 1994 (Table 31.5).

$$\text{RR}\ (\%) = \frac{\text{Postoperative score} - \text{Preoperative score}}{\text{Total score} - \text{Preoperative score}} \times 100$$

By this formula excellent indicates that recovery rate is above 75 percent. Good indicates that recovery rate is 50 to 75 percent. Fair indicates that recovery rate is 25 to 50 percent. Poor or failure indicates that recovery rate is less than 25 percent, whether no improvement and worsening or some improvement but less than 25 percent as shown in Table 31.5.

**Table 31.5:** Results

| Recovery rate | Percentage |
|---|---|
| Excellent | 75 |
| Good | 50–75 |
| Fair | 25–50 |
| Poor/unchanged | 25 |

Result of treatment by RR's formula (Satomi, 1994)

Recovery rates were calculated one day and six months after the procedure (Table 31.6). The results of sixty-three cases one day after procedure are shown in Table 31.6.

Forty-five cases showed excellent result or direct improvements. Six cases showed good results and eight cases showed fair results, while four cases showed poor results.

**Table 31.6:** Recovery rate one day after the procedure

| | |
|---|---|
| Excellent/direct improvement | 45 |
| Good | 6 |
| Fair | 8 |
| Poor | 4 |
| Total | 63 cases |

The results of sixty-three cases six months after the procedure are shown in Table 31.7.

Fifty-nine cases showed excellent results and four cases showed poor results. Gradual improvement was seen in five good cases, eight fair cases and one poor case toward excellent results. One good case experienced worsening toward poor result, because she could not reduce her full working activities to support her family's need since one week after the procedure.

The success rate of sixty-three cases by APLD after six months was 93.7 percent.

**Table 31.7:** Recovery rate six months after the procedure

| | |
|---|---|
| Excellent | 59 |
| Good | – |
| Fair | – |
| Poor | 4 |
| Total | 63 cases |
| Success rate | 93.7% |

Among these four unsuccessful patients, or 6.3 percent of the cases that failed, two were treated by conventional open surgery. Two patients refused further treatment after poor results following APLD.

There was no complication during the procedure and no recurrency up to 3 years after APLD.

## Discussion

Lumbar disc herniation and/or disc degeneration are the most common lesions afflicting the back in Indonesia and many other countries.

Most of these lesions can be treated conservatively, however, when they cannot, disc removal by partial hemilaminectomy, many kinds of fusion, such as posterior or anterior interbody fusion, and fusions with spinal instrumentation are the most common operative procedure to be used.

APLD appears to be an alternative less invasive procedure to treat certain disc herniation, mainly the protrusion stage with disc degeneration less than 25 percent DDD.

According to this strictly selected indication by CT discogram, the results of APLD procedure are 93.7 percent good.

However, the end results are not only determined by the procedure but also by load of activities during the period of natural healing of the disc. One good case experienced worsening toward poor result due to excessive activities one week after the procedure, but fourteen other cases got a gradual improvement toward excellent results over a period of six months.

A study of 75 patients who had undergone a simple laminectomy and disc excision by Swedish orthopedic and neurosurgeons and followed over a period of 15 years, showed that 95 percent experienced symptomatic relief within six months, but over the next fifteen years time span, only 40 percent remained pain free.

This indicates that the human lumbar spine is a continuously decaying structure and that problems with it must be treated more than once in a life time. It is incumbent upon spine surgeon to address this problem safely and with as little disruption of normal structures as possible.

The key to success is to select the problem properly addressed to the procedure, because every instrument and procedure is designed with its own specifications but also with its own limitations.

The current results show that APLD, because of its safety and efficacy, should play a valuable role in treatment of protrusion stage with less than 25 percent disc degeneration in primary as well as recurrent disc herniations.

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# 32

# Laser Assisted Percutaneous and Endoscopic Lumbar Discectomy

*Martin TN Knight*

## Introduction

Backache and sciatica is a common aliment. In the United Kingdom 2,00,000 patients present to the general proactitioners with back pain each month. It is the single, most common, work related injury and represent the greatest cause of lost days of work. It is a well known fact that 90 percent of the patients responds to conservative treatment. Sciatica occurs in 20 to 30 percent of the patients with backache and 50 percent of them responds to conservative treatment. Recurrence is common in 10 to 20 percent of the cases. Those who do not respond to conservative treatment are subjected to surgery and in the United Kingdom 3500 patients undergo surgery for backache and sciatica each year.

The principle of surgical intervention should be to remove only the degenerated disc tissue and where possible to restore the function of disc, soft tissue and the joints. Traditional surgical procedures involves exposure of the spine resulting in significant morbidity and prolonging the convalescence. The techniques also involve complications like nerve root injury, scarring in the spinal canal around the roots and iatrogenic instability in the motion segment requiring another major operation for stabilizing the spine.

## Laser System

The laser system provides the surgeon with the flexibility to treat small disc protrusions with selective ablation of degenerate material. It also helps the surgeon to undertake more major interventions encompassing disc extrusions, facet joint arthritis, percutaneous fusion and disc replacement to be undertaken using laser as the cutting tool. The most common cause, however, to which the laser is put to use is prolapse of lumbar intervertebral disc. This is, in fact the most recent modality for surgical management of prolapsed disc. It is now being more frequently used in several centers. In 1993 biomechanical studies using laser for evaporation of nucleus pulposus were reported from Germany.[1] In 1994 Stein and Stolman reported the first laser assisted laparoscopic lumbar discectomy from New Jersey. The 27 years old patient experienced immediated relief from backache and sciatica. A couple of more reports appeared in the same year.[2,3]

### Basic Principle

The basic principle involved in this procedure is on the same lines as for automated percutaneous lumbar discectomy with added advantages. The nucleus pulposus is evaporated by using laser, in such proportions as to cause decompression and reduce intradiscal pressure so that the compressive force on the nerve root is immediately relieved. A more sophisticated pulse surgical laser based on alumo-yttrium-garnet with neodymium ensures a complete bloodless discectomy.

### Principles of Surgery

It can be done either as percutaneous endoscopic laser evaporation known as percutaneous endoscopic laser decompression of the intervertebral disc (PELDID) or as microsurgical procedure known as microsurgical laser discectomy (MLD). In this procedure the laser is applied directly under vision with the help of microscope through laparoscopic exposure and contact laser application. The relief of backache and sciatica is immediate. The SLR improves immediately but like in percutaneous discectomy the bulge of the disc can be seen on repeat MRI studies although the pressure within it is reduced. The relief of pain in this procedure has to be more than 95 percent.

This is a minimally invasive surgery and the greatest advantage of such minimally invasive procedures is the fact that the patient can return to his original job with a minimum period of convalescence. Best results are obtained with unilateral disc prolapses.

## Material and Methods

The spinal foundation is equipped with 2 "Double pulse": Holmium 80 Watt laser generators and 2 KTP laser generators and a bar-coded database collection system developed with ICL. Theatre endoscopic picture capture, CD ROM Medline and a National patient referral base.

During a period of four years more than 850 laser discectomies have been carried out. In 300 of these cases laparoscopic techniques were used to visualize the inside of the disc or spinal canal.

## Investigations

Nothing surpasses a careful clinical history and detailed clinical examination. Non-weight bearing static X-rays do not give sufficient information. Plain X-rays are performed under weight bearing conditions and in flexion and extension.

An MRI scan is routinely performed to demonstrate the degree of disc protrusion and the degree of disc degeneration. MRI scan also show the position and shape of the disc prolapse and this helps in planning and defining the target more accurately. Definition of the shape of disc protrusion helps to decide the modality of laser treatment namely: Percutaneous laser disc decompression; Flexible endoscopic intradiscal discectomy or Endoscopic laser foraminoplasty.

When the signs of compression are confusing or when assessment of likely recovery of fuction is required electromyogram (EMG) is performed.

## Viviprudence

Viviprudence is the process of careful garnering of clinical history, clinical examination and investigations supplemented by the aware state procedures of spinal probing and discography. When the clinical findings are confusing discography helps to define the cause of sciatica. Viviprudence helps to avoid the problems of prefixed or postfixed nerve roots, bifid roots, lateral discs and far out lateral discs.

## Principles of Laser Surgery

- Only the degenerated disc material is removed.
- Disc height is maintained.
- The buffer/washer function of the intervertebral disc is preserved.
- The procedure delays the onset of facet joint arthritis.
- Creeping degeneration due to acids and enzymes in the degenerated disc is slowed down.
- The procedure can be offered to the patients much earlier than the standard procedure opening the possibility of a prophylactic approach to the treatment of backache.

## Treatment Options

The following options are available:
- Percutaneous laser disc decompression (PLDD)
- KTP or holmium wave length options.
  - Posterior wall reconstruction (PWR)
  - Flexible endoscopic intradiscal discectomy (FEID)
- Uniportal or biportal options
  - Endoscopic laser foraminoplasty (ELF)
  - Endoscopic intradiscal fusion (EIF)
  - Bionucleoplasty -Endoscopic disc reconstruction (EDR)
  - Endoscopic epiduroplasty (EE)

## Percutaneous Laser Discectomy

The percutaneous laser discectomy is achieved by passing a side firing laser probe into specific area of the disc under X-ray control (Fig. 32.1). The laser beam is then directed at the degenerated tissue and it is vaporized. The pressure on the nerve root is immediately reduced. It is most useful to remove all broad based disc protrusions.

## KTP 532 Laser Discectomy

A KTP 532 laser discectomy is useful in following conditions:
- Wide based disc protrusion
- Protrusion occupying less than 30 percent of the antero-posterior diameter of the spinal canal
- Weight bearing lumbar disc height of 4 mm or more
- Dynamic retrolisthesis of 3 mm or less
- A contained disc
- A primary disc (unexplored before).

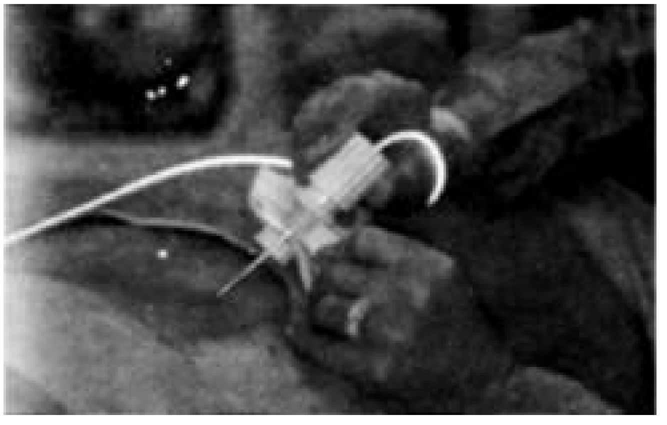

**Fig. 32.1:** Simple percutaneous KTP 532 laser discectomy through a 2 mm portal

## Holmium Laser Discectomy

Holmium laser is good where thermostatic effect is sought. Holmium wavelength helps to shrink the posterior wall. The depth of cut is 0.4 mm and should only be used when probe is closely approximated to the degenerate material. This wavelength is useful for FEID and ELF procedures. The Holmium wavelength has a thermoacoustic effect upon tissue and should be used in an vented environment in the presence of suction. The use of double pulse holmium laser system allows the use of higher energy levels and shortens the time of operation.

## Double Pulse Holmium Laser Discectomy

Double pulse holmium laser discectomy should be performed in patients with:

- A wide based disc protrusion
- A protrusion occupying less than 30 percent of AP diameter of spinal canal
- Weight bearing lumbar disc height of 4 mm or more
- Dynamic retrolisthesis of 3 mm or less
- A contained disc
- Previously treated disc with preserved height.

## Results

Laser discectomy using KTP 532 surgical laser system is a safe and effective alternative to open surgery discectomy. Our early result show that 92 percent of the patients are satisfied with the laser discectomy at the end of one year, 87 percent are satisfied at the end of 2 years and 85 percent are satisfied at the end of 3 years.

## Advantages of Laser Discectomy

- It can be performed as outpatient procedure
- Do not preclude alternative surgical options
- Reduce the risk of complications
- Provides immediate relief of pain
- Minimum soft tissue injury
- No bone is sacrificed
- No epidural fibrosis.

## Posterior Wall Reconstruction

Initially detection of radial tear on MRI was a chance finding and annular leaks failed to be detected by MR in 2 out of 3 cases. Discography, then, is the only method of detection of this pathology. They can be satisfactorily treated by KTP 532 laser. The thermostatic effect is utilized which shrinks the tear margins and is then supplemented with a blood patch serially laminated on the tear to reinforce the seal. This is known as posterior wall reconstruction. It takes three to four months for the seal to mature and leak to heal. Review at 18 months has shown more than 85 percent good results.

## Flexible Endoscopic Intradiscal Discectomy (FEID)

This procedure can be performed through one or two approaches (Fig. 32.2) but with the advance in technology it is possible to do discectomy through a single (uniportal) approach. The procedure is performed after doing discography. The endoscope is railroaded down to the disc. The wall of the disc is opened and the endoscope is inserted into the disc space. The disc material is ablated by a side firing probe using Holmium or KTP 532 wavelengths. It is useful in more advanced disc degeneration or when the patient is suffering from complications of previous surgery. It is also useful in narrow disc protrusions, protrusions occupying less than 40 percent of AP diameter of the spinal canal, weight bearing disc height of 3 mm or more, dynamic retrolisthesis of 4 mm or less, a contained disc (not useful when there is leak) and previously operated disc with preserved height.

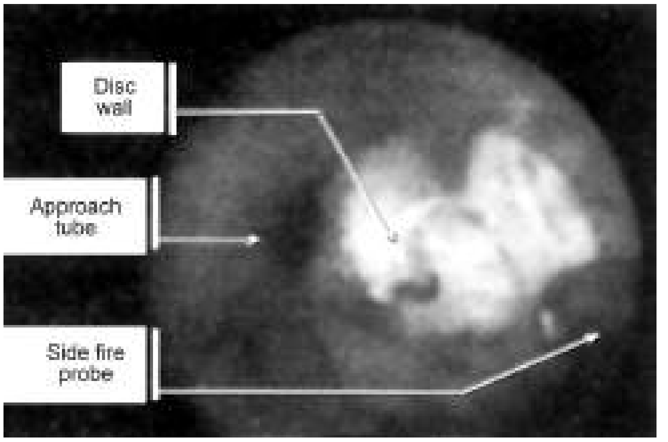


**Fig. 32.2:** Flexible endoscopic intradiscal discectomy (FEID). The laser probe is about to be inserted into the disc wall under vision

Review at two years have shown more than 85 percent good results.

## Endoscopic Laser Foraminoplasty (ELF)

With advances degeneration when the disc space is totally settled key hole surgery, minimizes disturbances to the spinal canal contents while using bloodless cut of the laser to maximum advantage. When the disc material is extruded it is excised by open fenestration. Through a key hole the endoscope can be guided along the nerve root through the foramen into the epidural space. Clearance of disc tissue from the disc space can be achieved with a side firing probe. The tear in the disc tissue can be seen and a FEID can be performed to clear disc material from within the disc space. The technique can also be used for lateral recess stenosis. Small curved endoscopes have been developed to assist the surgeon visualize hidden corners (Fig. 32.3). The ELF procedure opens the lateral recess, decompresses the nerve root, accepts the settlement and allows continued micromovement at the segmental level.

The ELF can be used satisfactorily in the following conditions:

- A narrow based disc protrusion with disc space settlement.
- Protrusion occupying less than 100 percent of the AP diameter of the spinal canal.
- Dynamic retrolisthesis.

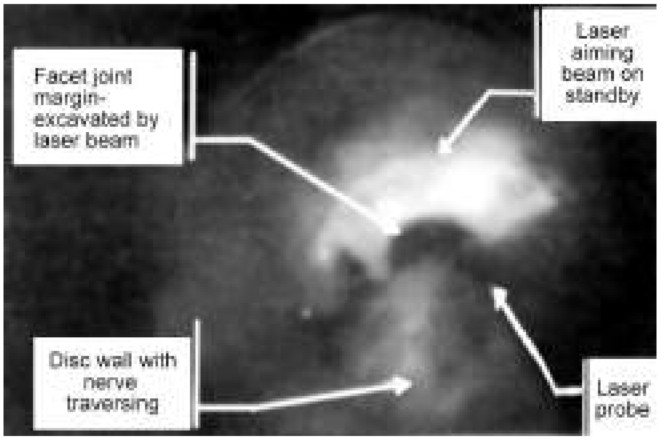


**Fig. 32.3:** Endoscopic laser discectomy with ablation of overgrown margins and osteophytic spurs over a compressed exiting nerve root

- Extruded discs.
- Scarring around nerve roots.

## Endoscopic Intradiscal Fusion (EIF)

Endoscopic intradiscal fusion can be used to stabilize the grossly unstable disc segment which appears to be too damaged to allow disc reconstruction (Bionucleoplasty) (Fig. 32.4). In multiple level disc degeneration where the lowest level has gross soft tissue laxity and instability it is fused and the upper degenerated levels are reconstructed. After an extensive FEID the height is restored hydrolically, the end plate is breached, stabilizing stents are inserted and bone grafts are positioned in the space. The procedure may need to be supplemented cryogenic rhizotomies to the facet joints but this technique has not been so far clinically applied.

## Bionucleoplasty-Endoscopic Disc Reconstruction (EDR)

Following extensive clearance of the disc material within the disc space by FEID bionucleoplasty of comparable size is inserted into the cavity through the approach tube. Bionucleoplasty alters its shape and height to fill the cavity and restore the disc height. The procedure should be used in every case where acceptance volume is increased by 1.5 mL. Presently this procedure is reserved for patients with large acceptance volume with or without lateral recess stenosis. In case bionucleoplasty gets spoiled it can be removed by laser techniques and replaced by a new one.

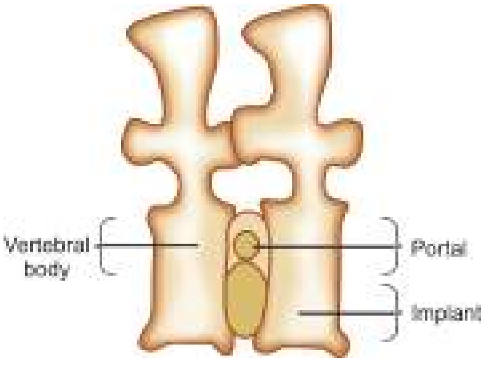


**Fig. 32.4:** Schematic representation of a bionucleoplasty inserted into the intradiscal space

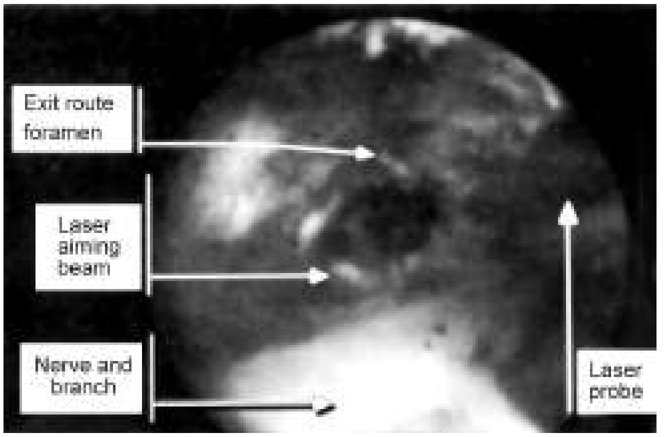


**Fig. 32.5:** Decompression of nerve root by excision of scar tissue from previous surgery. The white looking nerve root and its branch has been decompressed, the laser probe is pointing at the residual disc tissue which needs excision

## Endoscopic Epiduroplasty (EE)

During endoscopic laser foraminoplasty the anterior epidural space can be explored with the help of flexible endoscopes and any anterior epidural space surgery can be carried out (Fig. 32.5). Even the posterior epidural space can be approached through a posterior skin puncture and perforation of the ligamentum flavum. Any surgery in this region can be done with side firing lasers.

## Myeloscopy

The principle involved is the same as epidural endoscopic epiduroplasty. The dura is opened and the cord is inspected. Any adhesions, fibrous bands, etc. can be divided by means of laser. This approach may help cases of arachnoiditis. This site of inflammation can also be demonstrated. Even through the sacral hiatus, the endoscope can be passed up to the conus.

## Endoscopic Facet Joint Surgery (EFJS)

It is possible to visualize the facet joint innervation and specially the anterior nerve fibers and then divide them by sidefire laser probes and Holmium ablation. The joints can be opened and the rough surfaces can be sculptured using Holmius side firing laser probes. In future, it is proposed to combine this procedure with Bionucleoplasty when significant settlement requires correction in the presence of facet joint degeneration.

### Minimal Intervention Fenestrectomy (MIF)

Traditionally, fenestration is done for disc degeneration with significant bone overgrowth from the facet joints and the vertebral margins. Pure laser discectomy in these cases will be inadequate. When combined with laser foraminoplasty the facet joints and the osteophytes on the vertebral bodies can be cleared. A bionucleoplasty will restore the height and the nerve root will be free.

## Laser Techniques

### Preparation of Patient

The procedure is done under intravenous analgesia. Nonsteroidal anti-inflammatory drugs are usually given for 2 to 3 weeks after the procedure. The patient is positioned on the operating table in the shape of hump-backed bridge to facilitate the use of C-arm.

The skin is prepared and the entry point is anesthetized with local anesthetic. The skin is punctured with fine 1 mm diameter probe. The direction of the probe has to be predetermined and checked with C-arm. Through the probe a fine needle is passed up to the intervertebral disc which is pierced by the needle. Radiopaque dye is instilled and X-rays are taken. The interpretation of discography is done by seeing the X-rays, and the appropriate laser procedure is selected for the patient.

### Laser Decompression of Disc

For laser decompression of the disc the laser probe is passed down the tube up to the intervertebral disc and then into the disc itself.

The contents are vaporized with appropriate laser beam as discussed earlier. The peripheral disc material is coagulated to a mean depth of 0.42 mm. Vaporization and suction causes the disc wall to be pulled into the disc space away from the spinal cord.

### Endoscopic Discectomy

In this procedure, the disc is excised under vision. The procedure is done under local anesthesia like percutaneous Laser discectomy on a hump back table. A dilator tube is passed along the guide wire inserted into the disc. The dilator is withdrawn and the endoscope is introduced. The disc space is entered under vision. Flexible endoscopes and side firing laser beams allows disc material to be removed more completely from within the disc.

All other laser procedures can be done through the endoscope. For bionucleoplasty a 3.5 mm skin incision is required.

### Postoperative Course

The laser procedure, percutaneous or endoscopic, achieve their goals by minimizing the disturbance to tissues and natural architecture. Open procedures like laminectomy, microlumbar discectomy, fenestration, etc. open the tissue planes and lead to fibrosis. Key hole surgery cause very little tissue disturbance and allows rapid early mobilization. The postoperative convalescence is very short and the patient can be treated as day care patient.

### Complications

In inexperienced hands Neodymium YAG Laser can cause injury to bowel, aorta and other vessels. Neodymium YAG Laser travels up to 12 cm through water and certain tissues. The KTP 532 Laser travels 4.5 mm and the Holmium “Double pulse” Laser travels 0.4 mm through the tissues. There has been no such complication in our series. There were three case of intradiscal aseptic discitis following endoscopic laser procedure. All the three cases resolved satisfactorily.

Endoscopic procedures do not provide space for swelling and patients must be rehabilitated in a particular way to avoid discomfort caused by such transient swelling of the tissues. Nonsteroidal anti-inflammatory drugs are given for two weeks.

### Immediate Flare

Five percent of the patients develop dysasthesia almost immediately following surgery. Dysesthesia could be a chemical phenomenon from irritation by released tissue enzymes. This immediate flare lasts for 3 to 6 weeks. Following conclusion of the procedure local instillation of steroids decreased the rate of dysesthesias or immediate flare to 1 percent.

### Early Flare

Following endoscopic procedures, the swollen tissues have no place to ease. Early flare occurs between 7 and 14 days after surgery reproducing the preoperative symptoms. It does not require special attention and NSAIDs help to relieve the pain.

### Late Flares

Recurrence of pain a month after surgery arised from swelling in the synovial joints (facet joints) in the lumbar spine during the process of adjustments to the altered height and orientation of the disc.

### Contralateral Flare

Some patients following Laser procedure complain of pain on the opposite side at the same level. They complain of pain which was not there before. It is caused by spread of inflammation across the longitudinal ligament to affect the opposite side. It resolves with NSAIDs.

### Return to Original Job

Those patients doing sedentary work, traveling a short distance in their own car can return to light duties within seven to ten days following surgery. Moderate manual laborer resumes work after six weeks. Occupations involving heavy lifting will delay returing to these activities for 12 weeks.

Patients are reviewed at 6 weeks, 12 weeks, 6 months, one year and thereafter every year or as appropriate.

## Conclusion

The use of visualized Laser technique should allow us to effect more accurate ablation of the disc and more selective clearance of degenerate portions of the disc. The procedure is a short one done under local anesthesia. It can be done on a day care basis. The convalescence is short, relief of pain is more than 95 percent and prospects of returning to the original job in a short period of time are high.

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# Thermodiscoplasty and Percutaneous 360 degree Rhizolysis as a Treatment for Herniated Disc or Facet Lumbar Pain

*Enrique Osorio-Fonseca, Jorge Felipe Ramírez, José Gabriel Rugeles, Gabriel Oswaldo Alonso*

## Introduction

Due to the complex physiopathology of lumbar pain and its various multifactorial origins, along with this phenomenon's implications on public health, it is clear that the first options we should offer patients suffering from low back pain are conservative alternatives. These options should be applied sequentially, starting from the simplest and ending with the most complex, in other words, starting with clinical options like physical therapy, pain medication, external supports and even facet blocks.

After exhausting noninvasive possibilities, the next step should be minimally invasive surgical options. These techniques, having lower damage to adjacent structures, allow the patient a faster return to day-to-day activity with fewer risks and complications; they also are cost-effective and more esthetic. Likewise, due to their nature, they do not hinder the option of implementing conventional or open techniques in complex cases if they are possible.

Lumbar thermal therapy using percutaneous methodology has allowed patients suffering from low back pain to have new possibilities. These procedures have combined the concepts of minimal damage and fewer complications while using state-of-the-art technology.

Radiofrequency energy has proven to be an efficient and very safe option for thermal intradiscal treatment. Its versatility allows performing in only one surgical act, two interventions for the main cause of low back pain, namely disc herniation and facet osteoarthritis.

## Importance and Origin of Disc and Facet Pain

In 2003, the World Health Organization (WHO) defined low back pain as a "variable duration pain, which generally causes partial or total work disability, interfering with quality of life and an important cause for consultation".[1] It is the most expensive benign condition for the health care system in industrialized countries because, it limits people younger than 45, i.e. the productive stage of their lives.[2]

Low back pain does not show a particular distribution among the different segments of population. It occurs in similar proportion in all cultures. Figures in the United States of America show that approximately 80 percent of Americans have had low back pain at some point in their lives.[2] They estimate that approximately 3,091,150 people[2,3] are chronically incapacitated due to low back pain, and around 2 to 4 percent of the American working population receives a yearly compensation for this pathology.[2,4] In Europe, low back pain in responsible for 10 to 15 percent of working disabilities, and it has an annual prevalence between 25 and 45 percent, ending in chronic pain in 3 to 7 percent of cases.[4] In Colombia, figures from 2001 show that low back pain in 1992 was the third cause for consult in the emergency room and the fourth one for general consult, the first pathology causing working transfers, and 5 percent of the total causes for permanent disability.[5] In 2006, low back pain was divided in two diagnoses: lumbago and intervertebral disc syndrome.[6] When compared, it came as the second and third most common diagnoses regarding

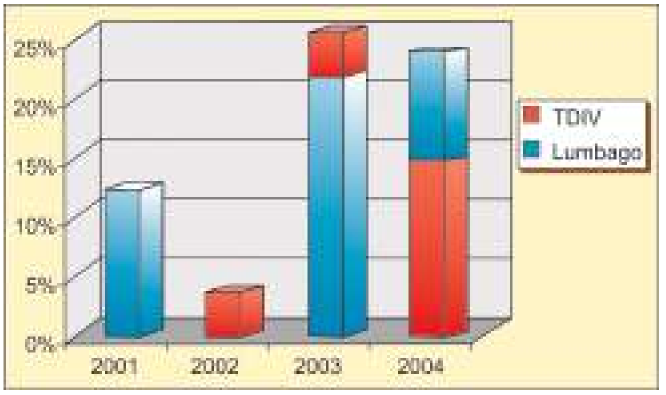
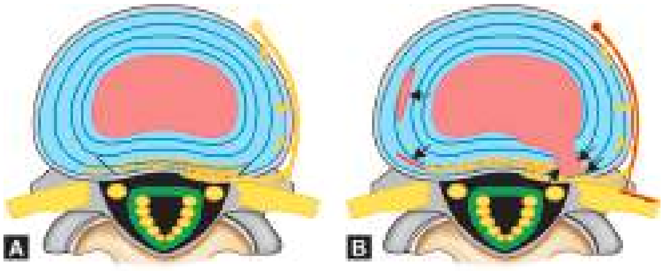



**Fig. 33.1:** Tendency of job-related illnesses related to low back pain in the Sistema Colombiano de Seguridad Social between 2001 and 2004 (*Source:* Ministerio de la Protección Social[6])




**Figs 33.2A and B:** (A) Healthy disc with nerve endings in external layers; (B) Degenerated disc with a neogenesis process of nerve and vascular endings

work-related illnesses, right after carpal tunnel syndrome. The increase in the incidence of these types of pathologies is shown in Figure 33.1.

Regardless of its importance in public health, the physiopathology of low back pain is not completely understood. This mainly happens due to its multifactorial nature.

There are a lot of theories about the origin of discal low back pain. One of them considers that with the microtraumas, disc tearing occurs followed by pulpy nucleus tearing. This tearing causes vascular and nervous neogenesis, and thus, there is the presence of nociceptors, which may be the reason for pain (Figs 33.2A and B).[7] Damage in the intervertebral disc and other mechanical factors could affect the orientation of the facet articulation, with this last factor being an important cause of low back pain.[8-10] Another hypothesis stresses the development of radicular symptoms and pain due to the pressure on the nervous system from the flavum ligament and the facet articulation, with symptoms getting worse when the articulation is calcified.[11]

As we said before, the facet component of low back pain follows biomechanical alterations of the articulation caused by pressure and weight, which affect the anatomy of the facet structures. Among these structures we have the hyaline articular cartilage, the synovial capsule and membrane, and the intra-articular meniscus. The degenerative process continues with the hypertrophy of the synovial membrane and the consequent progressive deterioration of the cartilage: fibrillation, cracking, fragmentation and, in severe cases, the presence of free intra-articular bodies. This damage to the cartilage alters the structure of the intervertebral complex, causing instability and pain. Excessive pressure and weight results in tearing the fibrous ring and the pulpy nucleus protrusion. Nociceptors in the sensitive fibers of the common posterior vertebral ligament react and generate low back pain.[10]

It is important to note that degenerative changes that affect each one of the structures that make part of the intervertebral space, the two articular facets and the disc are involved in generating back pain.

## Thermal Intradiscal (Thermodiscoplasty) and Facet Therapy for Low Back Pain

One of the most important advances in surgery in the last four decades has been the development of minimally invasive techniques. This development in back surgery started in 1931 with Burman and his myeloscopy,[12] but it was until the 90's that verifiable clinical results were obtained through the implementation of thermal energies, the use of fluoroscopy and the approval of the Food and Drug Administration (FDA) of this technique in humans.[13] The publications that started in that decade and the following ones have shown that minimally invasive spine techniques achieve clinical effects comparable to open techniques but they minimize the inherent risks of open surgeries.

In the treatment for low back pain from discal or facet origin, excellent results have been achieved when implementing less aggressive surgical techniques. Thermal therapies and thermal discoplasty and intra-articular rhizolysis (facet denervation) for facet osteoarthritis are classical examples of minimally invasive techniques.

The idea of using high temperature thermal therapy to treat low back pain was born from the experience and the results in other articulations like shoulder or knee articular capsules. This therapy, in high dosages, stabilizes the articulation with the acute shrinking, which is strengthened through time by biological remodeling. Studies using animal testing showed the regain of the articulation normal mechanical function between 30 and 90 days after treating the articular capsule, while for the tendon it occurred around 12 weeks after treatment.[14] *In vitro* studies reported an increase in cellularity, reactivation of the fibroblasts, increased vascularization, degrading and replacing of collagen fibers and granulation. All of these phenomena occurred between 90 and 180 days of the healing process.[11]

## Biological Effects and Physiopathology of Thermodiscoplasty

The energy used by each one of the devices in thermal discoplasty techniques is turned into thermal energy, meaning creating high temperatures in the intradiscal zone. Even though biological effects of thermal discoplasty are not clear yet, the following action mechanisms have been proposed: collagen modulation and shrinking of the disc with stabilization potential.[15]

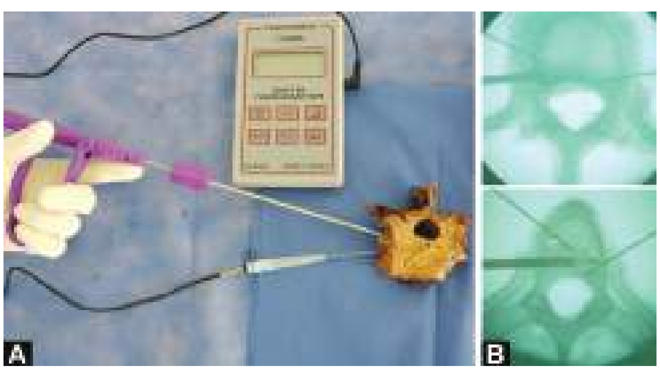

**Fig. 33.3:** Effect of collagen shrinking by heat

Heating the disc has two potential effects. First, due to the fact that the disc is rich in collagen, its heating may cause local denaturalization, shrinking and contraction (Fig. 33.3). This can potentially decrease the capacity for neovascularization and the growth of new nerves, and also helps to seal the annular crack. Second, the amount of heat to the exterior of the disc exceeds the necessary temperature to destroy annular nervous fibers, which are the origin of nociception. To achieve this, any of the used thermal energies must increase a minimum of 42°C to 45°C in intradiscal temperature.[16]

The evidence of the effectiveness and safety of this method in low back pain has been described in various reports. One of the first ones was done by Saal and Saal, who stated a hypothesis in which thermal energy may play a role in the treatment of radial tearing of the intervertebral disc and thus, treat low back pain. They performed the technique in 25 patients with discogenic chronic pain who did not respond to conservative treatment. From these, 80 percent had a two-point decrease in a one to ten pain scale and 72 percent tolerated reducing medication.[11,16]

Later, Hellinger and Feldman[17,18] and Ramírez, et al.[19] independently studied intradiscal thermal effect of 1.7 mHz high frequency using disc-FX radiofrequency in human samples. These studies showed a significant shrinking of the intervertebral disc and widening of the spinal canal. These studies also indicated the safety of the energy, which was done through continuous surveillance of the energy. The procedure is done by continuous monitoring using temperature sensors and observation with an infrared camera during nucleus ablation (Figs 33.4A and B) and ring modulation. These studies, along with the ones done by Yeung, et al.[15] proved that radiofrequency is a more refined and easier to canalize tool, which allows the surgeon to treat specific areas of the disc with a minimal impact on the adjacent tissue.

For this reason, nowadays thermal discoplasty and facet 360° articular rhizolysis using radiofrequency energy is one of the safest and more effective methods. An additional advantage is that, following indications, it can be performed in a single surgical act.




**Figs 33.4A and B:** Measuring intradiscal temperature[19]

## Thermodiscoplasty and 360 degree Rhizolysis

### Indications

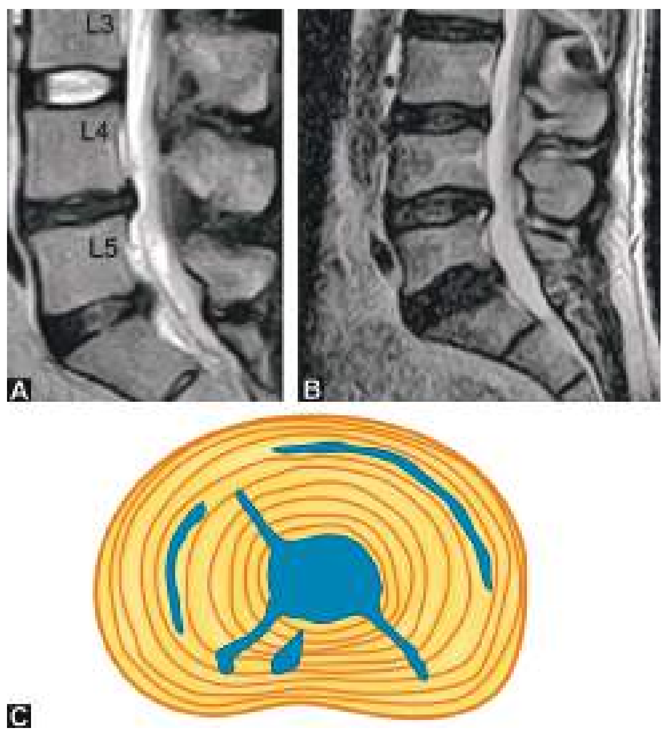
Among the indications for the performance of the procedure, we must find a patient with a previous clinical history longer than 6 months of discogenic pain, treated with NSAID, analgesics, lumbosacral support and physical therapy during at least 3 months.

In radiological findings, images consistent with degenerative disc disease, black disc disease, bulging disc disease, annular tearing, contained disc herniation, or facet osteoarthritis (Figs 33.5A to C) must be found.[20,21]

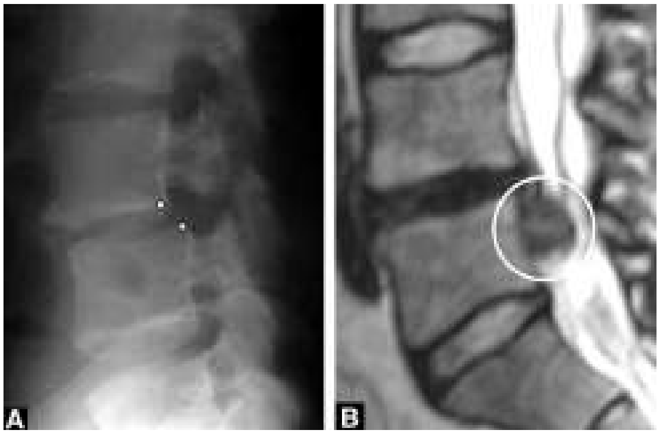
And lastly, within the surgical act, the surgeon must find positive discogenic evidence. This corresponds to 5 or more over a 10-point pain scale when performing the discography at the affected level corresponding to the clinical picture and images.

### Contraindications

There are some pathologies in which thermal discoplasty is contraindicated. These exceptions are: discopathy with height loss over 50 percent, segment instability (Figs 33.6A and B),[21]




**Figs 33.5A to C:** Thermodiscoplasty indications



**Figs 33.6A and B:** Contraindications

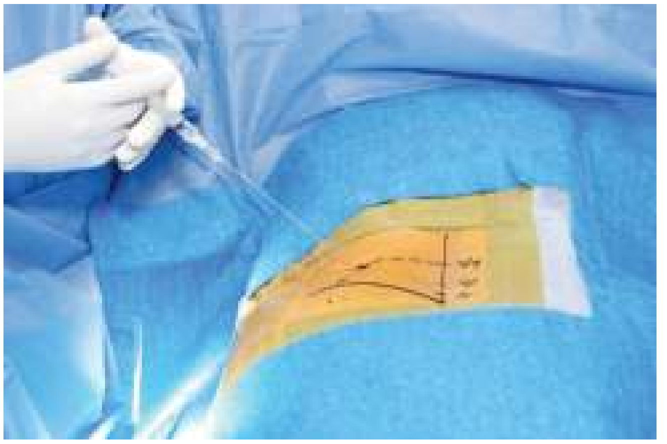


**Fig. 33.7:** Positioning of the needle and injecting the contrast agent in the disc

disc extrusion or sequestering, cauda equina syndrome, infection, incontrollable coagulopathy and bleeding disorders, discography that does not agree with previous low back or radicular symptoms.[22]

## Surgical Technique

*Thermal discoplasty.* The technique consists in accessing the affected intervertebral disc through a posterolateral approach. The patient is placed prone and entering percutaneously keeping a midline between 8 and 12 cm, with an epidural needle with a 45° angle. After verifying an adequate positioning using the fluoroscope with an anteroposterior and lateral projections, we proceed to perform the discography (Fig. 33.7).

Discography is a diagnostic test which allows an assessment of the disc from two points of view: the anatomical, because it allows observing its radiological pattern and the physical properties of the nucleus, along with presence of rupture in the ring; and the functional one, because it allows the surgeon to obtain a subjective measurement of the resistance to injecting the contrast agent and the reproducing of pain or the aforementioned discogenic test.

Access to the disc is obtained and the annulotomy using a dilating cannula and trephine system, which are passed sequentially and always under the safety and verification of the fluoroscope (Figs 33.8A to D).

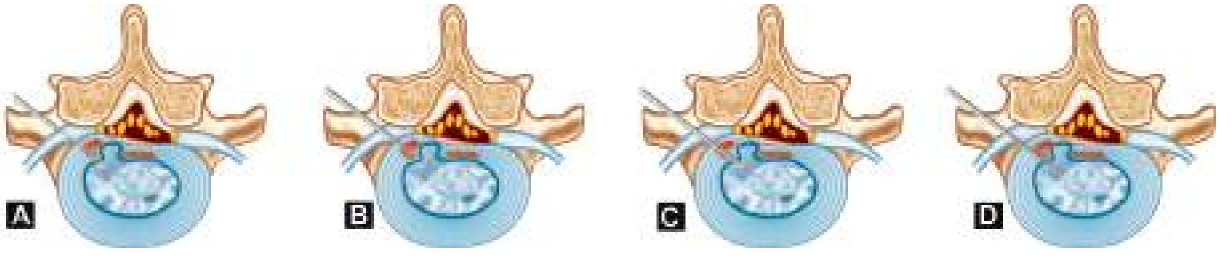
To allow an adequate access to the radiofrequency fiber and at the same time performing a nucleus resection, we do a mechanized discectomy using grasping forceps (Figs 33.9A to C). This procedure permits removing a great volume of the affected disc and, in this way, proceeding to perform the thermal therapy with radiofrequency achieving ablation of the nucleus and modulation of the ring with the aforesaid effects.

Depending on the indication and the pathology, this procedure may be complemented with an endoscopy, taking into account that it allows the visualization of the structures that might be compromising the nerve root, therefore being the source of radicular pain (for more information see the chapter on endoscopy).

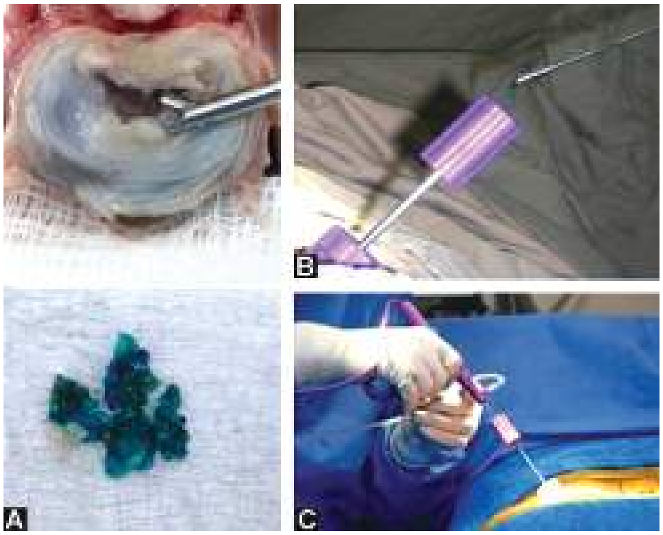
*Three hundred and sixty degree rhizolysis for facet syndrome.* Denervation with radiofrequency in the facet articulation is a complementary measure to low back pain treatment, and its success is based on the adequate selection of the patients, along with a strict follow up of the surgical procedure. One of the biggest advantages of this type of procedure is that both techniques may be done in the same surgical act without moving the patient, only changing the approach (Fig. 33.10).

The levels that are going to be treated have been previously identified based on clinical and radiological findings, taking into account that the most common ones correspond to the levels between L3 and S1.

The entry site is determined, which is the most lateral point of the pedicle, a caudal level of each lumbar level, except in L5-S1. Under fluoroscopic vision, we identify the facet of the affected level where the dilator and the cannula which will allow the radiofrequency fiber to pass are to be inserted (Figs 33.11A and B).



**Figs 33.8A to D:** Access to the disc and annulotomy with the disc-FX (Elliquence$^{TM}$) system. (A) Dilator I; (B) Trephine (Annulotomy); (C) Dilator II; (D) Cannula




**Figs 33.9A to C:** Mechanized discectomy and percutaneous thermal therapy

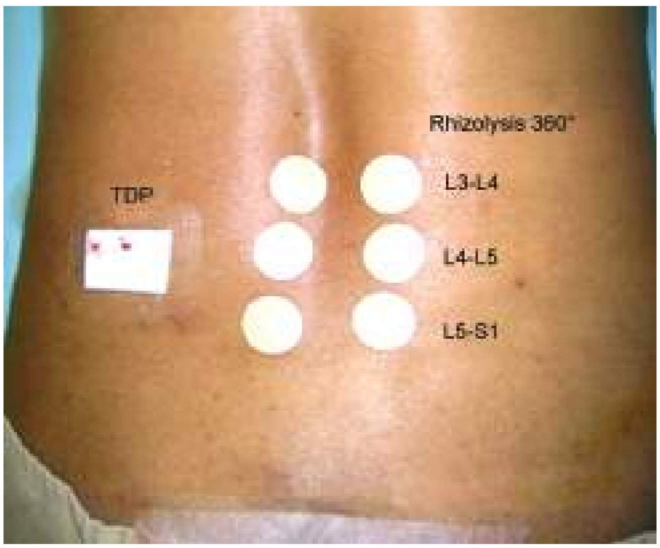
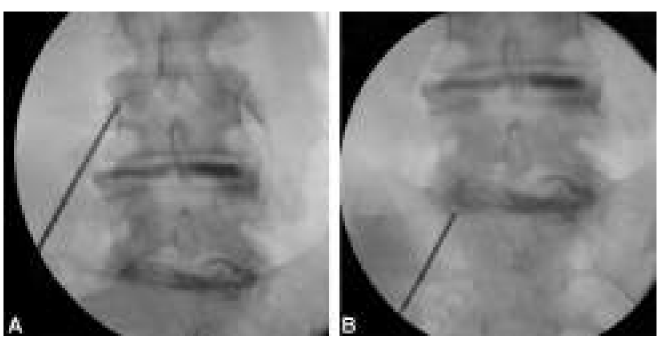



**Fig. 33.10:** Thermal discoplasty with posterolateral approach and rhizolysis with posterior approach in the same surgical act




**Figs 33.11A and B:** Positioning of the cannula for levels L4-L5, L5-S1

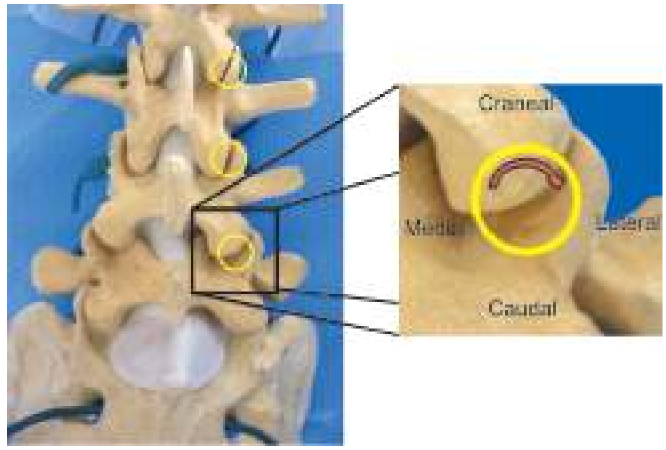



**Fig. 33.12:** Facet 360° rhizolysis diagram

Radiofrequency fiber is moved until contact with the bone is lost and its position is identified with fluoroscopy. A lateral view assures that the tip of the radiofrequency fiber does not go into the limits of the intervertebral foramen.

With the tip of the radiofrequency fiber located inside the facet articulation, the Surgimax$^{TM}$ (Elliquence LLC, New York) energy source is activated on the bipolar hemo mode to a standard intensity of 25 during 6 seconds. This reaches a 75 to 80°C temperature. Four points are established (cranial, lateral, caudal, medial) and the handle of the fiber is rotated 360° to completely cover the extension and, in this way, apply thermal therapy to nerves endings of the articular capsule (Fig. 33.12).

## Conclusion

The importance that low back pain has on public health (corroborated by the figures presented in different countries) creates the need of implementing techniques, which are improving to be more effective, safe and economical, and that at the same time cause less collateral damage to the patients. This diminishes complications taking into account that most patients are people in their productive stage in life.

Minimally invasive surgery for discogenic and facet low back pain permits in one incision (3–10 mm) and as an outpatient procedure, a quick rehabilitation and reasonable costs for a better quality of life for this frequent and disabling pathology.

Thermal discoplasty is designed to degrade collagen fiber and to cauterize granulated tissue in the posterior fibrous ring. Electrothermal coagulation requires the percutaneous insertion of a heating flexible electrode in the disc. These procedures are not exactly used to decrease intradiscal pressure; however, they greatly decrease pain due to thermal ablation of nerve endings.

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# 34

# Lumbar Discs Herniation Treated by Ozone Therapy

*Marcos Masini, João Flávio G Madureira*

## Introduction

Chronic low back pain (CLP) is a very common symptom and important sign of a clinical and social problem that affects every human being.[1] Approximately 70 percent of adults will suffer from back pain to varying degrees and at some moment in their lives. About 1.6 to 43 percent of these patients will have associated sciatica.[2] Around 5 to 15 percent of cases, the origin of low back pain are generally related to facet joint degeneration and disc disease.[3] Due to this high incidence, clinical treatment and/or surgical treatment of lumbar disc herniation is probably the most common procedure performed by a neurosurgeon in neurosurgical units around the world. Patients usually present with pain radiating to the lumbar and lower limb and are mostly initially treated medically with anti-inflammatory drugs, analgesics, muscle relaxants, physical therapy associated with relative rest. Due to the great variety of tools currently available, many patients are easily guided by specialists of other areas to performing imaging exams and thereafter they will come to our office holding a diagnose of a lumbar disc herniation (LDH).

The history of disc herniation is naturally favorable, the improvement of symptoms is common standard and most episodes are resolved spontaneously or after conservative therapy. Over a three month follow-up period, up to 80 percent of them will report relief of symptoms and return to its every day routine.[4] Usually, 20 percent of the patients will need to follow the next step of the treatment. The percutaneous techniques appear as an alternative between the treatment that fails and the more invasive procedures performed by surgery. Among these percutaneous techniques, there are mechanical aspiration, radiofrequency, laser and ozone approaches, each one with its own characteristics to reduce the two major factors of chemical irritation and the mechanical compression caused by intervertebral disc herniation on the root. The ozone therapy has emerged as an alternative for these patients mainly in Europe.[5,6] The purpose of this paper is to analyze the experience with the use of ozone therapy ($O_2O_3$) as part of an integrated treatment in patients with low back pain associated with lumbar disc herniation in the situations where the initial clinical treatment did not result in adequate relief of the symptoms. This technique, with minor variations, may be used in herniation that occurs in either dorsal or cervical segments of the spine.[23]

## Background

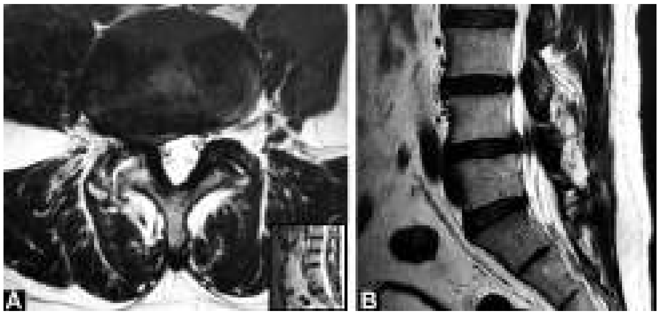
In 1952[7] Mixter and Barr introduced the concept as well as the classic surgical technique for the treatment of lumbar disc herniation in patients with persistent pain after treatment or with progressive neurological deficit. Since then, this technique was successively improved with the reduction of injury to normal tissues and precise removal of the pain-causing elements.[8-12] Thus, microsurgery has become the gold standard as an alternative for the treatment of lumbar disc herniation. In recent years endoscopic techniques have been developed in order to further reduce trauma to the tissues.[13,14]

In order to prevent the surgical manipulation of the root region and with consequent scar formation and persistence of pain, it began to be used as an alternative the puncture of the intervertebral disc through the safety triangle. By this technique one can aspirate, pinch and remove part of the intervertebral disc, reducing its volume and thus the pressure on the root. We can also inject chondrolytic enzymes, hydrocortisone, papain, and collagenase intradiscally in order to reduce the conflict between the root and the intervertebral disc. Thus, percutaneous techniques are used in radiofrequency,[15] electrothermy,[16] laser[17] and mechanical aspiration[18] were incorporated into the armamentarium of the spine surgeon aiming to use a less traumatic alternative pathway for the treatment of these patients. The percutaneous techniques minimize the invasive nature of procedures while protecting normal tissues and reduce the risk of complications such as postsurgical infection and scarring that can lead to permanent chronic pain and sciatica.[19]

The use of ozone is progressively becoming a practical, simple and safe alternative to this approach. The mixture of $O_2O_3$ is an allotropic form of oxygen, primarily known for its ecological properties, industrial use and therapeutic effects. It is used in medicine since the 30s for the treatment of pain in patients with thrombosis and segmental ischemia. The empirical observation of its potent effect on pain relief when applied to the lumbar spine muscles led to its use as an alternative to treat also the conflict between the root and the intervertebral disc. Several mechanisms of action have been proposed to explain the efficacy of ozone therapy, including analgesic, anti-inflammatory and antioxidant on the proteoglycans of the nucleus pulposus. Ozone is administered into a nontoxic concentration ranging from 1 to 40 micrograms per mL through various percutaneous methods.[20] Jacobs reported in 1982[21] the results of injections of ozone in various types of diseases demonstrating that intramuscular treatment relieves pain in most patients and lead to an improvement in circulation and absorption of edema with consequent release of mobility. It is worth mentioning that the muscle spasm that is associated to pain tends to push the vertebrae even more thus increasing the protrusion of the disc. Relaxation immediately causes a reduction in the volume of the protrusion as seen in image controls. This procedure, virtually free of complications, seeks to address the biochemical and structural changes in the short-term and long-term. Jucopilla 2005[22] was the neurosurgeon who started using the application of the mixture of ozone in intradiscal and periradicular region for treatment of low back pain and sciatica caused by lumbar disc herniation. The application of ozone in the disc and in the periradicular space causes an acute oxidative stress that stimulates the repair of the chronic imbalance provoked by the persistent lack of oxygen in these tissues due to circulatory failure caused by nerve root compression/scar or radicular/vascular leading to immediate relief of pain. Due to its persistent anti-inflammatory effect the relief is also durable.

## Patients and Methods

During the period of six years (2006-2011), it was carried out the treatment of 857 patients with herniated lumbar disc, the results of which are analyzed as follows: The patients selected for the use of ozone were those that failed with medical treatment and physiotherapy for an initial period of three weeks to three months. All patients underwent clinical examination on admission. All patients underwent imaging studies such as: Simple static radiography, computed tomography (CT) and/or MRI of the lumbosacral spine and electromyography (EMG) of lower limbs for diagnosis (Figs 34.1A and B). The procedure was indicated as the second option in the progressive treatment scale for pain in the spine.[23,24] Patients were offered this option as an alternative to relieve pain and stop the continued use of medications, aiming facilitate the activity and thus avoid surgery. Patients using steroid injections were discontinued in its use before the procedure. We treated patients with disc protrusion (bulging discs) disc subligamental herniation and disc extrusion. Patients with massive disc herniation occupying more than 80 percent of the spinal canal, patients with evident motor or sphincter neurological deficit, patients with painful symptoms over six months duration and patient with calcified disc herniation were referred for surgery and excluded from group to be treated with ozone.



**Figs 34.1A and B:** Patient with low back pain and MRI with lateral disc herniation L4-L5 on the right

The method chosen was the application in just one session with the possibility of complementation with intramuscular or tender points on an outpatient clinic basis, in those cases that had the persistence or emergence of symptoms on follow-up after the procedure, called carriers of a "hidden pain". A different pain, not like the initial pain or at a point not mentioned initially. The basic procedure is performed under sedation in the surgical theater and assisted by an anesthesiologist. Usually the patient should report details of their pain and be awake at the beginning of the procedure which allows confirming the location of tender points. It requires the use of an $O_2O_3$ Mixer Generator (Model Ozonic Medic AB) and needle electrodes to reach the disc, facets and foramen. The points defined during the physical examination should be checked by the surgeon prior to sedation and confirmed with the patient. Usually the intradiscal and foraminal application is made before the facet and the intramuscular application. With the procedure focused at multiple points one tries to avoid repetition of sessions as recommended by published protocols.[25-27]

## Technique

After being admitted, the patient is asked to sign the informed consent and then taken to the operating room, where he is comfortably positioned in prone (Fig. 34.2) on a Wilson's Supporter or adequate pillows being both radiotransparent. A light sedation is given only after the surgeon accurately locates

**Fig. 34.2:** Positioning the patient for ozone therapy

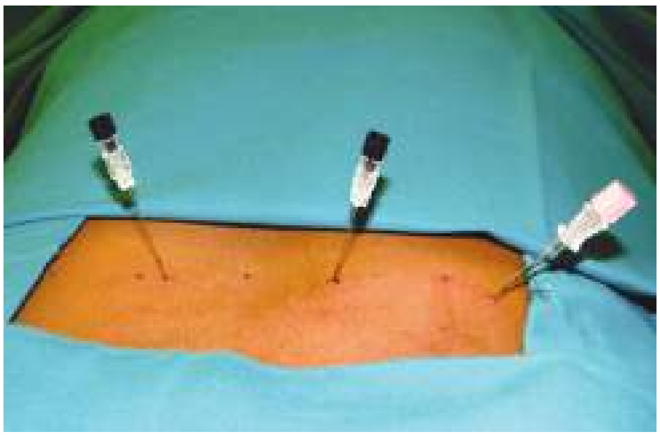
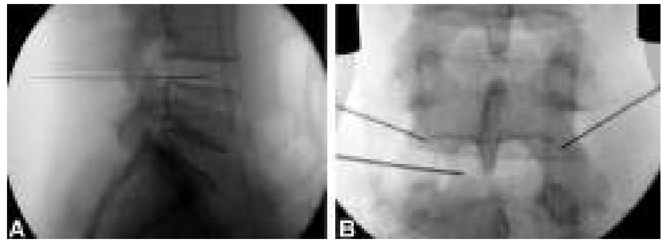


**Fig. 34.3:** Intradiscal needle placement L4-L5 from the right and over the facets of L4-L5 bilaterally

the points of pain, review the images and the plans set out for that patient.

## Via Facets

With the use of radioscopy we can locate the facets at the level of herniated disc (Figs 34.3 and 34.4), indicated as responsible for clinical symptoms of the patient, and of those above and below, being the entrance point at 4 cm laterally to midline. The tip of the needle must be located at the superior lateral aspect of the facet joint over the lateral posterior branch. Local anesthesia is undertaken with xylocaine 1 percent, without adrenaline (W/A), 3 cc. Note that the local anesthesia should be previously tested. Use 4 or 6 BD spinal needles 22 G x 3.5 or 9 cm that are placed into facets. The procedure is confirmed and documented by the AP and lateral images by radioscopy. This procedure is performed as an initial step because it facilitates the identification of the disc level that will receive the intradiscal procedure. By using needles electrodes one can confirm the proximity of the posterior branch by impedance or electrical stimulation.




**Figs 34.4A and B:** Placement of needles in the lumbar spine in AP and lateral

## Via Intradiscal and Foraminal

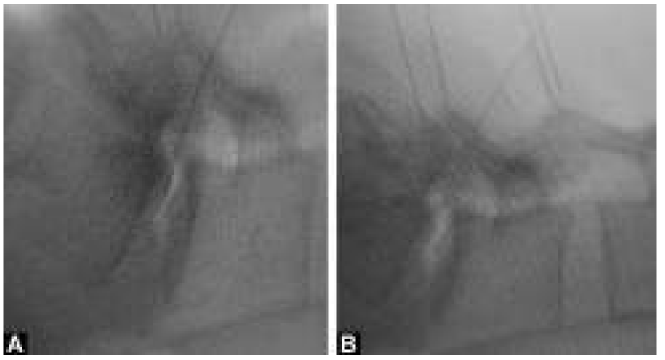
The location of the disc to be injected is performed with the use of fluoroscopy. Entry is performed at 10 cm lateral to the midline with an angle of 45 degrees medially controlled by radioscopy. It is performed under local anesthesia with 3 cc of xylocaine 1 percent W/A. A test of local anesthesia is carried on and a needle Chiba 22 G × 20 cm is placed into the disc. One must observe in the radioscopic triangulation that the needle is inserted in the central region of the disc. It is highly recommended that all the exams images are printed and included in the patient files.

## Via Epidural (Posterior Interlaminar, Hiatus or Epiduroscopic Approaches)

After local anesthesia of the skin by 1 percent xylocaine W/A 3 cc and with the use of fluoroscopy it is introduced a Tuohy needle 18 G × 9 mm through the posterior spinal epidural space between the laminas of vertebrae involved. If the choice is to go through the sacral hiatus, it can be located by palpation, with the needle inclined in the direction of the channel and with the support of radioscopy we can make the puncture and the placement of the guided needle (Myelotec). Confirm and document with image in AP and lateral. The technique of epiduroscopy can be used to add ozone directly in the region of disc herniation as it is described in detail in another publication. The epiduroscopy is preferably used in the cases the patient has been already operated, fused posteriorly due to hernia or in multiple recurrent surgical cases with chronic pain.[28,29] The most important factor here is to define if the patient's pain is neuropathic or neurogenic. In both cases it can be used as an associated procedure to relieve the chronic pain syndrome.

## Applications of Ozone

1. The first application to be held occurs within the intervertebral discs. A discography is performed with an average of 5 cc of ozone with a concentration of 30 μg/mL (μg = micrograms) progressively injected into the disc and visualized and documented by fluoroscopy. We believe that under pressure, a small amount of ozone can be injected into the disc even if the cavity is not present (Figs 34.5A and B). Short and sequenced movements of introduction and withdrawal may create the necessary cavity for the intradiscal application. Where there is no disc cavity for the application, it can be created by prior application of electrothermy, radiofrequency, laser or by mechanically clamping or suction. The radiological lateral




**Figs 34.5A and B:** (A) The intradiscal application allows for a discography and pressure test; (B) The injection in the foramen spread the ozone anteriorly to the dural sac

view will help in the visualization of gas discography. The foraminal application is performed as soon as you take out the needle of the disc and notice a clear reduction of pressure on the syringe. Then, another 5 cc of ozone are injected into the periradicular space. At this point another 5 mL of a 20 mL syringe containing 125 mg Solumedrol and 5 mL of Marcaine W/A 0.5 percent and supplemented with 0.9 percent saline solution are injected. By removing this needle 5 cm back and positioning it intramuscular, another 5 cc of 30 μg with ozone/mL (same concentration) is injected.

2. The second application is to be performed on the facets. The needles are placed with radioscopic control in the superior and lateral aspect of the facet followed by peri facet application of ozone 10 mL with a concentration of 30 μg/mL. If there is doubt as to the proximity of the posterior branch, the use of electrical stimulation or impedance can assist in their location. We use a 20 mL syringe with 125 mg Solumedrol diluted in 5 mL of Marcaine W/A to 0.5 percent and supplemented with saline 0.9 percent being the application intra and peri-facet of 5 mL or 3 mL for each facet. The needle is withdrawn by 5 cm and intramuscular application of 10 mL of ozone in a concentration of 30 μg/mL at each point is carried out slowly and the needle is fully withdrawn.
3. The third application is made by the Sacral Hiatus. Being injected into 15 mL of solution containing 5 mL of 0.5 percent Marcaine W/A, 125 mg Solumedrol and 0.9 percent saline to complement. The application of ozone at a concentration of 10 μg/mL is held between the first 10 mL of injected solution. The last five milliliters of solution are injected before removing the needle and after application of $O_2O_3$ with a concentration of 10 μg/mL. Due to the risk of dural puncture via inter laminar, authors prefer to use the puncture of the sacral hiatus. In specific cases, where exists a large scar tissue adhesion, this application can be performed through the epiduroscopy in the anterior region between the dural sac and intervertebral disc. In these cases, the technique previews a mechanical dissection with the use of epiduroscopic video guided needle and injection of a volume of saline solution and then, at the location of conflict, the application of ozone and a solution of 20 mL of a solution containing: Clonidine (0.5 micrograms per kg) (1 mL = 150 mcg) 0.2 mL of 40 kg, Marcaine 4 mL 0.25 percent epinephrine, Triamcinolone or Solumedrol 2 mL (80 mg); Fentanyl 0.5 mL (25 micrograms per mL). It also includes the performance of a direct application of 10 mL of epidural ozone at a concentration of 10 μg/mL. Remove the system and suturing.

## Guidelines and Assessments

After the procedure, the patients rest for two hours and are directed to physiotherapy and to progressively reduce the use of analgesics and anti-inflammatory drugs on the following 15 days. They are instructed to return to their activities in the week following to the procedure and to restart the physiotherapic prevention program and hydrotherapy with stretching and strengthening exercises. The ambulatory revisions occur with 10 days, 1, 3, 6 and 12 months after the procedure and follow each year thereafter. In selected cases and in an outpatient basis, we perform intramuscular applications of ozone in tender points using local anesthesia. The item pain is assessed using the visual analog scale (VAS)[1] before and immediately after the procedure, and at 1, 3, 6, 12 and 24. The difference between VAS1 and VAS2 is considered an index of analgesic effect. This difference was calculated as a percentage to allow direct visualization of the results. For this statistical analysis we used the statistical system of excel.

## Results

A group of 857 patients underwent 890 procedures for treatment by ozone therapy for lumbar disc herniation following the protocol described for the period of 6 years (2006–2011) being 507 (57%) female and 383 (43%) male, predominantly aged between 30 and 59 years (Figs 34.6 and 34.7). Seven hundred and seventeen patients (84%) were sequentially monitored for 2 years and were evaluated in 1132 opportunities in accordance with the visual analog scale (VAS) and overall patient rating scale (OPRS). The mean results ranged from 80 percent in the first evaluation to 86 percent at two year evaluation, being this

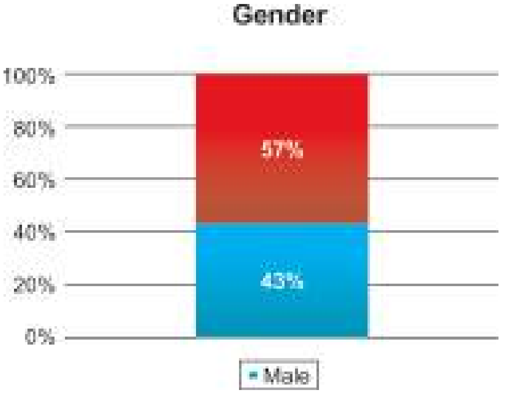



**Fig. 34.6:** Gender (507 female and 383 male)

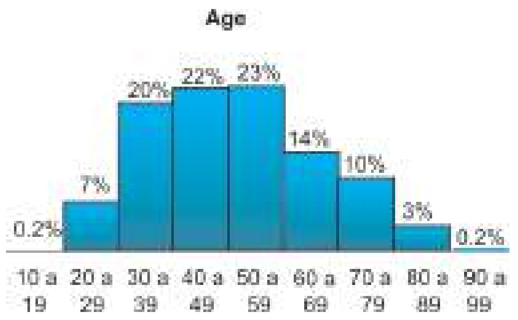



**Fig. 34.7:** Age

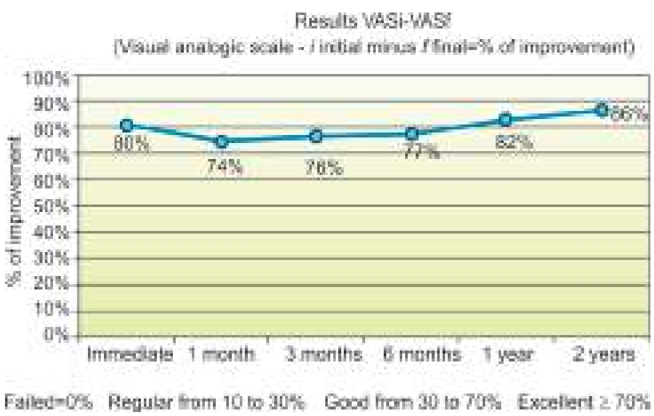



**Fig. 34.8:** Results of 1132 assessments from 717 patients


**Fig. 34.9:** Number and timing of cases that had surgical procedure. Forty-nine patients had surgery for lumbar disc herniation after ozone therapy (5.7%)

percentage relating to improvement of the patient by comparing the VAS initial and VAS final (Fig. 34.8). Of the total, 40 patients (4.7%) had additional procedures for completion of treatment over the five year follow-up, with concentration of occurrences between 3 months and 2 years from the first procedure. The most frequent causes that justified the repetition were the return of pain for causes defined as stress or trauma and the occurrence of pain in another segment of the spine. During the follow-up period, 49 (5.7%) patients had lumbar spine surgery, 45 for pure herniated disc and 4 cases associated with canal stenosis. The majority of patients[37] were operated in the first six months after the application of ozone (Fig. 34.9). Among the justifications to follow with the surgical procedure are persistent pain associated to bone compression by calcification or stenosis, return of pain in days or weeks, association to a trauma or physical effort; return of pain associated with an increased volume of the hernia. The same analysis of results, when applied to this group shows 96 percent improvement in the first evaluation and 75 percent improvement after 2 years follow-up.

## Complications

The concurrent use of multiple needles can result in inadvertent puncture of the dural sac and consequent headache in the days following the procedure. In this group, three patients had new hospital admissions for treatment of low CSF pressure headache in the immediate period after the procedure.

In the initial group, the use of the corticosteroid with high particulation caused radicular irritation with spasms in 9 patients. These symptoms begin immediately after application and revert progressively with the absorption of the corticosteroid over 6 to 12 hours. The treatment is performed using sedative, muscle relaxant type diazepam associated to an abundant hydration with analgesia and sedation. The indicated steroid use is with low particulation for epidural or periradicular injections. Paresthesia and paresis are transient and related to the combined use of anesthetics and justify a period of relative rest in the hours following the procedure and a test to be performed by the physiotherapist before the patient could return to walk independently. There were no infections. One patient developed an epidural hematoma with lower limbs paresis which recovered in a week with clinical treatment.

As there is always a tiny learning curve, the surgeon must be ready to repeat the procedure in those cases where the patient did not notice any change in the initial clinical scenario. Repetitions or additions of procedures during the follow-up period is only applied to a very few selected cases.

## Discussion

All patients are treated based on the progressive scale of treatment proposed by Bertangnoly,[24] here modified, which organizes the treatment decision by analyzing the possibilities from low to high rate of complications (Fig. 34.10). Our decision is always to start down the stairs and go up when a choice fails. In the second step, as can be observed in Figure 34.10, treatment for integrated ozone therapy is used before radiofrequency, electrothermy, laser and mechanical decompression. It is worth recalling that a small reduction of intradiscal pressure may result in significant relieve of pain. The sequencing procedures are driven based on the surgeon's training, as well as the available resources at his working place.

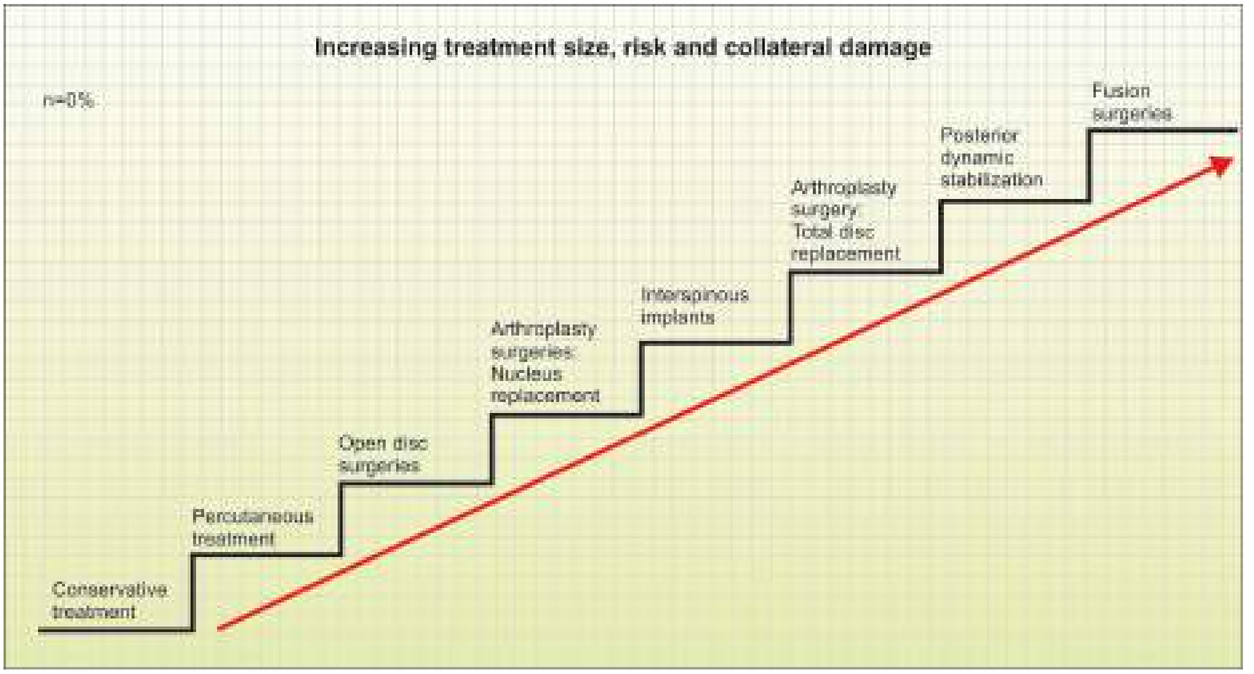



**Fig. 34.10:** Progressive spine treatment scale (modified)

Jacobs reported in 1982[21] the absence of side effects of ozone therapy applied for different pathologies. The paravertebral intramuscular injections cause pain relief and decongestion resulting in increased mobility. Experimental models suggest that material from the nucleous pulposus may act as a chemical or immunologic irritant to the nerve root and cause inflammatory response. This triggered the idea of injecting the ozone ($O_2O_3$ mixture) in the disc and periradicular area[20,30,31] as it was done successfully in the muscle. The injection of a modest volume of ozone stimulates antioxidant defenses as well reactivate the immune system and expression of antioxidant enzymes such as superoxide dismutase, catalase and other enzymes. After intradiscal injection, ozone can accelerate the degradation of proteoglycans in the herniated degenerated nucleous pulposus leading to reabsorption and dehydration with the consequent reduction of herniated material responsible for nerve root compression.[25,32] Pain is caused most frequently by metabolites coming from the degenerative process inside the disc and from ischemia of the nerve root and of the ganglion. Ozone acts as a powerful stimulus to activation of antioxidant defense, neutralizes the acidosis, increases metabolism, reduce edema causing oxygenation of the ganglion and dramatic and long lasting reduction of pain. Clinically, in the post procedure time the patient will have progressively reduction of the sciatica and return of the muscle strength by amelioration of nerve ischemia. Extruded disc are perfect indication for ozone therapy as far as the intradiscal injection of ozone will lead it direct to the extrude material with the above mentioned results.

Muto et al. published 3 studies between 1998 and 2008[33-35] using intradiscal injection of an oxygen-ozone mixture under CT guidance to treat approximately 3,700 patients and reported an 80 percent success rate at short-term follow-up (6 months) and a 75 percent success rate at long-term follow-up (18 months), with no major or minor side effects. Oder et al.[36] studied 621 patients to determine associations among the morphology of the disc disease, patient-specific data, and treatment outcomes. Six hundred twenty-one consecutive patients were subjected to CT-guided ozonucleolysis in combination with periradicular infiltration by steroids under local anesthesia. The patients received steroid and an oxygen-ozone mixture into the disc and periganglionic infiltrations by CT guidance. Each patient was monitored for a period of 6 months and documented with the oswestry disability index (ODI) and VAS. Patients younger than 50 years had significantly better values on the VAS and in ODI scores, 6 months after treatment.

Andreula et al.[37] reported a 78.3 percent success rate in patients treated with ozone therapy and periganglionic steroid injection compared with a 70.3 percent rate in those treated with ozone therapy alone. Complications occurred in 2 of 235 patients and consisted of episodes of impaired sensitivity in the lower limb on the treated side, which resolved spontaneously within 2 hours. Das et al.[38] in an Indian population cohort study, evaluated 53 consecutive patients with lumbar disc herniation. All presented with clinical signs of lumbar nerve root compression supported by CT and MRI findings. They were treated with a single session of intradiscal ozone therapy. Therapeutic outcome was assessed after 2 years. Pain intensity was significantly reduced following treatment (VAS baseline was 7.58; after 2 years, 2.64). Similar ODI results were seen ($P < 0.05$). No major complication was observed in this case series. Xu et al.[39] included 187 patients with sciatica and low back pain with positive Lasègue sign and diagnostic verification by CT and MRI exhibited disc protrusion with nerve root or thecal sac compression. They compared the effectiveness rates after one week (103 cases), 2 weeks (61 cases), and 4 weeks (23 cases) treatment sessions of intradiscal ozone therapy. They were evaluated by Macnab criteria at 48 months. The effective rate was 82.02 percent in all groups. However, there were no significant differences in the total effective rate in the 3 groups ($P = 0.280$).

Complications secondary to ozone therapy are rarely documented in the literature. There are reports of 5 different types of complications. Giudice et al.[40] reported bilateral vítreoretinal hemorrhages following ozone therapy for lumbar disc herniation. Furthermore, one case of thunderclap headache after oxygen-ozone therapy related to pneumoencephalus as a consequence of inadvertent intrathecal puncture was recently published.[41] Ginanneschi et al.[42] reported a case of a patient who experienced paresthesias along the anterolateral compartment of the left leg and hypoesthesia over the dorsum of the left foot, suggesting spinal nerve injury occurring a few minutes after percutaneous intradiscal infiltration of ozone for L4-L5 disc herniation. In 2004, Corea et al.[43] published a report of vertebrobasilar stroke during ozone therapy. In 2 of 235 patients, Andreula et al.[37] reported episodes of impaired sensitivity in the lower limb on the treated side, which resolved spontaneously within 2 hours. Fabris et al.[44] reported a subcutaneous hematoma at the puncture site.

Muto et al.[34] documented a reduction in herniated disc size in 63 percent of cases, confirming persistent satisfactory outcome. Thus, these authors stated that the equation large herniation = major symptoms, small herniation = minor symptoms, does not always hold true. It seems quite natural to assume that clinical signs and symptoms of disc herniation are not caused only by mechanical compression but that biochemical factors play an important role in inflammatory sensitization and immune response in the epidural environment of the nerve roots and ganglia. Based on the same reasoning, it seems logical to presume that mechanical removal of herniated tissue may not always be needed and that reducing the inflammatory process could essentially be sufficient to treat the symptoms. This hypothesis was partially confirmed by the cited study.[45,46] Ozone is a strong oxidizing agent that quickly reacts and oxidizes the proteoglycans in the nucleus pulposus, which results in a small reduction of disc volume and subsequently in pain relief. The suggested premise is that a small volume reduction results in a significant decrease in pressure. In addition, it has been shown to have anti-inflammatory/analgesic and natural antibacterial effects.[6,47] Additional discussion of ozone's mechanisms of action can be found elsewhere.[48] Ozone therapy for lumbar disc herniation is a procedure that is considered generally risk-free or as low as 0.1 percent[48] and has low or no adverse effects at concentrations used for therapeutic application (10–40 μg/mL).

Magalhaes[49] in his recent systematic review and meta-analysis of ozone therapy for low back pain secondary to herniated disc indicated the level of evidence is II-3 for ozone therapy applied intradiscally and II-1 for ozone therapy applied at the paravertebral muscle and periforaminally for long-term pain relief based on USPSTF criteria.[50] The available evidence yielded 1C strength of recommendation[51] for ozone therapy applied into the disc and 1B for ozone applied at the paravertebral muscles or periforaminally direct or by epiduroscopic approach.[52]

Our experience points out some concepts:

1. The indication of procedure should be made after clear bone visualization of the spine by CT. The result of this procedure in patients with bone compression will have shorter duration and will result in surgical procedure.
2. Patients with more than one level involvement can be treated in more than one level by the same technique at the same time.
3. If the symptoms are associated to myofascial syndrome, you may associate some muscle injections mainly in paravertebral and other affected muscular groups. Some patients may have associated bursitis or arthritis which may also be injected.
4. As the patient gets pain free, he or she will increase physical activities. As they have lost the pain protection system, they may develop neurological deficit without pain due to traumatic enlargement of the disc protrusion. This is an exceptional small group of patients that should be advised. We must emphasize about daily activities restriction to the same amount as we do for the post surgical patients.
5. Immediate reduction of the disc bulging can be related to muscle spasm release. Disc reduction late in the process is related to herniation dehydration. We would like to add other considerations, such as:
   - The procedures should be done in operating room with anesthesiologist supervision.
   - If there is any vascular invasion or suspected injury the procedure should not be continued and ozone injection should be postponed.
   - A modest concentration of ozone (10 micrograms per cc) can be used with no harm and excellent results.
   - Ozone, as any other technology should be carefully handled. Surgeons should be adequately trained on its use. It has a special smell but cannot be seen. If in doubt, its neurolitic properties can be tested over your surgical gloves with 30 micrograms per mL concentration.
   - Patient expectation for resolution of the pain should be considered as you can provide 85 percent immediate resolution with ozone and with the open surgical procedure you can provide 99 percent immediate resolution.
   - Association will certainly guarantee a better short and a long lasting relief than we have observed with steroids alone.
   - Periradicular injection should be associated as a routine mainly in chronic cases and in L2 where the ganglion plays a major role in maintaining the pain.

## Conclusion

The mixture of oxygen and ozone ($O_2O_3$) has been used for spine pain in the last years with no major complication and surprisingly good results even in chronic cases.[26,27,35,45] It is used always as part of an organized program that we call multimodal treatment. It involves not only the treatment of the pain using the progressive spine treatment scale[24] and integrative medicine concept but a sequence of orientation that will result in long lasting relief and future prevention of recurrence. The patients should learn from their doctors about all these steps and the concept of chemical pain before the beginning of treatment. They should have the previous consent information and agreement that will have to use medication to complement the pain treatment and follow physiotherapy and back pain school program. The human bio-psychosocial concept of treatment should be pursued at all time when treating spine diseases. It goes beyond the body disease concept used in most of the clinical approaches. The success of ozone to treat back and sciatica pain suggests that it may be a first line option for elder patients, severe diseased patients, patients who do not want an invasive surgical procedure, patients with conflicting clinical and/or imaging diagnoses, patients with previous surgical procedure and inconclusive image study. It is a simple technique, a short time procedure with low level of complications.

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35

# Use of Robots in the Surgical Management of Lumbar Disc Herniation: Dream or Reality

*PS Ramani*

## Introduction

Spinal surgery as a whole is becoming minimally invasive. Using microscopic, endoscopic and percutaneous approaches the surgical management of lumbar disc herniation has become totally minimally invasive. Patients are being discharged on the same day of surgery even to perform an assigned job arranged before surgical intervention.

Minimally invasive techniques depend heavily on image guidance specially for placement of implants. Imaging is also essential in minimally invasive techniques in lumbar disc surgery.

Robots are being introduced into the spinal surgery and have been found particularly useful in the placement of implants.[1] In today's minimally invasive spinal surgery medical robotics appear increasingly compelling.

## Clinical Use of Robotic Technology

In Russia, robots have already been used in the treatment of degenerative diseases of lumbar spine.[2.] It is but natural that surgeons should look at robots and find out its usefulness in the surgical management of lumbar disc herniation. The technology is improving all the time and Robots may find use in treating patients with challenging presentation of lumbar disc herniation although it may not find an easy place in day to day management of a given patient of lumbar disc herniation. But careful evaluation of patient, successful application of robots and its limitations must be well defined.

## Some Results

In Ohnmeiss series of 102 patients screws were placed successfully in 95 patients. One percent screws were misplaced possibly due to skiving of high speed drill. In 10.1 percent of patients the procedure had to be abandoned due to poor registration and technical trajectory issues. The robot could not be used in patients

- With severe deformity
- Heavy body mass index
- Osteoporosis
- Difficulty in platform mounting
- In patients with previously failed implants
- Technical issues of the device.

In view of difficulties mentioned above and in view of ease with which the herniated disc is excised by minimally invasive techniques within a short time surgeons may find it inconvenient to use robots routinely in lumbar disc surgery.

## Increased Popularity

In spite of several difficulties the robotic assistance has gained increasing popularity among young spinal surgeons. Konovalov has recently used robotic assistance in 16 patients with lumbar degenerative disease mainly for implant placement and found that

- It provide higher effectiveness
- Safety in patients with complicated anatomy like thin pedicles and rotational deformity

- Better precise documentation
- Better image guided oblique lumbar interbody fusion (Go-lif).

## Mandatory Requirements

In imaging besides X-rays and MRI, it is mandatory to do high resolution CT with 3D reconstruction before doing surgery.

## Current Application of Robotic Technology in Spinal Surgery

Interaction between spinal surgeons and robotic assistance is already established specially with the use of implants. Robots are now commercially available for clinical use and are being installed in several cities including India. Pilot studies on efficacy and implementation of robots and assimilation of robot in operating work flow has already proved the accuracy and usefullness of the system at least to an extent of 90 percent. In drilling thoracic and lumbar pedicle screws.[3] Current application appear promising.

## Discussion

It is believed that overall 30 percent of the patients undergoing surgery for lumbar disc herniation are not happy with the outcome.[4] Problems have stimulated over the last decade the development of a number of minimally invasive operative procedures. The principle of surgery is to decompress the nerve roots which is compressed by mechanically removing, dissolving or evaporating the disc material while preserving the integrity of the motion segment. With this aim in mind spinal surgeons are all the time looking for newer innovations which can help them to remove the offending disc without causing any morbidity to the patient so that he can be sent home as quickly as possible. One of the parameters of such procedures is precisely targeting the offending disc so that it can be excised without even manipulating the nerve root. To achieve this aim imaging and modern technology is essential and still spinal surgeons are not very happy when they look at their results. They are looking for more precision and once robot becomes clinically popular it should be used in targeting the herniated disc so that it can be excised with utmost safety to the patient and his spine. In times to come Robot will become popular for lumbar disc surgery. In future more stress will be laid on safety, efficacy and effectiveness.

Continuous development of technology has led to the diversity of procedures in use which prevents generalization of results. This aspect is noted not only with minimally invasive procedures but also in standard techniques like laminectomy or hemilaminectomy.

## Future Developments

Use of robots in spinal surgery is in its infancy. The technology is being updated everyday. Current clinical applications are promising and its success compels aspiring spinal surgeons in its use in a variety of spinal procedures including herniated lumbar disc. Future developments seem far beyond imagination. The advantages and disadvantages of robots have still not been fully sorted out. Finally patients safety is at the heart of each spinal surgeon. Future spinal surgeons may use it as an important supplement and I have no doubt that robots will be used effectively in the surgical management of lumbar disc herniation.

## Conclusion

As of today robotic assistance is not used while using minimally invasive technique to excise, evaporate or dissolve the offending portion of the intervertebral disc. However it is safe, precise and target oriented. Future spinal surgeons are bound to make its use in surgical management of herniated lumbar intervertebral disc after overcoming the learning curve which is absolutely essential before one start using robots in the operation theater.

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Section

5

# Surgical Techniques Infrequently Used in Lumbar Disc Herniation

## Section Outline

# 36

# In-Space Interspinous Distraction Device for Stabilization of Lumbar Spine in Motion Segment Instability in Lumbar Disc Herniation

*PS Ramani*

## Introduction

Motion segment instability, degeneration, lateral recess stenosis and retrolisthesis are very common in the middle age but are usually unrecognized. They are an important cause of low back pain, stiffness and neurogenic claudication. However, paucity of signs in these patients tends to delay the diagnosis. Recognition and correct treatment of these conditions are rewarding.

## Pathophysiology

These patients have typical symptoms of neurogenic claudication, which are relieved on flexion. The pathophysiology behind this is that, during extension there is buckling of the ligamentum flavum, protrusion of the posterior annulus and forward displacement of the superior facet leading to decrease in size of the spinal canal and foramen thus causing compression of neural structures. These changes are reversed during flexion and so the patient has relief of symptoms on flexion.

## Principles of Management

These patients can be treated by:
- Internal decompression of spinal stenosis (IDSS)
- Discectomy
- Stabilization of the segment (interspinous process device).

### Interspinous Devices

Interspinous spacers are implants, which are inserted between the posterior spinous processes. Their purpose is to restore the tension of the ligaments between the spines. This reverses the infolding of the ligament into the spinal canal and restores some of the midline (axial) volume to the spinal canal and may reverse axial (central) narrowing (stenosis), restores the alignment of the facet joints and normalizes their alignment. An increase in the volume of foramen and thus, counters the effects of facet joint opening and narrowing of the exiting pathway of the nerve (lateral recess stenosis/narrowing).

### Types

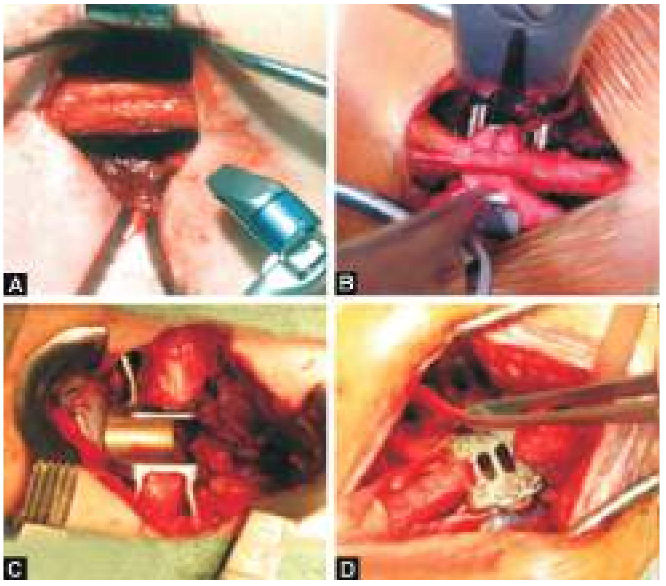
Interspinous devices come in two types. Those which can be inserted directly in the space after its surgical exposure and those which can be inserted percutaneously without surgically exposing the interspinous space.

### Open Posterior Approach

Several devices available in the market which can be fitted directly, following surgical exposure, into the interspinous space are shown in Figures 36.1A to D. In our department, dynamic interspinous assisted motion (DIAM) was used but later we have been using In-Space device which is inserted percutaneously (Fig. 36.2).

In-Space interspinous device inserted by minimally invasive percutaneous approach.

In-Space is intended to stop the segmental extension and to distract the interspinous space at symptomatic level between L1 and L5. It acts as a space holder and protects the posterior elements by:
- Maintaining the foraminal height
- Opening up the spinal canal



**Figs 36.1A to D:** Type of implants available in the market: (A) X'Stop; (B) DIAM; (C) Coflex; (D) Wallis

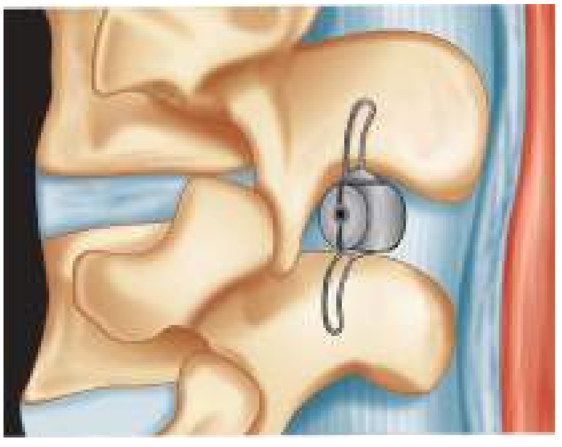


**Fig. 36.2:** In-Space device in position between the two spinous processes

- Reducing stress on the facet joint
- Relieving pressure on the posterior annulus.

## Indications

In-Space can be implanted at one or two levels from L1-L5. It can be used in patients with:

- Central, lateral, and foraminal lumbar disc herniation with leg, buttock or groin pain, which can be relieved during flexion
- Soft disc protrusions with discogenic low back pain
- Facet syndrome due to facet osteoarthritis
- Degenerative spondylolisthesis up to Grade I with hyper-lordotic curve
- Degenerative disc disease with retrolisthesis
- Interspinous pain arising from Baastrup syndrome (Kissing spines).

## Contraindications

- Severe osteoporosis
- Conus/cauda syndrome
- Severe structural spinal stenosis
- Fractures
- Spondylolysis
- > Grade 1 spondylolisthesis
- Scoliotic deformity at that level
- Seqestrated disc
- Infection
- Morbid obesity.

### Caution

The stability of this device depends on the following structures:

- Supraspinous ligament
- Laminae
- Spinous process
- Facet joints.

Hence, intactness of these structures is mandatory to insert this device as significant or complete removal of these structures will lead to device migration.

### Advantages

- Percutaneous, lateral approach
- Preservation of the paraspinal muscles
- Muscles just bluntly dilated
- Not sharply dissected from their natural attachment
- Preservation of the supraspinous and interspinous ligament
- Less perioperative pain
- Early recovery
- Less scarring
- No iatrogenic trauma.

### Disadvantages

- It cannot be used in high-grade instability
- It is expensive.

## The Implant (In-Space Device)

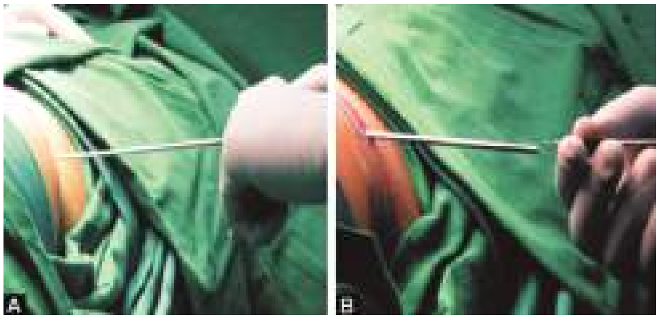
This implant (Fig. 36.3) has been designed by Dr Michael Meyer and is manufactured by AO Synthes.

The implant is available in five different sizes ranging from 8 to 16 mm (with 2 mm increments). It consists of a body made of PEEK Optima which is radiolucent but sturdy. The central screw, and the wires which are made of titanium alloy to allow proper radiological assessment of the correct implant position.

### Principle of Action

- Acts as a space holder
  - Distracts the interspinous space
  - Prevents the extension at the stenotic level
- In-Space mainly protects the posterior elements in extension
  - Maintains the foraminal height


**Fig. 36.3:** In-Space AO Synthes implant with two parts of the PEEK body attached with titanium central screw and two lateral prongs




**Figs 36.4A and B:** Insertion of guidewire through small incision

**Fig. 36.5:** Position of guidewire checked with C-arm

 - Opens up the spinal canal
 - Reduces stress on the facet joints
 - Decreases pressure on the posterior annulus
 - Controlled mobility
- Motion preservation
 - Prevents extension
 - Allows flexion, rotation and lateral bending.

## Essential Preoperative Requirements

In addition to routine preoperative investigations, X-rays and MRI, flexion extension views are strongly recommended as they provide better understanding of the active interspinous flexibility and rule out gross translational instability. A pre-CT scan is done in patients in whom spinous process or laminar dysplasia is expected and in patients where the implant is inserted between L1-L3 levels to make sure that the abdominal contents are away from the surgical trajectory.

## Surgical Technique

### Anesthesia

The procedure is done under general anesthesia (It can be done under local anesthesia as well, in cases where internal decompression is not mandatory).

### Patient Positioning

A radiolucent flexible table is used. The patient is placed in prone position over the bolsters and the table may be flexed slightly to decrease the lordosis of the spine.

### Procedure

Under fluoroscopy guidance, the level is identified and the entry point is marked approximately 9 cm away from the midline on either side. A small incision (1 cm) is made at the entry point and the guidewire mounted on its handle is then inserted under fluoroscopy to lie between the two spinous processes (Figs 36.4A and B). Over the extended guidewire multiple distraction sleeves are passed while holding the guidewire still in place. The distraction sleeves are available in sizes ranging from 8 to 16 mm. Sequentially increasing sleeves are inserted till sufficient distraction is achieved which is suggested by the parallel vertebral end plates. An excessive distraction should be avoided as it leads to loss of physiological lordosis.

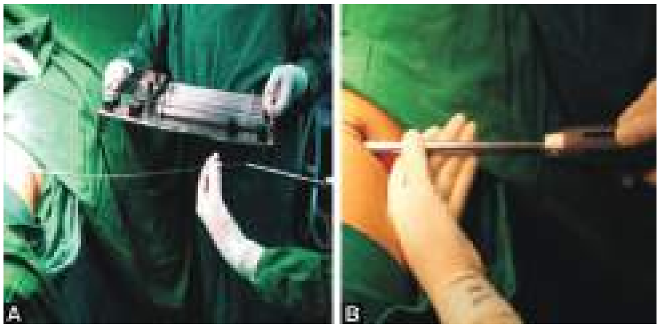
Through a small incision about 9 cm away from the midline the guidewire is inserted percutaneously into the interspinous space (Figs 36.4A and B).

The position of the guidewire is checked with C-arm. The direction is slightly oblique in keeping with the shape of the spinous processes (Fig. 36.5).

Set of dilators starting with 8 mm and increasing in width by 2 mm are inserted serially until it snugly fits the spinous processes (Figs 36.6A and B).

Once the desired distraction is achieved, the corresponding implant insertion sleeve is inserted over the last dilator. The maximum insertion depth is verified on fluoroscopy where the markings on the inserter sleeve are equidistant on either side of the spinous processes (Fig. 36.7).

The implant size corresponding to the diameter of the implant insertion sleeve is selected and attached to the implant holder (Fig. 36.8).



**Figs 36.6A and B:** Insertion of dilators in serially increasing diameter

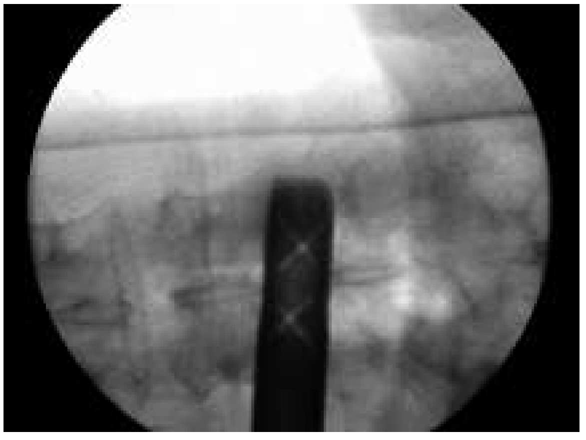
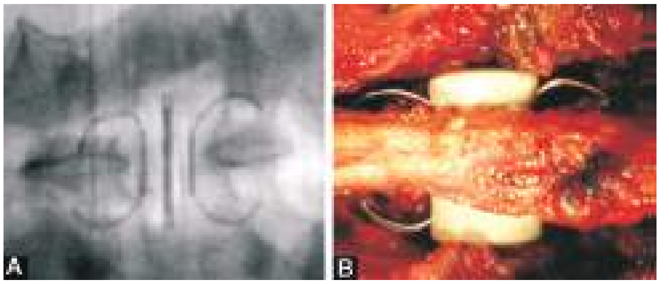


**Fig. 36.7:** The sheath in position as shown by markers on either side of spinous processes

**Fig. 36.8:** The cage mounted on the carrier is about to be guided through the insertion sheath towards its destination

The implant is then inserted into the insertion sleeve and a screw driver is attached to it. The screw driver is turned clockwise to deploy the wings of the implant under fluoroscopy imaging. A green colored ring appears on the screw driver shaft once the wings are completely deployed. The implant holder is then disconnected from the implant and removed. The inserter sleeve is then pulled out slowly (Figs 36.9A and B).



**Figs 36.9A and B:** (A) X-ray showing In-Space device in position holding the upper and lower spinous processes; (B) Operative exposure of the implant showing it in position

### Postoperative Period

Usually, the postoperative period is uneventful. Patient is mobilized on the same day of the procedure and discharged home on the next day after doing the X-rays.

### Follow-up

The patient is seen at 1 week, 4 weeks, 4 months and 1 year. He is relieved of the symptoms and spine is mobile.

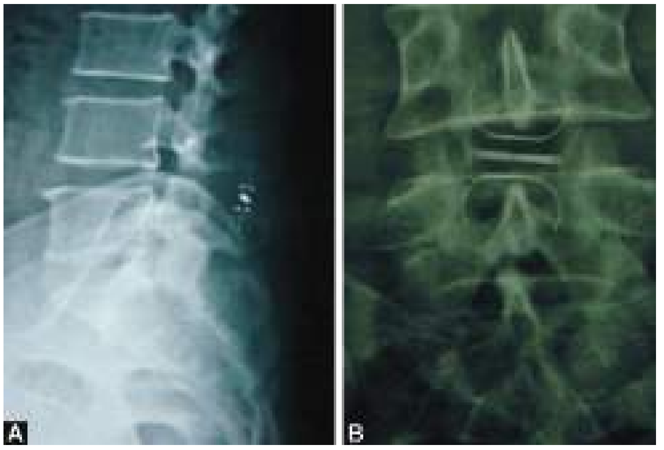
## Results

Over a period of 1 year, 19 cases have been operated upon. All of them have resumed their original work within 3 weeks. There is no spasm in the paraspinal muscles and they can walk comfortably (Figs 36.10 to 36.12).

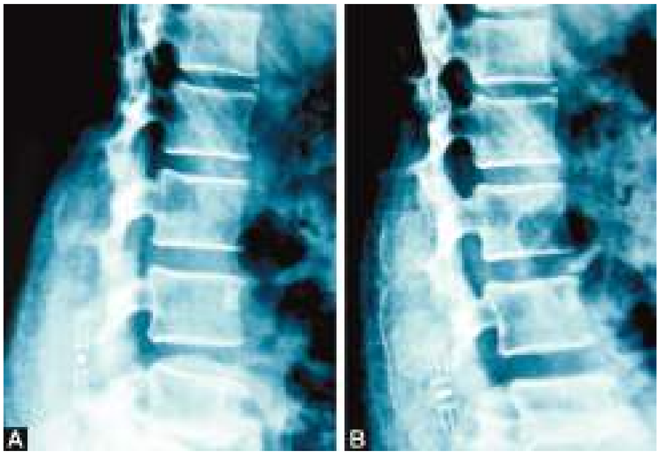
## Complications

So far we have not faced any complications, but one has to be careful about infection in the presence of an implant. There has been no migration of the implant from its position and there has been no hardware malfunction.

**Figs 36.10A and B:** Preoperative X-ray and MRI pictures showing lateral recess stenosis, an ideal case for In-Space device



**Figs 36.11A and B:** Postoperative X-rays showing *in situ* In-Space interspinous process device



**Figs 36.12A and B:** Postoperative X-rays in flexion and extension showing stabilization of instability

## Conclusion

In-Space percutaneous device is very simple to insert and very useful in maintaining stability in a given segment which is unstable. It is very simple to insert and provides dynamic stability to the spine.

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# 37

# New Surgical Method for Lumbar Disc Herniation Associated with Lumbar Canal Stenosis

*Futoshi Suetsuna, Taito Itabashi*

## Introduction

The most standard surgical method for lumbar disc herniation is Love method. The Love method excises the herniation by the posterior approach through the yellow ligament as reported by JG Love in 1939.[1] Thereafter, the Love method was modified to include partial resection of the lamina and excision of herniated disc and in our country even now is the basic surgical method for lumbar disc herniation (LDH).

At present, a lot of methods for surgical treatment for lumbar disc herniation have been performed. However, the modified Love method is the standard method that has remained for over 70 years.

Since microendoscopic discectomy (MED) was put into practical use by Foley and Smith in 1997,[2] it has spread quickly in our country. On the other hand, Casper and Williams reported microscopic discectomy (MD) in 1977[3] and in 1978.[4] We could obtain bright and magnified surgical fields by the use of the microscope, and a safer operation was achieved. Now, MD has been more widely utilized over MED in our country. In addition, there have been several other methods such as percutaneous discectomy and percutaneous endoscopic discectomy for LDH.

However, when deciding which method to choose for LDH, we must first have a full understanding of the morbidity of LDH. The level of herniated disc, the type of sequestration, the morphology of the spinal canal, and the compression on the spinal nerves should be fully analyzed before the suitable surgical method should be chosen. The existence of spinal canal stenosis, especially lateral recess stenosis, and appreciation of the facet joint angle are important. Simple laminectomy tends to cause iatrogenic excision or fracture of the inferior articular process. Moreover, if eyes see only a herniated disc, and the decompression of the lateral recess is overlooked, it will necessitate the need for a surgical revision.

Although LDH frequently occurs in the lower lumbar spine, it may also occur in the upper lumbar spine. The spinal canal in the upper lumbar spine has steep facet angles and the distance between spinous processes and facet joints are short. Also the level of interlaminar space is lower than the intervertebral disc.

In the lower lumbar spine, iatrogenic total resection or fracture of inferior articular processes sometimes happens in cases accompanied by lumber spinal canal stenosis. This is especially the case with steep facet angles or short distances between facet joints and spinous processes. In the presence of these findings, it is difficult to treat with the conventional modified Love method for LDH of the upper lumbar spine or LDH accompanied with lumbar spinal canal stenosis (LSCS).

The author describes a new surgical approach for LDH of the upper lumbar spine or LDH accompanied with LSCS because we cannot safely perform a discectomy by conventional modified Love method, microdiscectomy or microendoscopic discectomy.

## Surgical Technique

### Posture

The patient is placed prone on the Hall frame (four-point frame). It is made of carbon, and we can easily control intraoperative imaging. We apply a catcher mask made from plastic to the face and secure a sufficient space for the face to reduce the danger of pressure on the eyes (Fig. 37.1).

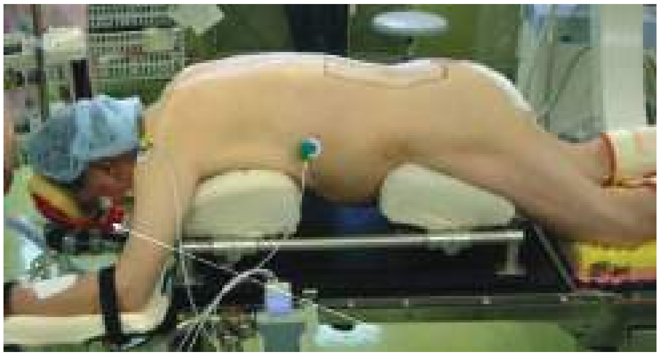


**Fig. 37.1:** Prone position on the Hall frame. Catcher mask (arrow) is applied to the face


**Fig. 37.2:** Exposure of L2-3 spinous processes

## Marking

Carry out marking to the spinous process of upper vertebral bodies of the intervertebral disc of the lesion under C-arm imaging.

## Skin Incision

An incision about 4.0 cm long is made on the skin over on L2-3 spinous processes. Subcutaneous tissue is divided, and then the top of the spinous process of L2 and L3 lumbar spine are checked (Fig. 37.2).

## Exposure of L2 Lamina and L2/3 Interlaminal Space

The L2/3 supra- and interspinous ligaments are first divided into right and left from midline is excised and then the lower end of L2 spinous process using diamond burr (Fig. 37.3). Then, obliquely the L2 spinous process is cut using a microbone saw. In cases with spinal canal stenosis that needs decompression on both sides, oblique cutting of L2 spinous process are performed right and left side (Figs 37.4A and B). In cases that need only

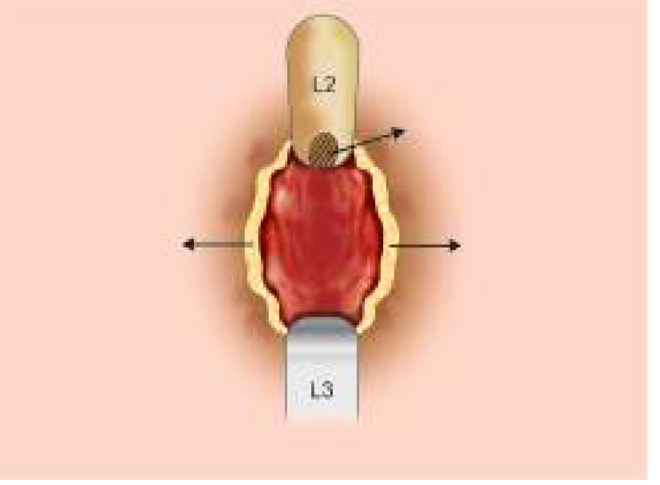



**Fig. 37.3:** Supra- and interspinous ligaments are divided into right and left (arrows), and the lower end of L2 spinous process is deleted using diamond bar


**Figs 37.4A and B:** Oblique cutting of the L2 spinous process

**Fig. 37.5:** Spinous process is divided into right and left

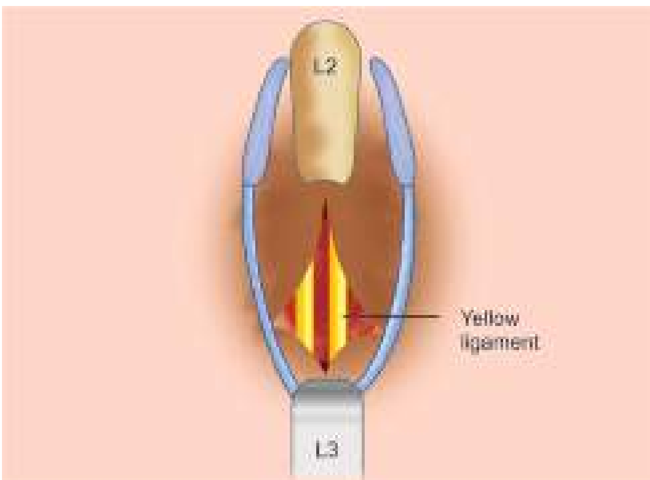
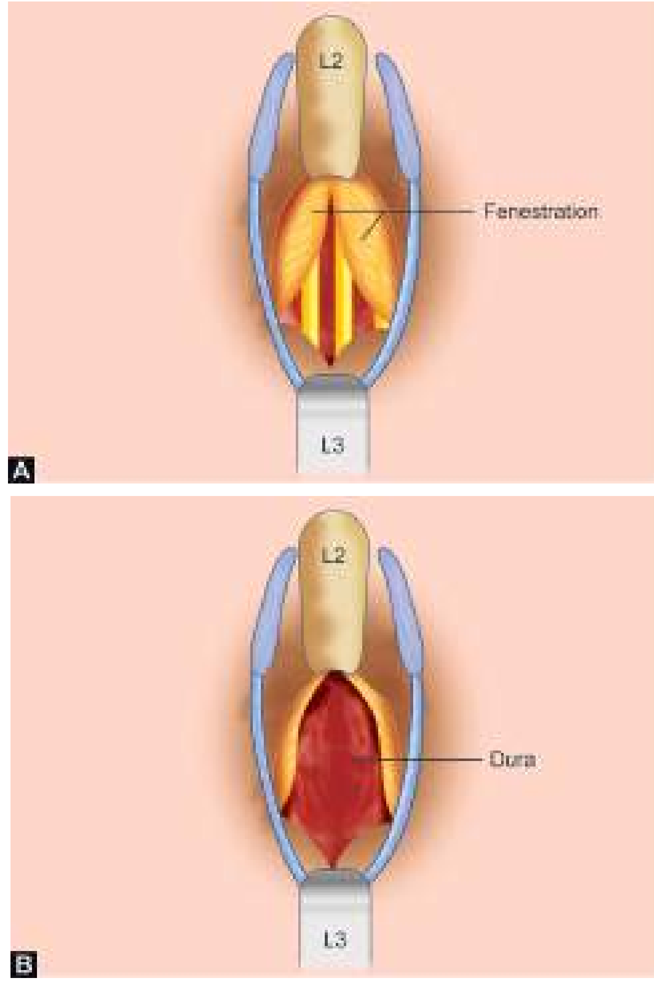



**Fig. 37.6:** Division of spinous process into right and left preserving the posterior ligaments

decompression of one side or bilateral decompression from ipsilateral approach, oblique cutting of the spinous process on one side is required. Then, the spinous process is divided into right and left (Fig. 37.5) while preserving the posterior ligaments, and L2 lamina and L2/3 yellow ligament are exposed (Fig. 37.6).

## Fenestration

Fenestration was done on one side with the air drill under microscope or loupes, over yellow ligament on left side. We use a steel bar at first, and change to the diamond burr after that. If it leaves the yellow ligament then we delete the medial part of the inferior articular process, and decompression can be advanced safely. With sufficient field of view, we can decompress obliquely from the midline (Fig. 37.7A). Since the angle of the facet joint in the upper lumbar spine is steep, we preserve 1/2 or more so that the facet joints may not be compromised too much. We can view the sufficient surgical field from the midline. Fully preserving the facet joint decompression is possible.




**Figs 37.7A and B:** Fenestration. (A) Before fenestration; (B) After fenestration

A bone resection is carried out to the limit of yellow ligament attachment, and the yellow ligament is excised after exposing it. Then the dura mater is exposed and the nerve roots are also checked (Fig. 37.7B). Laminectomy of the portion in which the yellow ligament does not exist should be carefully carried out because the yellow ligament exists from the upper end of lower lamina to the lower end of upper lamina. This will help prevent the dura mater from being torn.

In many cases, the only range of decompression that the yellow ligament permits is enough as the upper and lower decompression is range. In addition, we fully decompress the lateral recess of the spine in cases with LSCS. We should ensure that decompression of dorsal root ganglion has been carried out thoroughly; especially in cases was the ganglion found in the spinal canal.

## Excision of Disc Herniation

We confirm the nerve root level of the lesion. We carefully retract the nerve root inside, and then cut the posterior longitudinal ligament (PLL) and the disc herniation under the PLL is excised.


**Fig. 37.8:** Making holes in the spinous process on the right and left once separated, and the spinous process which remains

We have to check and ensure that there is no residual disc fragments and decompression of the lateral recess is adequate. A drain is placed on the lamina after enough washing of the surgical field.

### Resuturing of Detached Spinous Process

We make two holes with an air drill in the spinous process on the right and left once separated by microbone saw, and the spinous process which is remaining behind (Fig. 37.8).

Then, we pass one nonabsorbable suture at a time through a hole in a figure-of-8 pattern, the detached spinous process on the right and left is drawn near in a figure-of-8 pattern, resuturing the detached spinous process to the base of the spinous process in the midline is carried out and the supraspinous ligament continuously divided to the right and left in the midline is sutured (Figs 37.9A and B).

### After Treatment

On postoperative day, one the patients start to walk with a soft corset which is worn for about 6 weeks.

## Case Presentation

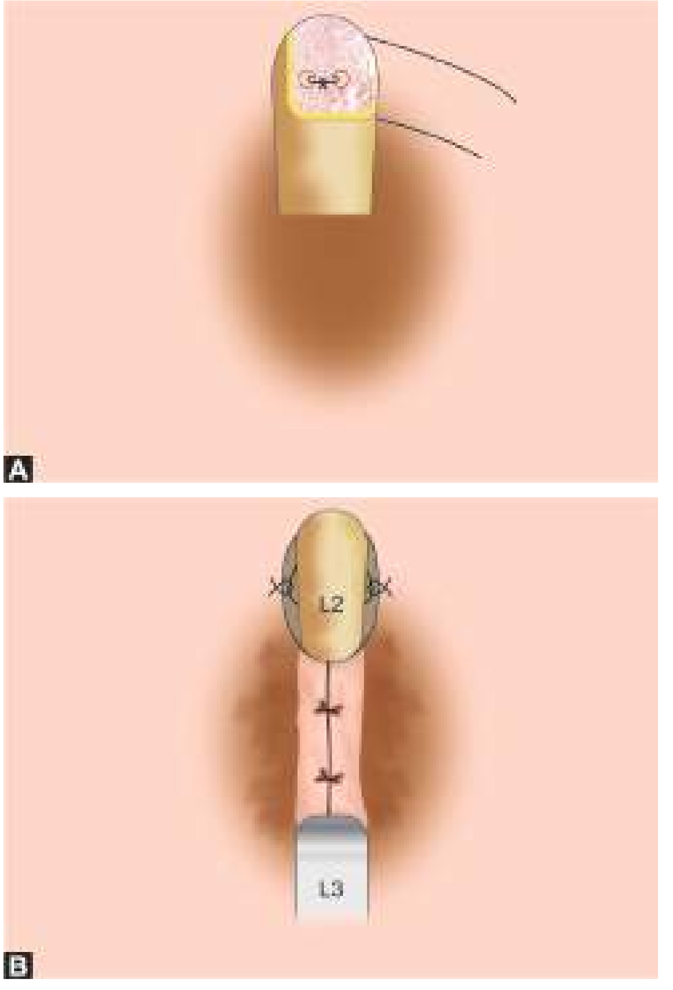
A 67-year-old female
*Clinical Complications:* Left gluteal pain and thigh pain.

### Past History

Diabetes mellitus, cerebral infarction.

### Present History

One-year history of left leg pain that failed to resolve with conservative treatment. So, she visited our hospital. Left L3 selective root block was performed and her left leg pain improved immediately but recurred the next day.




**Figs 37.9A and B:** Resuturing of the detached spinous process to the base of the spinous process in the midline and the supraspinous ligaments

### Radiographic Examination

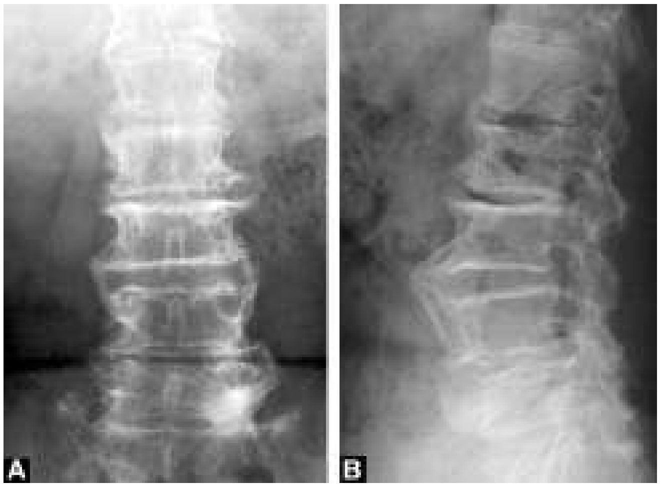
Plain radiographs of the lumbar spine revealed L4 spondylolisthesis with 9.3 percent slip in flexion position, L2/3 vacuum phenomenon and L3/4, 4/5 anterior spur formation (Figs 37.10A and B). T1- and T2-weight MR images showed severe stenosis with left paracentral herniation at L2/3 level (Figs 37.11A and B). Myelo-CT showed steep facet angle and severe stenosis of L2/3 level and a sequestrated herniation mass at the upper end of the L3 vertebral body (Figs 37.12A and B).

#### *Neurological Examination*

Deep tendon reflex (PTR and ATR) of lower legs were present. She had no neurological deficit.

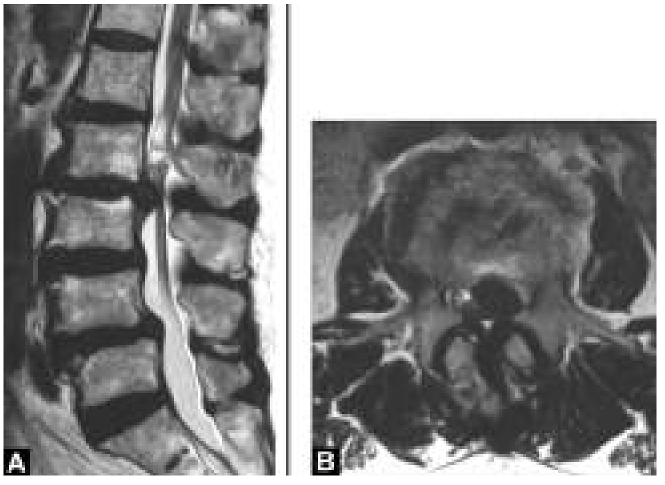
### Surgery

Surgery was done as above mentioned through 4.0 cm skin incision (Fig. 37.13). We partially resected lower end of L2 spinous process using diamond bar and L2/3 supra- and inter-spinous ligaments were divided into right and left (Fig. 37.14).



**Figs 37.10A and B:** Preoperative X-rays of lumbar spine. (A) Anteroposterior view; (B) Lateral view


**Fig. 37.13:** 4.0 cm skin incision



**Figs 37.11A and B:** Preoperative MRI. (A) Sagittal view (T2 weight); (B) Axial view at upper end of L3 vertebral body (T2 weight)

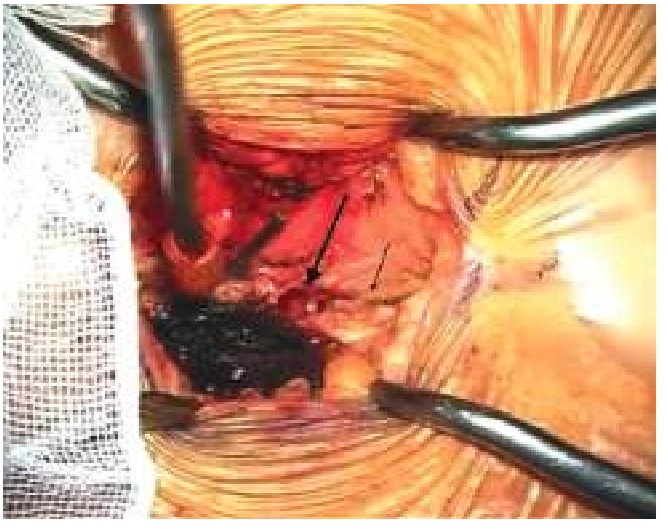
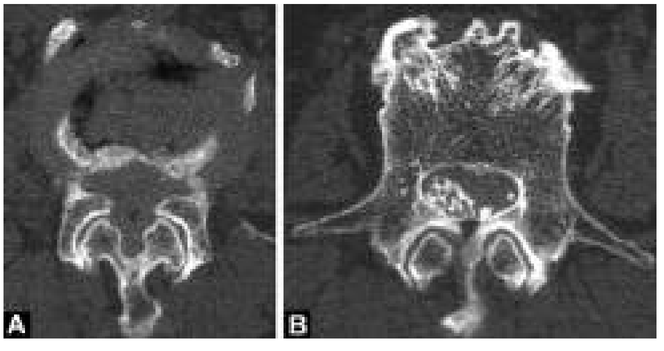


**Fig. 37.14:** Deletion of the lower end of L2 spinous process (large arrow) and division of supra- and interspinous ligaments (small arrow)



**Figs 37.12A and B:** Myelo-CT. (A) Axial view at L2/3 level; (B) Axial view at upper end of L3 vertebral body

Then, oblique cutting of L2 spinous process using microbone saw was performed right and left (Fig. 37.15). Then, the spinous process of L2 was divided into right and left while preserving the posterior elements. Then, we decompressed obliquely from the midline and left L2/3 sequestrated herniation was excised (Fig. 37.16). We passed two nonabsorbable sutures at a time through holes of L2 spinous process to attach back the cut portion (Fig. 37.17).

## Postoperative Findings

Plain X-rays showed bilateral L2/3 fenestration (Fig. 37.18). Postoperative CT revealed bilateral fenestration with preserving

**Fig. 37.15:** Oblique cutting of L2 spinous process using microbone saw

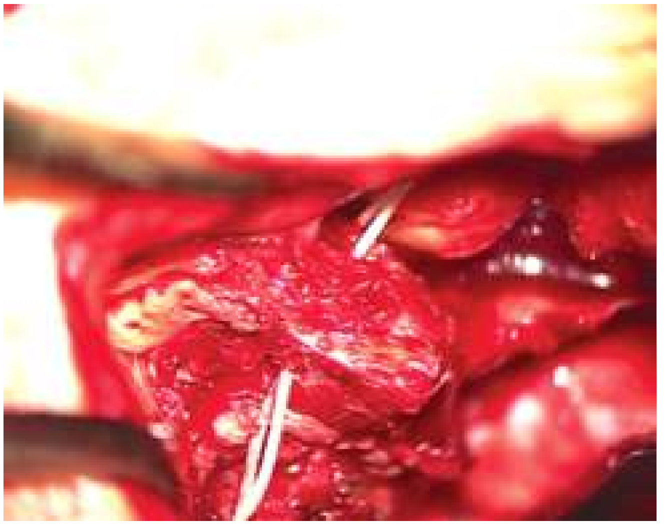


**Fig. 37.17:** Passing of two nonabsorbable sutures at a time through holes of L2 spinous process

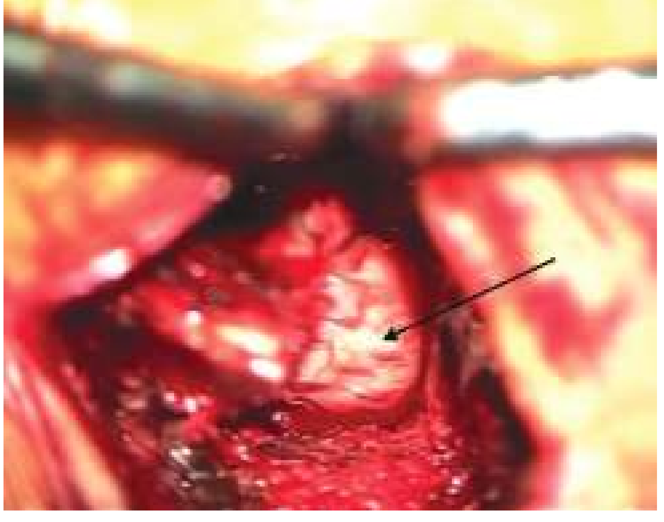


**Fig. 37.16:** Oblique decompression of the dura and roots (arrow)

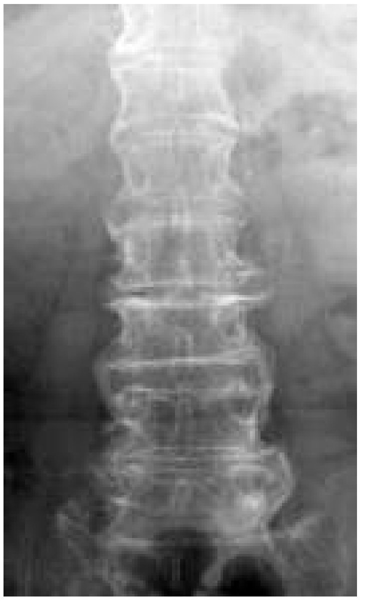


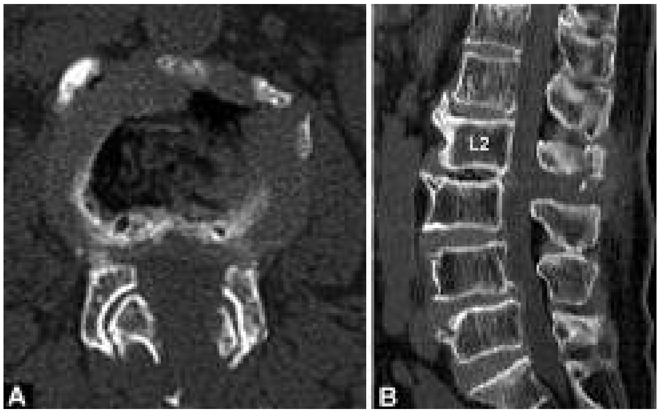
**Fig. 37.18:** Postoperative X-ray (anteroposterior view)

facet joint of L2/3 level (Figs 37.19A and B). Magnetic resonance imaging (MRI) showed complete decompression of sequestrated herniation at L2/3 level and upper end of L3 vertebral body. In addition, MRI showed no remarkable muscle damage from this surgical approach (Figs 37.20A and B). Her left leg pain was resolved.

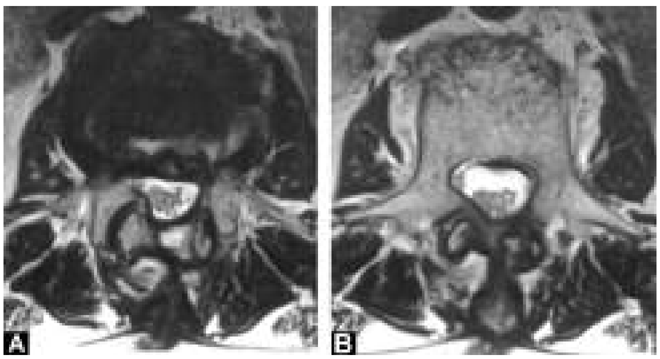
## Discussion

The standard surgical method for lumbar disc herniation is the Love's method first reported by Love[1] in 1939. It is a simple and basic method commonly used now even after 74 years. However, the surgical field of view is limited, it has a deficiency in brightness, and there are problems with the hemostasis of the extra-dural veins, etc. Since then, microendoscopic discectomy (MED) was put into practical use by Foley and others in 1997. This minimally invasive surgery has spread in our country over the past several years. However, this procedure has a steep learning curve to obtain the skills necessary for this surgical technique and it also needs an image intensifier during surgery.

On the other hand, the microscope has been commonly used in the past by neurological surgeons. It gives us bright surgical fields of view and allows to easily cauterize the extradural veins. In addition, there is the added benefit of surgeons and assistants




**Figs 37.19A and B:** Postoperative CT. (A) Axial view at L2/3 level; (B) Sagittal view of lumbar spine (L2 spinous process)




**Figs 37.20A and B:** Postoperative MRI. (A) Axial view at L2/3 level; (B) Axial view at upper end of L3 vertebral body

sharing the same surgical views allowing the surgeons to perform simultaneous educational instructions. Moreover, the learning curve is also not as steep. Then, we change into MD from MED and have continued up to now. Although the length of skin incision is slightly longer than that of MED, it does not add to extramorbidity.

On the other hand, wide laminectomy including the medial side of the facet joint for lumbar spinal canal stenosis (LSCS) was the gold standard method until 1980.[5] However, the morbidity of spinal canal became clearer and it has turned out that there are many cases that show improvement by partial lumbar laminectomy (fenestration).[6,7] Since the author also performed the fenestration surgery to LSCS in 1985 for the first time, it has been one of the standard methods for treating LSCS to this day.

However, in cases with steep angles of the facet joints in LSCS or LDH of the upper levels, it is difficult to preserve the facet joint below 1/2 with the conventional fenestration, and it may cause iatrogenic excision or fractures to the inferior articular process. Especially, in cases that have large spinous process and short distances between facet joints, the spinous process becomes obstructive. So, it is very difficult to perform fenestration with preserving enough of the facet joint. However, it is possible to decompress while preserving the facet joint from the midline approach.

The spinous process midline splitting approach that Watanabe[8] reported is an outstanding method for LSCS which preserves posterior elements of the lumbar spine. However, in order to divide a spinous process to the right and left after midline vertical sawing, there are problems with continuity of the spinous process that was cut, and the lever arm dysfunction of the spinous process.

Then, applying the midline splitting spinous process approach, we devised the new method preserving the inferior articular process as much as possible from midline approach.

We remove the spinous process obliquely from the top of the spinous process to right and left without separating the spinous process itself and preserve the periosteum and bone together, and resuture the detached thin separated spinous process to the remaining spinous process after decompression. Our method completely reproduces the posterior elements including the spinous processes.

We can safely perform bilateral decompression from the midline under the bright microscope. This method has indications for not only standard LSCS but also LSCS or LDH with steep facet angles.

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# 38

# Lumbar Instrumentation Surgery with Pedicle Screws in Lumbar Disc Herniation

*Motoi Shoda*

## Introduction

Posterior Lumbar Interbody Fusion (PLIF) with Pedicle Screw (PS) fixation technique is useful in lumbar disc herniation in the elderly. However, there are some problems such as:

- Many surgical techniques
- Elderly patient
- Osteoporosis
- Complications
- Recurrence of the symptoms.

Even PLIF and PS fixation technique has such problems this surgical procedures provide good outcome and satisfaction for lumbar spondylolisthesis patients. Good outcome has been reported by only laminectomy alone, but patient satisfaction becomes worse year after year. The role of instrumentation for lumbar spondylolisthesis is decompression of the nerve root, correction of lumbar pathologies, bony fusion and early mobilization. Recent trend for lumbar surgery is minimum invasive spinal surgery (MISS). Instrumentation surgery is not the MISS anyhow, because of artificial material apply to decompression the nerve for this technique. PLIF and PS surgical techniques are presented in this chapter.

## Evaluation of the Patient Lumbar Spine

Most common is L4 Degenerative spondylolisthesis (DSL). In L4 DSL L5 superior facet and yellow ligament compress the L5 nerve root. In L5 ISL L5 superior facet and intervertebral foramen of L5/S1 compress the L5 nerve root. Preoperative functional lumbar X-ray, MRI and CT (+myelogram) examination are necessary to check nerve compression. To evaluate osteoporosis, vertebral rotation, instability, percent slip, pedicle diameter and relationship with the iliac crest is checked before surgery. Most important point is to evaluate the facet conditions. Figures 38.1A to F show various pathologies. Figure 38.1A shows severe degeneration of DSL, Figure 38.1B shows typical isthmic portion of facet. Figures 38.1C and D show vertebral anomaly, Figure 38.1E shows dysplastic type and Figure 38.1F shows pedicle fracture. Surgical indication of spondylolisthesis is still no clear criteria. The reason is because of these complicated pathological situations. Scoliosis and adjacent level problems are other important problems.

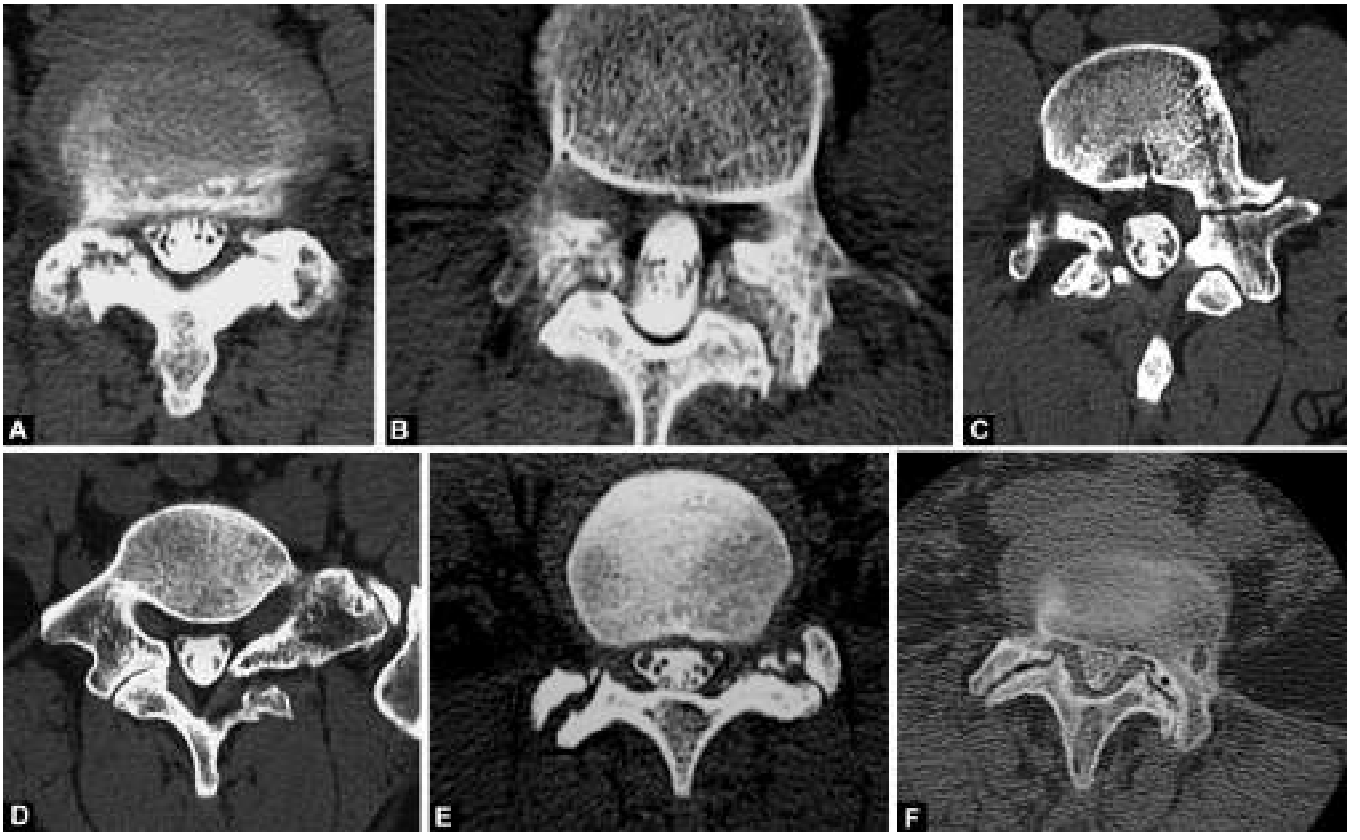
## Surgical Procedure

Before start surgery, check the pedicle and alignment of patient lumbar spine under fluoroscope. This procedure is important to insert instruments accurately. Iliac crest is most important information which prevents the accurate direction of PS at S1, sometimes L5 pedicle.

## Exposure and Decompression

Skin incision is 1st level wider rostral and caudal, and muscle dissects from spinal lamina until confirm the origin of transverse process. Take the X-ray before remove the lamina. Yellow ligament was removed totally from the attachment of upper level of lamina.

Microscopic manipulation starts after remove the lamina. Check the upper nerve root and vertebral disc. Then remove



**Figs 38.1A to F:** Various pathological features in the facets associated in the elderly with lumbar disc herniation

the superior facet and lower lamina, to decompress the nerve root until lower level of pedicle. Hemostasis is very important to prevent the dural and nerve injury, at implant insert. Venous plexus under the posterior longitudinal ligament makes severe bleeding. Meticulous hemostasis is required around this manipulation. Remove the disc and cartilage endplate.

## Cage Insertion

We use cylindrical cage in most of the case. As the patient of DSL is elderly, we do not use autograft because of osteoporosis. We use Hybrid Cage (Titanium cage filled with Hydroxyapatite) in spondylolisthesis patient (Fig. 38.2). Initially, short distracter applies in counterside of cage insert side, then long distracter applies on same side of cage insert side. Following insert the guide protector and the reaming of inter vertebral space, Hybrid cage insert in disc space under the fluoroscope. Good osteosynthesis was seen by postoperative CT (Figs 38.3A to C).

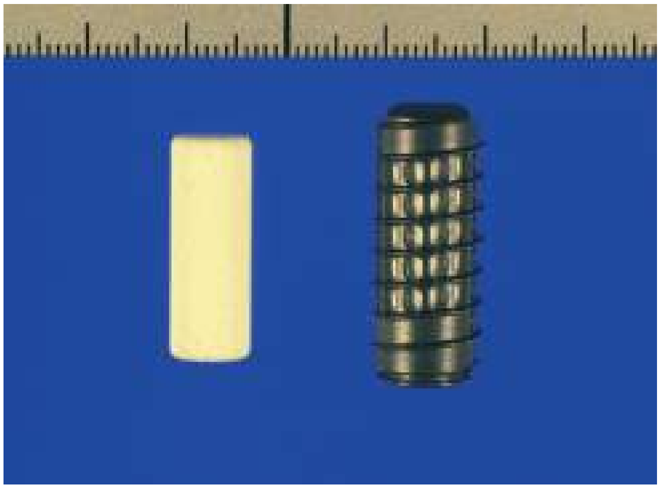
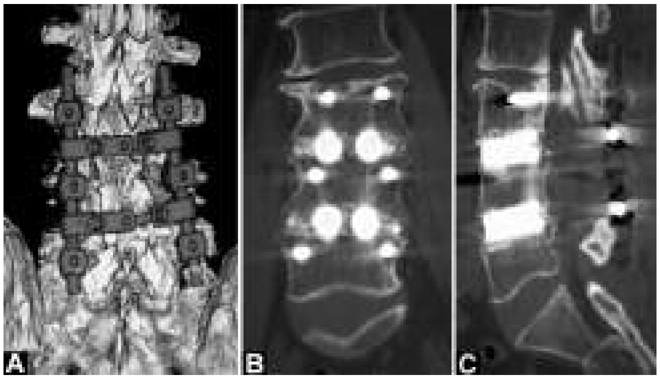


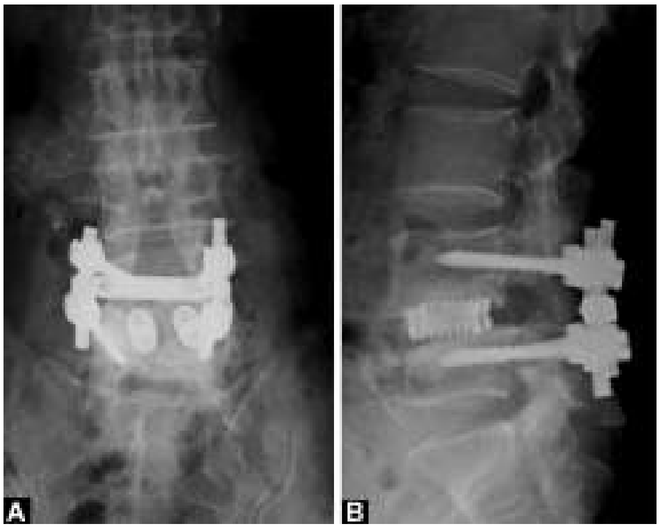
**Fig. 38.2:** Left: Ceramic graft; Right: Titanium cage

## Pedicle Screw Insert

Insert point of PS is just lateral of pedicle. Accurate insertion is required and very important to prevent nerve injury and long-term outcome. Transverse process and pedicle is good land mark. Screw size is decided after test screw guide. Single trial is very important to prevent screw loosening and backout. Screws were fixed by rod, and transverse crosslink implant (Figs 38.4A and B).




**Figs 38.3A to C:** X-rays showing fusion in the grafts




**Figs 38.4A and B:** Pedicle screw fixation along with interbody cage, a crossbar has been used

## Closure

After washing the surgical area with saline, again hemostasis procedure done meticulously. Drainage tube is inserted in epidural space, which is removed 36~48 hours postoperatively.

## Postoperative Care

Wound condition, CRP, ESR, fever, back pain and neurological examination were checked after surgery. Deep infection is important problems. We check progressing anemia, is one of important index after surgery.

## Surgical Outcome

We have done 350 cases of spondylolisthesis. Hybrid cage was done in 314 cases (Table 38.1). *Patient background:* 62.5 (16–84) years old, (Fig. 38.5), male : female = 153:197, follow-up period is 61.2 (1–180) months. *Pathology:* DSL is most common 255 cases. ISL is 65 cases. Dysplastic is 10 cases, fracture is 5 cases and DSL+ISL is 1 case (Fig. 38.6). *Operative site:* L2:6, L3:23, L4:210, L5:58 cases. Multilevel surgery is L2-3:2, L3-4:45, L4-5:2, L2-3-4:4 cases (Table 38.2).

**Table 38.1:** Type of surgical procedure used

| | |
|---|---|
| • Total cases | 350 cases |
| • Surgical procedures hybrid cage | 314 |
| – Pedicle screw + cage | 331 |
| – Pedicle screw + cerabone | 2 |
| – Pedicle screw + autograft | 17 |
| – Posterior decompression | |

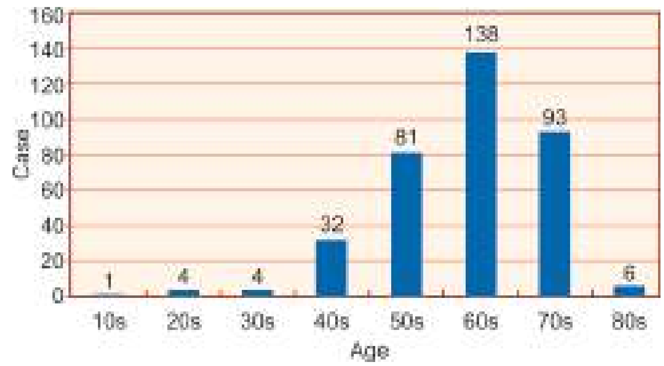



**Fig. 38.5:** Age distribution of elderly patients undergoing fusion

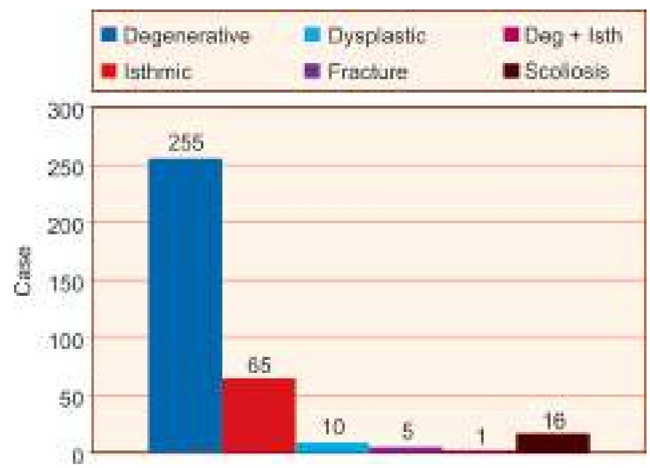



**Fig. 38.6:** Classification of spondylolisthesis

## Postoperative Radiological Evaluation

Postoperative radiological evaluation was revealed. The %Slip and Slip angle are improved statistically, but lumbar lordosis did not improve postoperatively (Fig. 38.7).

**Table 38.2:** Clinical data

| | | |
|---|---|---|
| 1. | Age | 62.5 (16–84) years old |
| 2. | Gender | Male : Female (153:197) |
| 3. | Follow-up | 61/2 (1-180) months old |
| 4. | Location | |
| | L2 : 6 | L2, 3 : 2 |
| | L3 : 23 | L3, 4 : 45 |
| | L4 : 210 | L4, 5 : 2 |
| | L5 : 58 | L2, 3, 4 : 4 |

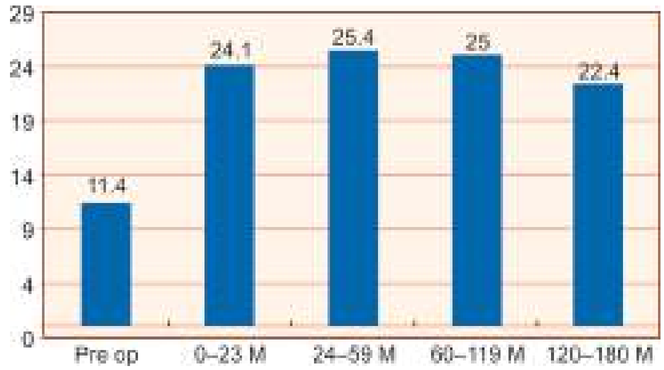



**Fig. 38.8:** Surgical outcome of JOA

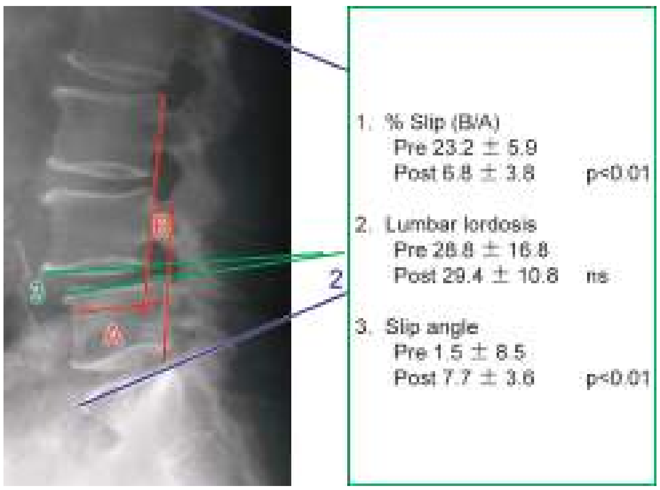



**Fig. 38.7:** Postoperative radiological evaluation for spondylolisthesis with PLIF + PS

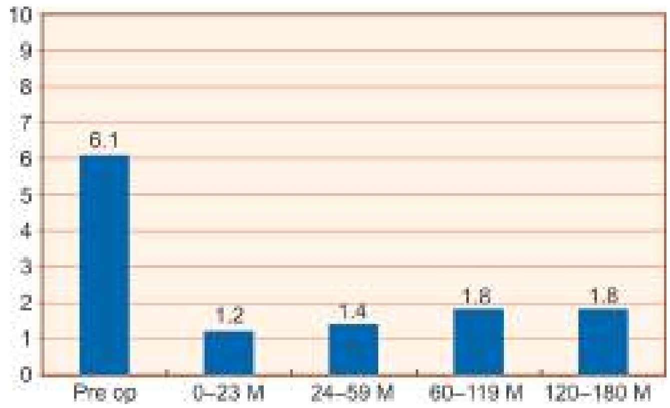



**Fig. 38.9:** Outcome of VAS for pain

### JOA Score

Postoperative improvements by JOA (Japan Orthopedic Association) score is 11.4 before surgery, 24.1 (postoperative within 2 years), 25.4 (postoperative 2–5 years), 25.0 (postoperative 5–10 years) and 22.4 (postoperative 10–15 years) (Fig. 38.8).

### Visual Analog Scale (VAS) Pain Score

Preoperative VAS pain score is 61 mm, and 12~18 mm until 180 months postoperatively. Patient can tolerable pain in less than 20 mm in VAS pain score (Fig. 38.9).

## Complications

No root injury, and systemic complication except 4 cases of CSF leakage during surgery. Two cases were reoperated in whom cage with autograft migration due to pseudoarthrosis. Two cases had to undergo screw and cage system removal due to infection. Two cases of adjacent level stenosis had to undergo operation 10 tears after surgery in this study.

## Conclusion

Rigid fixation (PLIF + PS) technique for lumbar disc herniation in the elderly provides good and surgical result for over 15 years. This technique is not MISS but this achieved good satisfaction for patient for long period.

# 39

# Total Disc Replacement of Lumbar Spine

Kyeong-Sik Ryu, Chun-Kun Park

## Introduction

The golden standard of surgical treatments in a patient with degenerative lumbar disc disease (DDD) is known to be an entire discectomy of painful disc with interbody fusion of the index segment. However, a patient treated with this fusion surgery can have fusion-related complications such as pseudoarthrosis, and pain or infection on the graft donor site, and some investigators reported that even successful fusion did not necessarily guarantee successful surgical outcome.[1] Besides, it has been reported that loss of motion in the index segment by fusion increases mechanical load on the adjacent segments, and results in increase of the onset potential of adjacent segment syndrome.[2-7]

The total disc replacement (TDR) surgery of lumbar spine had been developed to supplement such shortcomings of fusion surgery so as to preserve segmental motion postoperatively and to maintain normal spinal dynamics, and it is actively being applied in current clinical setting. Treatment by TDR, unlike fusion surgery, could avoid fusion-related complications, and minimizes the fusion effect such as an increase of mechanical load on adjacent segments, so that it is expected to get out of fusion-induced degeneration of adjacent segments.

For development of prosthetic intervertebral disc, the first attempt was studies on experiments using silicon, polymer, spring and piston system for the purpose of preserving visco-elastic property of intervertebral disc or studies to observe on preservation of intervertebral disc mobility by using various mechanical devices from 1950s.[8,9] Most of these early studies were to examine the mobility of prosthesis in the cadaveric lumber spines, and identify whether a prosthesis was firmly fixed or not on the vertebral body, but rarely used for actual clinical application. In the late 1950s, Fernström firstly performed such procedures in patients actually.[10] Fernström had developed a prosthetic intervertebral disc in the form of metal ball, and inserted that prosthesis between lumbar spines in 250 patients. But, his procedure could not be continued any longer due to the problems caused by hypermobility of operated segment and the prominent subsidence caused by penetration of metal ball into the endplates. Fassio, in 1977, developed a silicon structure made in shape of a flying saucer, with globular shaped center and flat outer side, and implanted it to three patients, but from 4-year follow-up period, the complications were observed including the subsidence of the operated level, loss of segmental mobility, and implant migration.[11] Then, an implant, which was made of HP-100 silicon elastomer (AcroFlex disc) and developed by Steffee et al. was clinically applied in TDR operation. Although the initial clinical results appeared to be successful, its use was suspended in further follow-up, because a defect was found in the silicon.[12] In 1984, SB Charité was developed by Schellnac and Büttner-Jans of East Germany for the first time and used in clinical setting, but it was also suspended for use as the implanted prosthesis moved in location and stress fractures were observed in follow-up. Since 1987, SB Charité III, 3rd generation was introduced after 2 times of amelioration and has been clinically used up until now.[13-17] Afterward, various types of implant for TDR including ProDisc-L, Maverick, and PCM, have been introduced and actively applied in clinical practice throughout the world.

## Biomechanics

Human intervertebral disc has been evolved functionally to endure the compression load on the spine in standing posture. The nucleus pulposus absorbs the compression loads, redistribute them in radial shape, and convert the load delivered from annulus fibrosus into tensile load. When the disc loses moisture, the internal pressure of nucleus pulposus becomes insufficient and durability of motion segment against the compression load is deteriorated, which leads to a series of degenerative reaction including split or tear of annulus fibrosus caused by addition of shearing strength on annulus fibrosus. Lumbar spine receives very large physical load to the extent of 1~2.5 times of body weight, which is loaded on the lumbar intervertebral disc during normal walk.[18,19] Approximately, 80 percent of the compression load is delivered to the anterior part of lumbar spine and the rest is delivered to the facet joint of spine. Degeneration of intervertebral disc and decrease disc height can affect to the physiological spinal segment's rotation axis. These degenerative changes move the rotation axis to posterior, and cause excessive load on the facet joints.[20,21]

The instantaneous axis of rotation (IAR) for flexion-extension of normal lumbar vertebra is located slightly just below the upper endplate of inferior body and just behind the midline of vertebral body on sagittal plane.[22,23] Nevertheless, IAR varies by segments and individuals, and changes by the spinal movement. The motion range of lumber spine also varies by individual. Therefore, reproduction of the physiological back motion by an artificial disc which has similar biomechanics and properties with human disc in the lumbar spine is not easy.

TDR currently in use can be classified into two types in connection to the pattern of motion in prosthesis: semi-constrained and nonconstrained types. Semiconstrained type includes ProDisc-L (Synthes Spine, West Chester, PA, USA) and Maverick (Medtronic Sofamor Danek, Memphis, Tennessee, USA) as its representative products, both of which are based on the type of ball-and-socket joint. It is possible for these prostheses to make lateral flexion and rotation movements but to constrain segmental translation as they have a fixed center of rotation. Nonconstrained type includes SB Charité (Depuy Spine, Inc. Raynham, MA, USA) as a representative product, which is composed of upper and lower metal plates and the core between the plates. This core can have this prosthesis perform forward, backward, side to side flexion and translation, which makes the rotation axis of segment also move along, reproducing the movement pattern similar to physiological IAR.

The posterior spinal structures take important parts in motion physiology of lumbar vertebrae. The facet joint that impedes excessive lumber extension and anterior transposition should cover the compression load being given during excessive extension and anterior shear loading.[24,25] The facet joint is not affected from posterior shear loading. And posterior column ligaments (supraspinous ligament, interspinous ligament, facet joint capsule) resist the backward shift of segment, receiving the extension load. The degeneration degree of posterior spinal structures can have substantial effects on the surgical results in TDR, therefore it requires careful observation on the degeneration degree of posterior spinal joints when considering any implementation of TDR. When the motion is recovered by performing the replacement on the segment that used to loss preoperatively most of motility due to progression of degeneration, or when postoperative hypermobility occurs on the operated segment, these cases can induce new compression and shearing load on facet joints that will cause postoperative pain in the posterior spinal structures after TDR. In the semiconstrained type, because the rotation axis is fixed and segmental translation is restrained, the shear force being added to facet joint before and after TDR can be minimized, and the prosthesis may enable to expect the effects of shear force on the facet joint insignificant, but when the shear force incurs to forward to backward and side-to-side just like constrained type, the shear load at a certain degree will act continually on the facet joint so that it is expected that the degenerative change may be accelerated.

The loss of segmental motion after fusion surgery is known to put more weight on adjacent segment as mechanical load, to interrupt the physiologic sagittal array and to accelerate the degenerative change by demanding excessive compensative movement.[3,6,7,26] Although it is expected that TDR minimizes such postfusion effects on adjacent segment, the biomechanics of spinal motion segment vary depending on individuals and segments,[17,26] and artificial discs clinically in use have different structure and structural mechanics in comparison with those of human vertebral discs. In order to obtain successful long-term clinical results, an ideal artificial vertebral disc should be required that can reproduce and maintain similar motion dynamics, structural mechanics and physiologic function with those of the vertebral disc actually existing in the human body.

## Types of Artificial Disc and Insertion Techniques

ProDisc-L is a representative semiconstrained typed prosthesis, which was designed by a French orthopedic surgeon, Thierry Marnay in late 1980's and it had been evolved into the current form, and began to be applied to the clinical setting from the late 1990's.[27] It was designed based on globular joint form, composed with 3 different complex components including two pieces of metal end plates made of cobalt-chromium-molybdenum (CoCrMo), as contacted to the upper and the lower endplates of target segment, and at the center part between them, a mono-convex layer (inlay) is located as made of UHMWPE (Ultrahigh Molecular Weight Polyethylene) (Fig. 39.1).

Maverick is also an artificial disc in semiconstrained type, which had been designed by Mathews et al., as prosthesis in the form of ball-and-socket manufactured by using metal only without polyethylene.[28] The upper and the lower metal end plates of Cobalt-chromium are interlocked directly to each other and constitute the joint side. These two devices are designed to be fixated as being nailed into the upper and the lower vertebral bodies as a keel is installed in the center of the upper and the lower end plates. The constraint of segmental translation by fixation of rotational axis is a mechanical characteristic of these devices (Fig. 39.2).

SB Charite' is a representative artificial disc in nonconstrained type, being constituted with a core made of UHMWPE material in the middle of two metal plate at the center in between them, this core works as a part to provide the segmental

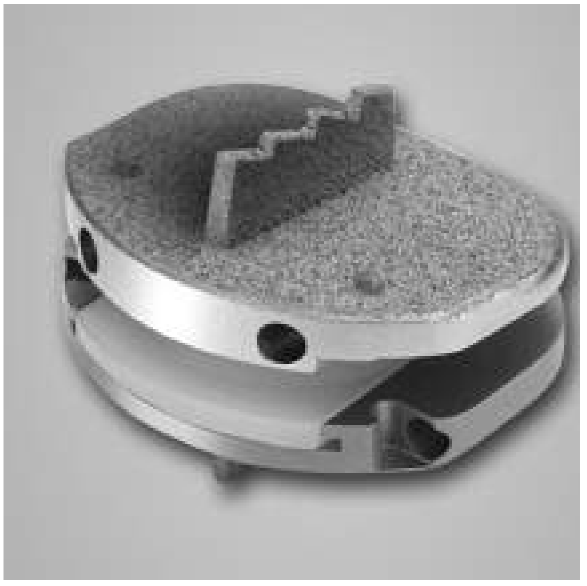


**Fig. 39.1:** ProDisc-L artificial disc

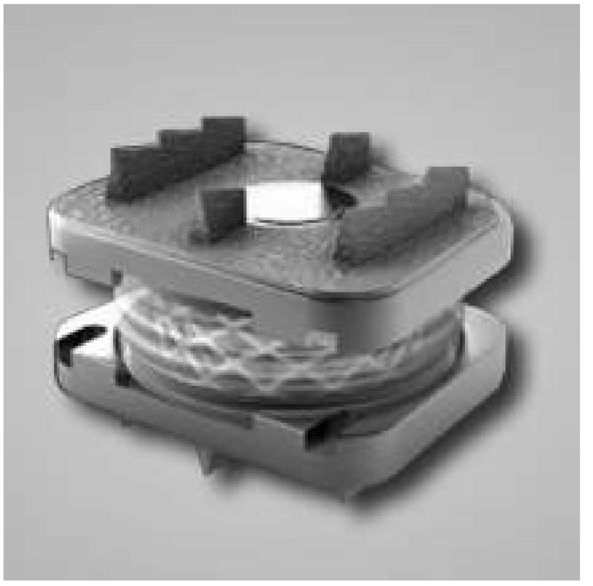


**Fig. 39.3:** SB Charité artificial disc

**Fig. 39.2:** Maverick artificial disc

motion including translation as it moves as being slipped forward, backward and side-to-side according to all directions of motions[14] (Fig. 39.3).

TDR with an artificial disc must be done through anterior approach. Because vena cava is a structure which has a difficulty in dissection and traction, and is located at the right side of the lumbar spine mostly, the left side approach is more preferred. However, in a male patient with L5-S1 lesion, the right side approach is usually recommended because hypogastric plexus is usually located in the left anterior part of promontory of the sacrum and its damage can be avoided. The damage of hypogastric plexus brings about one of most serious postoperative complications, retrograde ejaculation in male. In this procedure, a patient is under the general anesthesia, and lies on a radiolucent operation table that allows the penetration of X-ray on supine position, and the posture is fixated on the table as shown in Figure 39.4.

One of the most important steps in TDR surgical procedures must be correct placement of prosthesis into the middle of disc space on coronary plane and as much posterior as possible on sagittal plane. To achieve the correct placement, it must be confirmed that patient is placed correctly on an operation table and accurate anteroposterior and lateral images can be obtained by C-arm fluoroscope.

An anterior access with retroperitoneal approach is typical in lumbar TDR but most of spine surgeons are not familiar with and are even reluctant to take this approach due to potential risks of large vessel damage. Lately, artificial discs designed suitable for lateral or anterolateral approach to lumbar discs are introduced.[29,30] XL-TDR (NuVasive, Inc, SanDiego, CA, USA) is a representative prosthesis for lateral approach and a semi-constrained type artificial disc in the form of ball-and-socket made with Cobalt-chromium (Fig. 39.5).

It has spikes at the center and both lateral sides of metal end plate, which fix the disc as they stick into adjacent upper and lower vertebral bodies. For lateral approach, left side is preferred as it is performed with procedures to position the patient in lateral decubitus and make transversal incision on the skin where the incision site is determined at the place matching to the disease disc as identified from the images of lateral C-arm fluoroscope for approaching to the pathologic disc. Retroperitoneal transpsoas approach using sequential dilator could expose lateral side of the disc, and in such case, it requires a real time nerve monitoring such as EMG in order to avoid the damage of lumbosacral nerve plexus. This approach has the merit that it does not need the manipulation of abdominal major

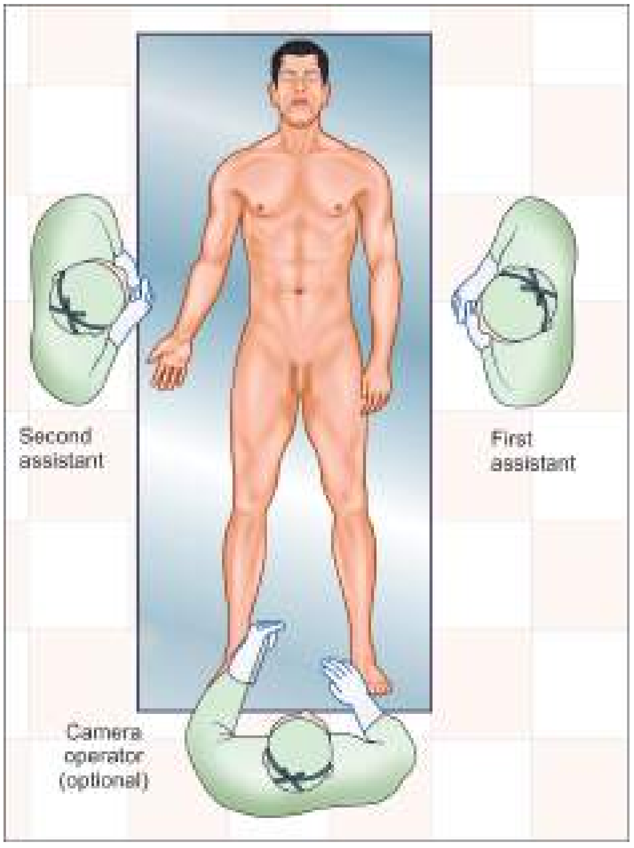



**Fig. 39.4:** DaVinci position. The patient is placed in supine position with arms abducted 90° and legs abducted 30° to 40° on radiolucent operating table

**Fig. 39.5:** XL-TDR artificial disc

vessels but also has the demerits of high-risk of nerve plexus injury and difficult accessibility due to iliac crest in case of lower intervertebral discs.[30] FlexiCore (Stryker Spine, Allendale, NJ, USA) is a semiconstrained type artificial disc in structural form of ball-and-socket made with Cobalt-chromium and designed to possess the possibility of anterolateral approach (Fig. 39.6).

The artificial discs manufactured only for anterolateral approach include O-Maverick (Medtronic, Sofamor Danek, Memphis, TN, USA) and ProDisc-O (Synthes Spine, West Chester, PA, USA). They have a strong positive point of minimizing the manipulation of large abdominal vessels, but it has been reported that it was practically hard to place them correctly in position and they presented postoperative subsidence frequently.[29]


**Fig. 39.6:** FlexiCore artificial disc

Surgical procedures to assemble the prosthesis and to insert the assembled one into the disc space can vary depending on the types of prostheses but the procedures to prepare the designated disc for TDR, which include removal of disc material, intersegmental distraction and preparation of the end plate have some similarities among the artificial discs regardless of their type. Also, it is essential to mobilize the segments after removal of disc. Intersegmental distraction following mobilization of the index segment enables an implant to be placed into the disc space properly in size, and it helps maintaining the motion of prosthesis after surgery. It is important to select the most adequate size of template for a patient. Selection of large footprint as possible can reduce the postoperative subsidence of implant. The height of implant needs to be selected referring to the height of adjacent normal segment, and any excessive restoration of disc height may reduce range of motion at the index segment and increase the compression load on the facet joints, which may result in degenerative arthropathy followed by further reduction of mobility of an artificial disc consequently.

## Indications

TDR of lumbar spine has been introduced as an alternative to the existing fusion surgery in the treatment of intractable discogenic lower back pain caused by internal disc disruption, DDD, or post-discectomy. Thus, the most important matter would be accurate diagnosis of discogenic lower back pain before surgical treatment is planned. Discogenic lower back pain could be defined as follows. Firstly, the pathologic disc presents black in color on T2 weight MR imaging. Secondly, it also presents typical findings of disc degeneration on discography. Thirdly, in provocative test during discography, concordant pain is usually provoked in the pathologic disc although no pain is provoked in the adjacent normal looking discs. Lastly other causes such as facetal pain, muscular pain, or psychosomatic disorders should be ruled out.

There are many kinds of selection criteria for TDR according to policy of each institute and surgeon and independent criteria made public by payers, insurance companies for reimbursement in each country including Korea. Currently, criteria to get the most proper patents, so-called "Prime patients" for TDR have been proposed: Single level DDD (dark disc on MRI) with disc height >4 mm, no facetal degeneration, no adjacent segment degeneration, and intact posterior elements. Meanwhile, the prime patients should undergo conservative treatments for more than 6 months but present no improvement before decision of surgical management.

The contraindications of TDR, which must be more importantly considered than the indications for good surgical outcome, include patients with spondylolisthesis, spondylolysis, advanced facet arthropathy, spinal stenosis, deformed spine by scoliosis or kyphosis, infection, and osteoporosis. And it is also contraindicated in patients with severe disc herniation presenting radicular pain in lower limbs or cauda equina syndrome, history of severe foreign body reaction to implant, and history of major intraperitoneal surgeries. Lastly, in case of pregnancy, severe abdominal obesity or a past history of abdominal surgery, anterior approach may be difficult to perform.

## Clinical Results

Lemaire et al.[31] have performed SB Charité in 105 patients and followed them up for 51 months in average and was reported 79 percent of patients responded as very satisfied and 87 percent of them was able to carry out normal labor works. Tropiano et al.[32] analyzed the outcomes of 57 patients who underwent TDR with ProDisc-L and could be followed up for 8.7 years in average. They have reported that 40 patients had presented notable symptomatic improvement, showing 74 percent of success rate, and they had no implant-related complication but had 5 cases of approach-related complications including deep venous thrombosis, injury of vein, retrograde ejaculation and hernia.

Mayer et al.[33] have performed ProDisc-L in 34 patients and reported the clinical outcomes after mean 56 months follow-up period. They reported that visual analog pain score (VAS) was reduced to postoperative mean 2.4 from preoperative mean 6.3, and ODI (Oswestry disability index) also improved from mean 19.1 to mean 11.5. They reported 1 case with forward displacement of polyethylene core, 1 case of L5 radiculopathy, and 1 case of retrograde ejaculation. Kim DH et al.[34] performed ProDisc-L in 32 patients consecutively, and reported the clinical outcomes of 30 patients who could be followed up over 24 months, in which the mean VAS after 30 months in average (24~41 months) reduced from 7.2 to 1.2, and ODI also reduced from 18.3 to 4.1. The mean motion range of entire levels operated was 4.78 degree, but it was presented as 2.9 degree at L5-S1 level, indicating the motion preservation is not so notable in compared to other level segments.

Lately, highly recognized prospective random controlled multicenter studies with artificial discs and fusion surgery groups were carried out, and their clinical results have been reported. Among these studies, the results of a random controlled comparison study between SB Charite and anterior lumbar interbody fusion (ALIF) with BAK have been reported by Blumenthal et al.[35] This study was performed in patients with single segment DDD (L4-5 or L5-S1) and included 14 healthcare institutions in USA. The randomization was done in the ratio of 2 TDR: 1 ALIF, SB Charite in 205 patients versus ALIF with BAK in 99 patients. In its clinical results, the clinical outcome parameters such as VAS score and ODI revealed significant improvements in both groups, but no significant difference between two groups throughout follow-up period. However, the satisfaction rate was higher in TDR (90.2%) compared to ALIF group (82.8%). And the in-hospital staying days were 3.7 days and 4.2 days in average respectively, indicating that TDR group showed rather good results compared to ALIF group in respect to only other nonclinical outcome parameters. Zigler et al.[36] presented the results of a randomized, controlled multicenter study with ProDisc-L carried out in 18 healthcare institutions in USA to compare between ProDisc-L and 360 degree spinal fusion surgery. This study was conducted in patients with single level DDD of lumbar and consisted of 161 patients in TDR and 75 patients in fusion group. Follow-up period was 24 month. In this study, symptomatic improvement and radiological outcomes were observed. In the results, the postoperative improvement of ODI was observed in 91.8 percent of TDR and in 84.5 percent of fusion group, while the cases whose ODI was improved by ≥ 15 percent were 77.2 percent in TDR and 64.8 percent in fusion group, indicating that the treatment results of the ProDisc-L group was better than those of fusion group, and TDR group presented higher score in both mental and physical items of SF-36 health survey.

The authors very recently have reported the results in clinical outcome of ProDisc-L of 35 patients with minimum 5-year follow-up.[37] According to this report in succession of minimum 2-year follow-up report, postoperatively, all outcome scores (VAS, mean ODI, PCS, and sports activity scores) immediately improved and these improvements were maintained at last follow-up visits with statistical significance. But, outcome score improvements were appeared to be slightly reduced, though not significantly at the last follow-up compared to 2-year follow-up report.[35] Eighty-eight percent of patients were "satisfied" or "somewhat satisfied" with treatment and 60 percent were willing to undergo the same treatment again. Twenty-five patients (71.4%) achieved over-all clinical success.

## Complications

Intraoperative complications related with retroperitoneal anterior approach to the lumbar spine are similar to those of anterior lumbar interbody fusion.[38] When any large blood vessel is injured including abdominal aorta, vena cava and iliac artery and vein, it requires rapid repair as massive bleeding can happen.[39] Also when traction of large vessel is prolonged, it can cause the incurrence of thromboembolism. Ureter could be damaged as well during approach procedures. When the sympathetic nerve chain is located at the outside of lumbar vertebral body, the patient may complain burning sensation in the lower limbs after surgery. In case of male patient, if the hypogastric plexus is damaged, it may cause retrograde ejaculation or erectile failure in less than

5 percent.[40] Such neural structures are mostly enveloped by serosa, making difficult to distinguish on operational sight. Therefore, in order to avoid any unexpected damages, it is essential to prohibit from using a monopolar cautery and to minimize even using a bipolar one during dissection in front of vertebral body or disc.

Postoperative short-term complications associated with the artificial disc include displacement of implant from its original position, vertebral body fracture, positioning error of implant, postoperative radiculopathy and infections. The vertebral body fracture happening during implant insertion can be prevented by avoiding surgery in patients with osteoporosis and by avoiding any excessive interbody distraction during operation. Positioning error of implant is a rather frequently reported complication. But minor positional errors are put into observation usually. The postoperative radiculopathy of lower limbs can occur, mostly caused by iatrogenic HNP or excessive facet joint distraction. The potential possibility of iatrogenic HNP is very low, and facet joint distraction is rather frequent but mostly temporary and relatively well controlled with facetal block. The iatrogenic HNP can incur when the implant is inserted into the disc space under the circumstance of incomplete discectomy.

As for long-term implant-related complications, in the early days of TDR, the fatigue fracture of metal endplate had appeared with high prevalence, but development of metallurgy had enabled the prevalence to be reduced.[12] Subsidence into the vertebral body is comparatively frequently reported complication.[16,28] Subsidence can cause not only the motion loss of operated segment but also secondary symptoms induced from foraminal stenosis so they are emerging as important tasks to cope within the area of artificial disc replacement. However, as aforementioned, when prohibited the operation in patients with osteoporosis and if possible, by inserting a device with bigger foot-print compared to the disc end plate, it would be possible to prevent any subsidence complications.

Heterotopic ossification after total hip replacement is a well-known complication that can reduce the motility of implant or can cause natural fusion.[41-45] There have been some reports on heterotopic ossification and natural fusion occurring after TDR,[39,46] but definite reason of these unexpected sequel has not been identified until now. Some speculated such complications are the influence of chemical substances secondarily freed after muscular damage,[41-45] and some had argued that intake of anti-inflammation agent can reduce prevalence of such complication.[47,48] However, the post-TDR heterotopic ossification in the lumbar spine is reported comparatively less than the one in the cervical spine.

## Prospects

Artificial discs available these days for lumbar TDR have some drawbacks. The representative drawbacks are: (1) The only access to reach the anterior and mid-part of pathologic disc is transperitoneal or anterior abdominal and retroperitoneal approach; (2) There are neither safe ways nor reliable surgical tools available for salvage surgery; (3) No artificial disc may be well compatible with human anatomy and physiology such as no shock absorption property and nonharmonious motion of artificial discs with human back motion, which may result in early facetal degeneration at the index level.[35] These issues strongly require betterment of the current implants.

Whoever an ordinary spine surgeon is, it is hard for the surgeon to stand a burden of the anterior surgical approach because of major large vessels blocking surgeon's approach to the anterior and mid-portion of pathologic disc. Especially in a salvage operation, it can be a big burden and difficult job for even a vascular surgeon to expose a failed artificial disc, which is just beneath the large vessels embedded and surrounded by adhesion and granulation tissues. During manipulating the large vessels, a surgeon should take a risk of large vessels injury, which can be fatal.

To overcome these shortcomings, the design and the way to place prosthesis were recently improved, with which an artificial disc can be inserted via anterolateral or lateral approach without dissecting major large vessels to avoid intraoperative vessel injury and to lighten surgeon's burden both in primary TDR surgery and secondary salvage surgery. However, it may be not easy to place an implant in proper midline position via anterolateral approach. With regard to TDR's nonharmonious motion with physiological back motion, from a quantitative point of view, artificial discs' range of motion in human body following TDR has appeared to be very similar with that of human, but an artificial disc qualitatively identical with human disc is not available in clinical setting yet.

Artificial disc's functional deficiency of shock absorption could be one of its critical disadvantages, because the most important function of human disc is buffering and absorption of axial load longitudinally along the spinal column and also shock incurring between intervertebral bodies. This deficiency would result in acceleration of degenerative changes of the facet joints at operated segment. Such critical disadvantage is expected to be resolved by developing new materials to be consisted of the core of artificial disc. Recently, an artificial disc designed and developed to possess shock absorption property by allowing silicone, polyurethane and rubber in the sandwich form core between the upper and the lower metal end plates has been clinically introduced. Its clinical efficacy and long-term outcome are now under investigation (Fig. 39.7).

Artificial discs these days in use may need more improvement. A newly designed artificial disc must overcome various shortcomings which the present artificial discs have. Furthermore, it must be recognized by a randomized controlled prospective multicenter clinical trial that therapeutic efficacy and long-term surgical outcome of TDR significantly superior to those of fusion surgery in patients with lumbar DDD. If the advantages of this future artificial disc are prospected in detail, they may possess shock-absorption property, be compatible and qualitatively harmonious with physiologic human back and spinal motion, easy access and easy placement without manipulating the large vessels, confirmed their preventive effect against adjacent segment syndrome, have no side effects of assembled artificial disc materials, and have an authentic ways and special tools for a salvage operation without fatal risks of second surgery.

**Fig. 39.7:** M6 artificial disc (Spine Kinetics, Inc. USA)

The authors are confident that advance of science can have spine surgeons use this kind of sophisticated artificial disc but not so expensive in the future, with which TDR becomes surgeons' most favorite and one of the most popular spine surgeries.

## Epilogue

It had been expected by spine surgeons that TDR would replace fusion surgery in order to avoid various expected and unexpected drawbacks related with fusion surgery in the lumbar spine. Since early 2000, clinical, biomechanical and radiological outcome of TDR have been elucidated by numerous investigators and institutes throughout the world. The advantages of TDR have been reported, for instance early ambulation and return to work, high satisfaction rate, maintenance of back motion and reduction of secondary surgery rate. And it has been reported that clinical outcome of the DDD patients treated with TDR such as pain score and disability index presented comparable, somewhat better but without statistical significance, to that of fusion surgery patients in the noninferiority studies of TDR to fusion group. Meanwhile drawbacks and surgical complications of the artificial discs were coming out and recognized one by one: relatively low incidence but more serious. Based on these results insurance companies refused to reimburse artificial discs and related medical expenses in many countries because of no confidence about cost-effectiveness of the expensive prosthesis, artificial disc compared to that of fusion surgery, in other words expensive implant but similar outcome with fusion. The payers' refusal to reimburse them and the disclosed some serious drawbacks might have TDR become out of most ordinary spine surgeons' interest. Although some specific and special spine surgeons including the authors still apply TDR using a current artificial disc in the surgical treatment of a patient with DDD, advance and improvement of current artificial discs and TDR procedures in terms of their design, material and surgical approaches and tools are inevitably warranted to regain their popularity.

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# Techniques, Indication and Outcome of Transforaminal Interbody Fusion in Surgical Management of Lumbar Disc Herniation

*Christopher WK Mak, David TF Sun*

## Introduction

Low back pain is a common condition that affected 70 to 80 percent of people in their lives. The causes of this condition are diverse. The pathophysiology of low back pain was only better understood in recent decades. In 1934, Mixter and Barr demonstrated the association between low back pain and rupture of lumbar intervertebral disc.[1] Crock and colleagues were the pioneers who suggested that low back pain with disc origin was not due to mechanical compression.[2,3] Degeneration of lumbar discs is due to recurrent shear and compression. It is more common at L4/5 and L5/S1 level. Structural changes occurring inside the degenerated disc lead to biochemical and structural irritation of the adjacent nerve endings and ingrowth of new nerves into the interior portion of the disc. All these contribute to symptoms including low back pain and referred leg pain.

The most common cause of chronic low back pain requiring surgical intervention is discogenic pain syndrome, which comprises disc herniation, segmental instability, spinal stenosis and degenerative disc disease (DDD). Conservative management of DDD consists of moderate rest, physiotherapy and medical treatment including anti-inflammatories, analgesics, muscle relaxants and antidepressants. Further interventions such as epidural steroid injection, coblation nucleoplasty, and radiofrequency treatment can be considered, if the above measures fail.

Surgical treatment options aiming to (1) decompress neural element, (2) remove damaged disc (pain generator) and (3) stabilize mobile segment, vary from microdiscectomy, laminotomy and laminectomy to removal of intervertebral disc followed by various arthrodesis techniques or artificial disc replacement.[4-7] There are several approaches for lumbar discectomy and techniques for arthrodesis. Among the most used approaches are: posterior lumbar fusion (PLF), posterior lumbar interbody fusion (PLIF), anterior lumbar interbody fusion (ALIF), circumferential 360° fusion (front and back), transforaminal lumbar interbody fusion (TLIF) and other newer approaches such as DLIF/XLIF (lateral transpsoas approach) and AxiaLIF.

## Lumbar Interbody Fusion Techniques

The original PLIF was first introduced by Cloward in 1940 and remained widely adopted after a number of revisions of the technique. The advantages of PLIF include the ability to access the majority of disc space as well as the nerve roots bilaterally. However, the need of bilateral approach, soft tissue disruption and the more significant neural retraction are the main drawbacks of this approach. ALIF permits direct visualization and allows excellent removal of the disc, segmental immobilization and restoration of lumbar lordosis. It preserves the integrity of posterior complex. Nevertheless, the approach carries risk to large blood vessels and presacral plexus (causing retrograde ejaculation in man). It may be also difficult to perform adequate posterior decompression which is more common in DDD. In 1982, Harms and Rolinger reported another technique: TLIF.[8-11] It is a more lateral approach to the disc with less thecal sac or nerve roots retraction compared with PLIF. Epidural scar is less common than midline posterior approach. The need for paraspinal muscle dissection and retraction however is a major problem of TLIF. This can lead to muscle atrophy and consequently persistent low back pain. In 2002, a modified technique called minimally invasive TLIF (MI-TLIF) was developed by Foley et al. with the aim to reduce tissue damage associated with the exposure of the facet joint while maintaining the ability to achieve neural decompression and adequate interbody fusion.[12-14] This approach was reported to have shorter hospital stay, lesser blood loss and analgesic usage, and earlier postoperative ambulation but require a longer learning curve for the surgeon.

## Surgical Technique of Open Transforaminal Lumbar Interbody Fusion

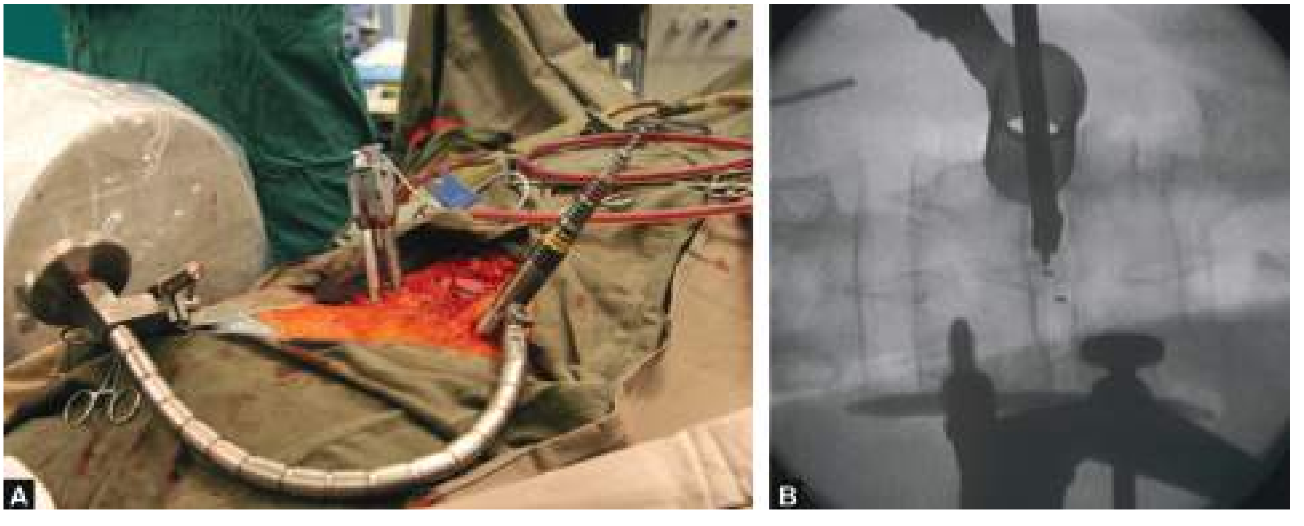
Open TLIF gains access to the intervertebral disc through the far lateral portion of the vertebral foramen rather than through the vertebral canal where the dural sac and spinal nerve roots lie. Patient was put under general anesthesia and was put in prone position. We preferred Wilson frame on top of OSI table to keep the lumbar spine and both hips in flexion position while allowing C-arm in place. C-arm was used to localize the disease level and confirm screws positions. Intraoperative monitoring needles were then positioned for somatosenory evoked potential (SSEP), motor evoked potential (MEP) and electromyography (EMG) monitoring. Muscle relaxants were omitted after intubation to facilitate the MEP and EMG monitoring.

Midline incision is employed and by subperiosteal dissection, paraspinal muscles are dissected from spinous process all the way to the facet joints. Unilateral resection of the inferior articular facet of the superior vertebra and the superior articular facet of the inferior vertebra were performed to expose the unilateral intervertebral foramen. Exposition of the posterolateral portion of the ipsilateral disc space through the vertebral foramen was done. Troublesome bleeding from epidural venous plexus can usually be controlled by gentle coagulation or compression so that visualization and protection of the dura at the medial side can be achieved more easily. Endplates were prepared for cage insertion with bone graft *in situ* under X-ray control. An anteroposterior X-ray screening should be performed to ensure the cage has been passing through the midline. Posterolateral fixation with pedicle screws was performed bilaterally with or without X-ray guidance. Muscle and skin were closed in layers.

## Surgical Technique of Minimally Invasive Transforaminal Lumbar Interbody Fusion

Patient position and intraoperative neuromonitoring set up were similar to open approach. Paramedian incision (around 3–4 cm from midline) at the corresponding level over symptomatic side was made. The exposure of facet joint of the responsible level can be achieved either by a mini-open muscle-splitting technique (the Wiltse Approach), or by percutaneous instrumentation techniques (referred as percutaneous TLIF). Tubular retractors system (e.g. Medtronic METRx™ System) or other minimally invasive expandable retractors systems (e.g. DePuy Synthes PIPELINE® Expandable Access System) was usually employed and inserted right over the facet joint (Figs 40.1A and B).

Microscope was brought in and facetectomy was performed as open TLIF. Superior articular process with part of the lamina can be removed in one piece as autologous bone graft. Dura sac or traversing nerve root may be encountered during the drilling and should be protected. Adequate laminectomy can then be performed in selected cases. Discectomy, endplates preparation and cage insertion were performed in the same manner as open technique but within the minimally invasive retractors system. Posterolateral fixation with pedicle screws for both sides can be achieved through special percutaneous instrumentation system (e.g. The CD Horizon® Sextant™ (Medtronic) spinal system and VIPER® MIS Spine System (DePuy Synthes)). Contralateral pedicle screws insertion can then be performed by making stab wounds first (around 2–3 cm from midline). Jamshidi needles, followed by guidewire and pedicle screws were inserted under




**Figs 40.1A and B:** Minimally invasive TLIF: Facetectomy, discectomy and intervertebral cage insertion are performed through the tubular retractors system. Contralateral side shows the percutaneous pedicle screws system

**Figs 40.2A to E:** (A and B) A 56-year-old patient presented with claudication symptoms. MRI showed grade I spondylolisthesis at L4/5; (C and D) Postoperative X-ray showed percutaneous TLIF with implants *in situ*; (E) Postoperative scars: one scar for percutaneous facectectomy, discectomy, cage insertion and pedicle screws system; the other scar for pedicle screws system

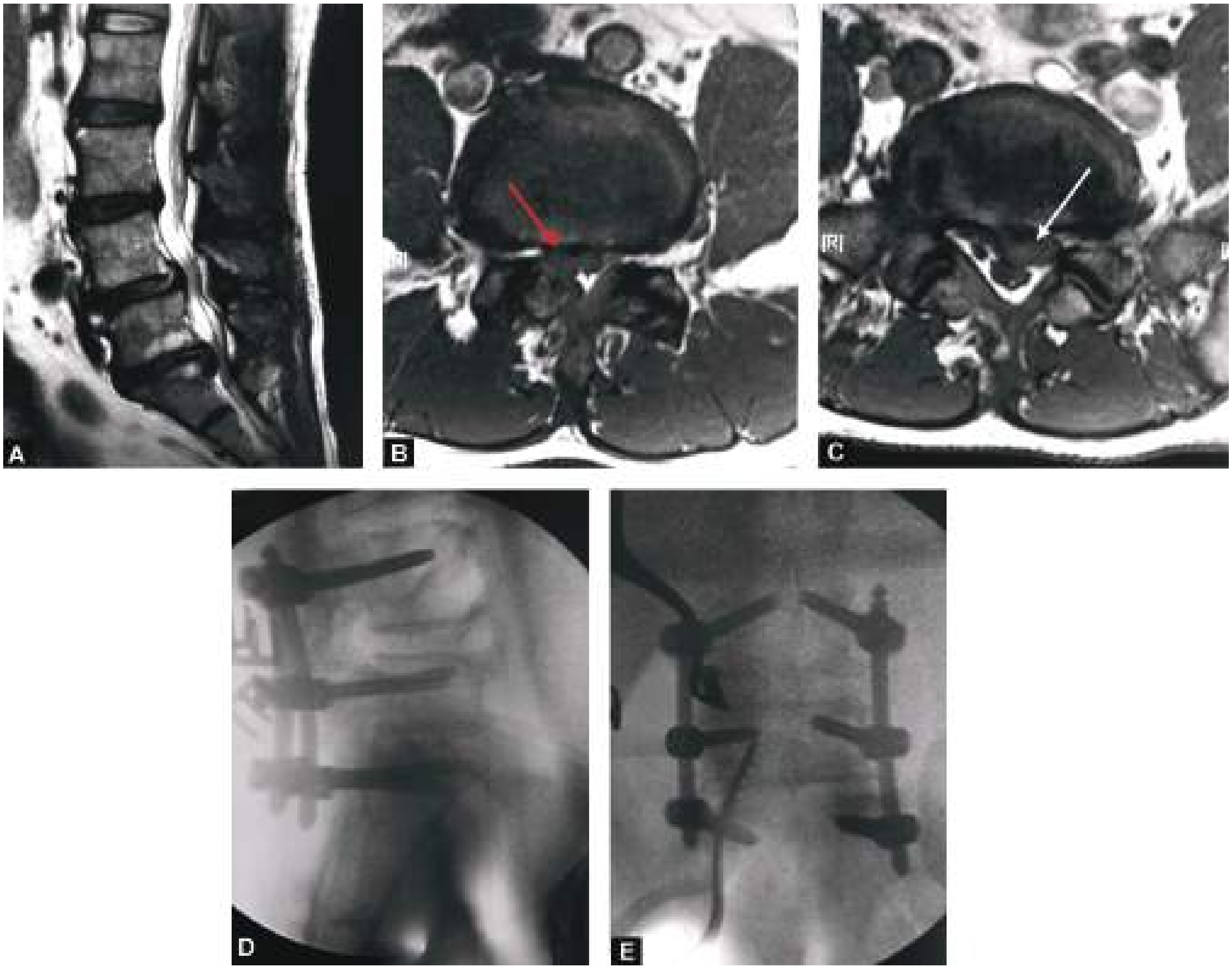
guidance of fluoroscopic images and trigger EMG monitoring. Rods were inserted and set screws were tightened according to the mechanisms of different systems. Hemostasis was secured and skin closed in layers (Figs 40.2A to E).

We have no preference in doing facetectomy or pedicle screws insertion as first step of the procedure. In case of more significant spondylolisthesis, pedicle screws insertion on contralateral side is suggested to perform first (Figs 40.3A to E).

## Decision Making in Selecting Different Approaches of Interbody Fusion

There is no single approach that fits all clinical condition. The choice of approach also depends on surgeon's experience and preference. ALIF provides the most direct view of disc with no retraction of neural structure but the access may be hindered by lumbar veins and major vessels. It can provide the best way to maintain or correct the sagittal balance of the lumbar segment. In special situation, osteotomy can be performed for better alignment of the spine. We prefer to reserve ALIF for revision or infection cases such as tuberculosis. PLIF is not as good as ALIF in correcting or maintaining lumbar lordosis. The approach is easier but significant retraction of neural structures may be required. TLIF has the least ability to correct lumbar alignment. It, particularly MI-TLIF, has a steep learning curve. It has the advantage of direct access of the disc through the foramina. Retraction of neural structures is less as compared with PLIF. In terms of fusion capability, theoretically, the approach of TLIF provides a narrow corridor for the surgeon to prepare the endplates that may make TLIF has a lower fusion rate. On the other hand, recent report showed that the fusion rate of MI-TLIF could be comparable to other conventional approaches.

In our center, we perform MI-TLIF in most cases of lumbar DDD, lumbar stenosis and Grade I-II spondylolisthesis requiring fusion surgery. The authors do not advocate for lumbar artificial




**Figs 40.3A to E:** (A) A 62-year-old man complained of severe bilateral sciatica. MRI showed prolapsed discs at L4/5 and L5/S1; (B) Shows disc prolapse (red arrow) at L4/5; (C) Shows disc prolapse (white arrow) at L5/S1; (D and E) Two-level MI-TLIF

disc replacement because of inconsistent surgical outcome and difficulty in revision surgery. Other motion preservation techniques could be considered for selected patients.

## Indications for Transforaminal Lumbar Interbody Fusion

History of symptom is the single most important factor for decision of surgical treatment. Radiating pain to lower limb with concurrent radiological findings is good indication for surgical intervention. Claudication symptoms with radiological spinal stenosis and instability (mechanical) pain with or without spondylolisthesis are also frequent surgical indications. Patients with axial symptoms alone however are usually not good surgical candidates. Patients with probable discogenic pain have to be evaluated carefully to exclude other possible pain generators including facet joint or musculoskeletal in origin. Injection therapies can be useful in both therapeutic trial and diagnostic tool. Value of provoking discography is controversial unless in cases when MRI is contraindicated. Authors would only opt for provoking discography for multilevel diseases in order to identify culprit level(s).

As mentioned above, conservative measures including physiotherapy and medical therapy remain the first step of treatment. Patient with mild disc prolapse and no significant neural compression nor instability can be considered to have other minimally invasive interventions. Only for those patients with resistant symptoms affecting daily activity would be considered for surgical intervention.

Radiological examinations including plain X-ray with dynamic views, computerized tomography (CT) and magnetic resonance imaging (MRI) are required not only to document the concurrent abnormalities to account for the symptoms. The bony consistency has to be assessed by plain X-ray. Osteoporosis is a relative contraindication for pedicle screws insertion. Cement-augmented screws can be considered as an option for patients with osteoporosis. CT scan is required to assess bony contour as well as facilitate preoperative screw trajectory planning and measurement. Dynamic and/or standing MRI, if available, can be a good tool to assess if the symptoms are consistent with radiological finding in some particular postures.

## Clinical Outcome and Fusion Rate of Minimally Invasive Transforaminal Lumbar Interbody Fusion

Foley introduced MI-TLIF in 2002. A number of reports came up and showed satisfactory results.[15-20] We started our first MI-TLIF cases in 2005. In 2006, we prospectively analysed our first 10 consecutive cases of MI-TLIF with follow-up up to 12 months. VAS and ODI dropped from 7.4 to 1.9 and 50 to 13 percent respectively. Despite the steep learning curve, favorable clinical result can be obtained in well selected patients.

Before 2008, we used commercially available tricalcium phosphate granules or putties as bone grafting material incorporated into a PEEK cage. From 2008 onwards, we started to employ recombinant human bone morphogenic protein (rhBMP; Infuse. Medtronic). We compared the fusion rate of tricalcium phosphate (Group 1) and that of rhBMP (Group 2). Twenty consecutive patients from Group 1 (before 2008) and 15 consecutive patients from Group 2 (after 2008) were analyzed. Monthly CAT scan of lumbar spine was done to monitor evidence of fusion. The fusion rate of Group 1 and Group 2 were 70 percent and 93 percent respectively. Mean time of fusion was 6 months in group 1 as compared to 4.5 months for group 2. The evidence of fusion could be seen in Group 2 as early as 2 months after the operation. There was no implant failure in both groups.

We studied factors that can affect fusion rate including age, gender, level of TLIF, smoking history and rhBMP usage. In multivariate analysis, only smoking habit and usage of rhBMP had significant effect on fusion rate. For age, younger patients (<50 years old) showed significantly better fusion rate in univariate analysis ($p < 0.05$) but did not reach statistical significance in multivariate analysis ($p = 0.074$).

In terms of postoperative complication, we only encountered one case of postoperative radiculopathy (6.7%) in which MRI showed no compressive lesion. No wound problem nor other major complication was recorded. From this study, we suggested that rhBMP could be used as an option in patients with older age (>50 years old) and smoking habit.

Different kinds of complication from rhBMP were reported.[21-23] The most common complication is heterotopic bone growth with radiculopathy, arachnoiditis, wound problems, etc. Impotence, dysphagia, airway problem and even mortality were reported in the usage for cervical spine cases. In our experience, we used low dose rhBMP. We place the rhBMP soaked sponge into the anterior portion of the disc space. The prerequisite is to keep the anterior longitudinal ligament intact. Another piece of rhBMP soaked sponge is incorporated into the PEEK cage which is then inserted into the disc space under X-ray guidance. We had never put any rhBMP sponge near to neural structures. No adverse effect from the rhBMP was noted in our series.

## Conclusion

The TLIF offers the advantage of being an efficient fusion techniques through single access with minimum risk to neural structures. At the same time, it allows adequate posterior and foraminal decompression. MI-TLIF offers a good surgical option which produces less posterior structure damage while maintaining comparable clinical outcome and fusion rate as other arthrodesis techniques.

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41

# Association of Lateral Recess Stenosis with Lumbar Disc Herniation

*PS Ramani, Sumeet Pawar, Sudhendoo Babhulkar*

## Introduction

Degeneration of lumbar spine increases with age. It is rare to find a normal disc after the age of 60 years. It has become a major cause of disability in working population. Backpain can be caused due to many factors like bone, joints, ligaments, muscles and intervertebral discs.[1]

Natural history of degeneration includes relation to age, with gradual loss of bone. Loss of vertically oriented trabeculae leading to weak load bearing capacity.

### Normal Motion Segment

It has 3 joints, the intervertebral discs and 2 facet joints. Even a minor trauma can cause degeneration in the intervertebral disc. Studies have found that even 0.2 mm settlement of disc space can cause facet joint degeneration.

### Lateral Recess Stenosis (Figs 41.1 and 41.2)

It is defined as a condition where the narrowing reduces the available space within the exiting doorway (foramen) of the spinal canal. This may be caused by arthritic degenerative overgrowth of the facet joints, degeneration of the disc with loss of disc height and overriding of facet joints with consequent bulging of disc (disc herniation). This resultant loss of space in the foramen can cause squeezing or pinching of the nerve roots as they exit the spine through the foramen.[2]


**Figs 41.1A to C:** Magnetic resonance imaging (MRI) of lumbar spine in axial view reveals various degrees of lateral recess stenosis


**Figs 41.2A and B:** The MRI sagittal view reveal stenosis in the lateral recess of spinal canal

## Dilemma

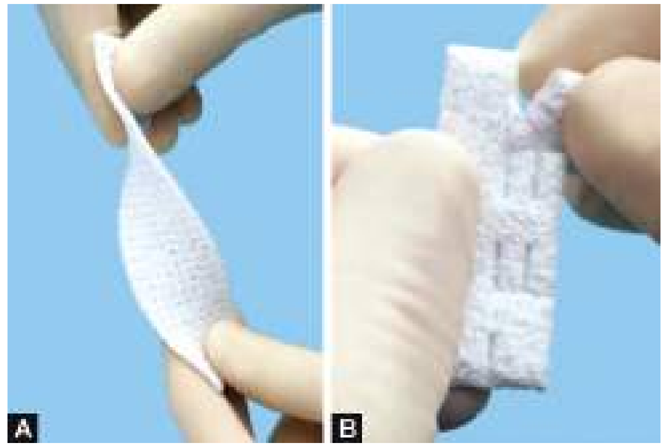
More often than not we find that investigations reveal lateral recess stenosis is associated with mild to moderate instability.[3] Whereas for moderate grade instability, pedicle screw fixation is preferred treatment option, such is not the case for mild instability. Not every patient with mild instability can be subjected to pedicle screw fixation due to large 3 number of patients and absence of obvious instability. Further more it is found that liberal laminectomy and foraminotomy can cause further instability which can aggravate the problem further leading to complications like spondylolisthesis. In such cases a more conservative and accurate method of correction is advocated.[4]

## Principle of Treatment

To promote fusion in the facet joints with the aim to halt the further degeneration and at the same time prevent recurrence of symptoms. This can be achieved by using a ChronOS strip spread over the facet joint following laminectomy and internal decompression of spinal stenosis (IDSS).

## What is ChronOS Strip?

It is a synthetic strip consisting beta tricalcium phosphate (B-TCP) granules embedded in lactide co-caprolactone polymer. It is good for osteoconduction by acting as a scaffold and allowing bony ingrowth. It converts to bone during remodeling process over period of 6 to 18 months. The polymer degrades by hydrolysis over a period of 9 to 12 months.




**Figs 41.3A and B:** ChronOS strip can be twisted to conform to the shape and can be cut as per required size

## Advantages of ChronOS Strip

- It can be spread and retained in one place
- It can be cut, folded, twisted to conform to the shape of the spine (Figs 41.3A and B)
- It can be sutured or fixed to hold in place
- It promotes accelerated fusion
- It can be seen on X-ray
- It is available in 2 sizes:
  50 × 25 × 3 – good for 2 facets
  100 × 25 × 3 mm good for more than 2 facets.

The perfusion packaging of the strip allows homogeneous saturation of blood/bone marrow in the strip. 10 mL blood is adequate for 50 mm strip while 15 mL for 100 mm strip. The marrow helps to form 4 times more bone postoperatively.

## Procedure

See Figures 41.4A to E.

## Clinical Data

We started this project in 2012 and so far have used this technique in 28 patients. Patients selected had lateral recess stenosis with or without lumbar disc herniation. Patients were symptomatic for at least 3 years (+ 4 months ). Average age of patients was 58.3 years. Patients commonly presented with morning stiffness (72%), neurogenic claudication (52%), sciatica (49%), woolly sensation of the foot (41%) (Table 41.1). Backpain was not very common symptom (29%). It was more common in patients who were obese, diabetic, hypertensive, smoking, drinking. Patients were accustomed to sitting on ground in squatting position.

Positive predictors of lateral recess stenosis:
- Obesity
- Diabetes
- Hypertension
- Smoking
- Drinking
- Type of work.

**Fig. 41.4A:** The perfusion package is opened under asceptic precautions at the end which is compatible with any standard syringe

**Fig. 41.4B:** 10–15 cc blood collected by anesthetist under asceptic precautions is then injected into the package and then the blood is withdrawn again about 4 cc. This process is repeated 4–5 times to ensure adequate mixing of blood into the matrix of the strip

**Fig. 41.4C:** The perfusion package is then opened and the ChronOS strip is cut as per required size

Of the 28 patients, 4 patients had ChronOS strip used along with pedicle screw fixation. In rest of the 24 patients, only strip was used after debriding the facet joint (Figs 41.5A to I).

## Results

Short-term results of the study are looking promising but that could be due to neural decompression. Long-term results need to be accessed over 15 months follow-up.

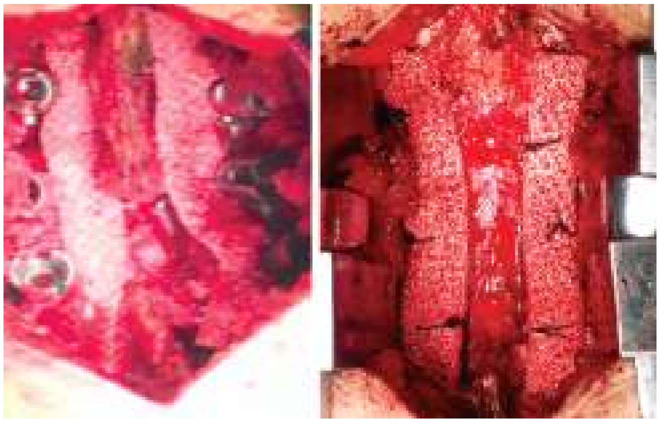


**Fig. 41.4D:** This strip is then used for fusion at the facet joint either in isolation or along with pedicle screws after debriding the facet joints with drill bit

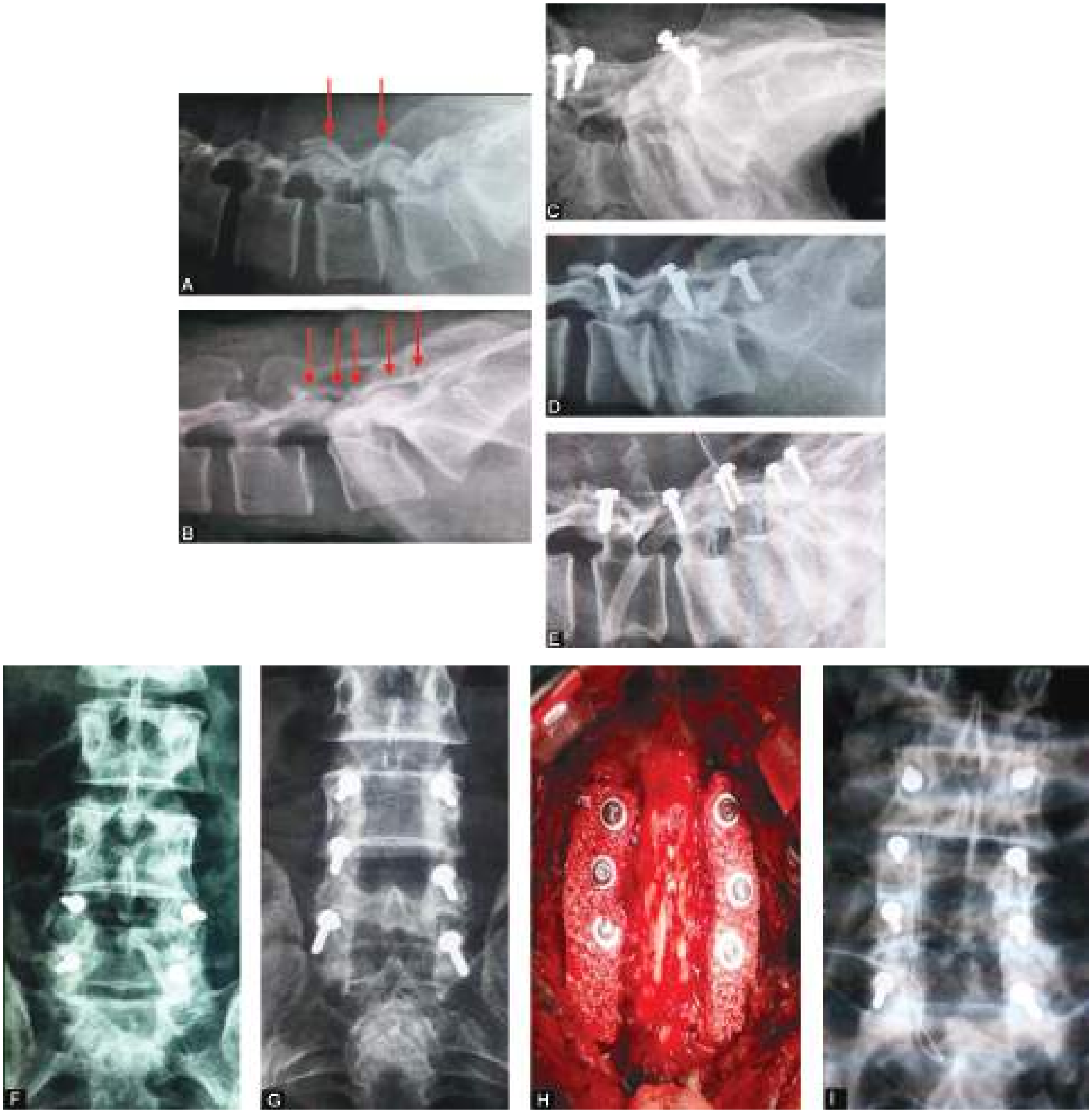
**Fig. 41.4E:** Instead of stitches, 14 mm cortical screws can also be used to fix the ChronOS strip

**Table 41.1:** Common presentation of patients

| Symptoms | Number of patient (%) |
|---|---|
| Morning stiffness | 68 |
| Neurogenic claudication | 52 |
| Sciatica | 49 |
| Wooly sensation of feet | 41 |
| Backpain | 35 |

## Conclusion

Synthes ChronOS strip used for facet fusion has been found to be very useful by us in the management of degenerative lateral recess stenosis in providing stability in the immediate postoperative




**Figs 41.5A to I:** X-rays and operative picture showing strip and screws at several levels

period giving the patient feeling of comfort and with no adverse effect in short-term follow-up.

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42

# Minimally Invasive Space Shuttle Laminotomy for Degenerative Lumbar Spinal Canal Stenosis

*Shunji Asamoto*

## Introduction

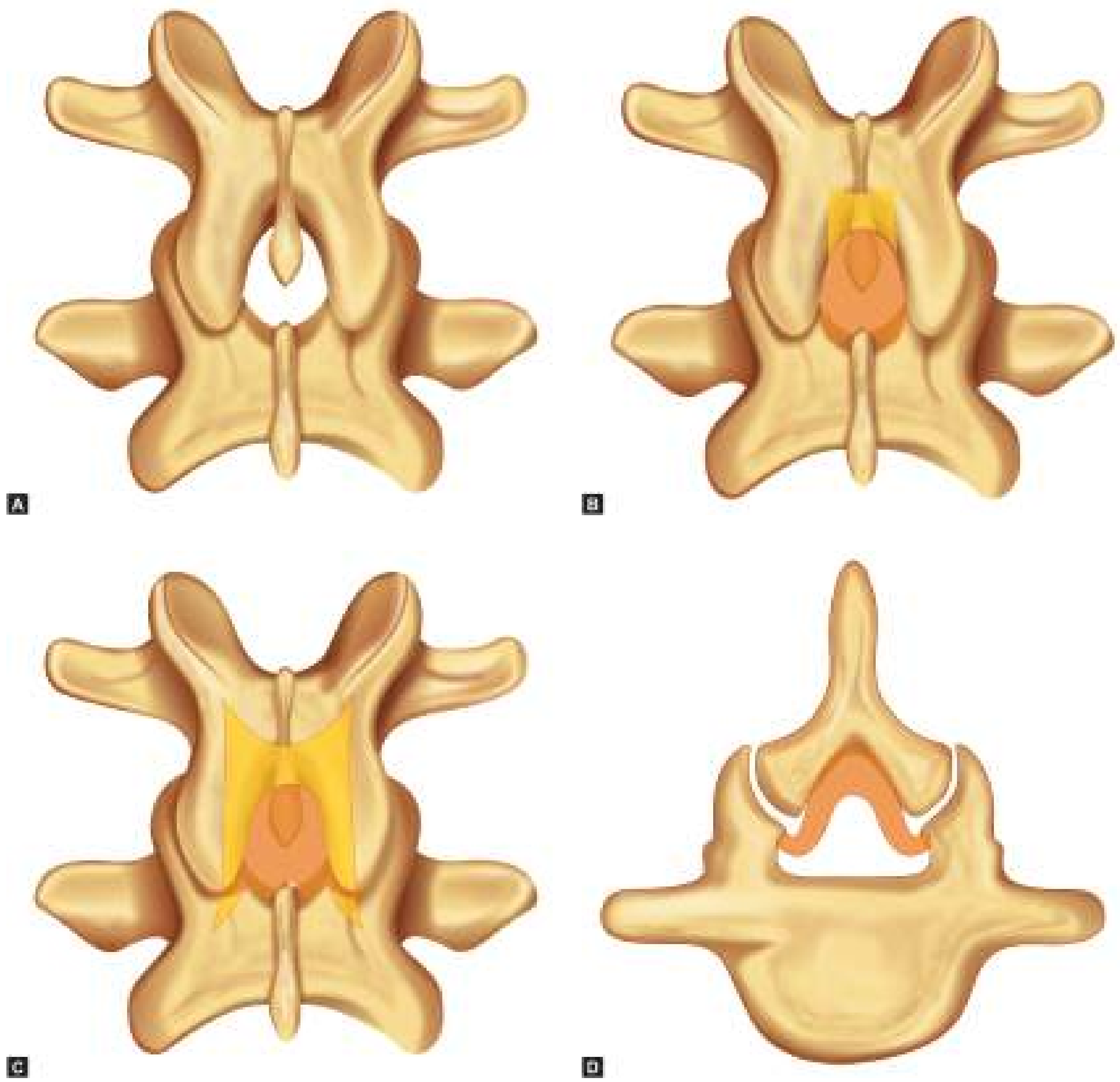
There are a variety operation of lumbar spinal canal stenosis. Recently, in particular, minimally invasive surgery (MIS) is advocated, such as a microscopic surgery or endoscopic surgery. Described here is the surgical technique of "minimally invasive space shuttle laminotomy (MISSL)" with microscope for lumbar spinal canal stenosis (LSCS) after having known normal anatomy well, especially anatomy of ligamentum flavum (LF).

## Anatomy of Ligamentum Flavum

Firstly, the normal anatomy of ligamentum flavum (LF) is described in detail (Figs 42.1A to D). The ligament is thick and short. It is a symmetrical structure on both left and right sides. On each side, LF divides into a medial and lateral portion. The upper attachment of the medial portion of LF is to the lower half of the ventral surface of the lamina and the attachment of the lateral portion is the inferior aspect of the pedicle. The medial portion passes to the back of the next lower lamina and attaches to the upper quarter or so of the dorsal surface of that lamina. The lateral portion passes in front of the zygapophysial joint formed by the two vertebrae that the ligament connects. It attaches to the anterior aspects of the inferior and superior articular processes of this joint, and forms its anterior capsule. The most lateral fibers extend along the root of the superior articular process as far as the next lower pedicle to which they are attached. The part of lateral portion of LF has fibrous continuous connection with synovium. That point is just a medial side of pars interarticulalis. There is a root sleeve under this point. Dorsal side of LF has continuous attachment to the ventral part of the interspinous ligaments.

## Surgical Technique of Minimally Invasive Space Shuttle Laminotomy

This technique is performed under the microscope. In this article, basic one level laminotomy is described, if it is necessary, this technique can be applied to multiple levels. 3 cm long skin incision is adequate if it is one segmental stenosis. Both the rostral and caudal spinous process of the given level are exposed and inferior one-third of rostral spinous process with interspinous ligaments is resected until base of spinous process. The facet joint is never sacrificed and multifidus muscles which cover the facet joint capsule is to be preserved as much as possible. It is shifted sequentially to microscopic operation. The shape of the facet and width of the spinal canal should be confirmed before the operation. The facet can be drilled with the diamond burr. For width of laminotomy of rostral side lamina of the respective segment (if it level is L4-5, its mean is L4 side lamina), about 10 mm wide excision is enough. To keep less 10 mm can protect facet joint and its capsule. But it can not be said always so because L1-2 or L2-3 is narrow in comparison with L4-5 or L5-S1 physiologically. And the width becomes narrow so as one advances to rostral side. As for this part, decompression of canal is not so important, but decompression of root sleeve is a purpose. Therefore, width of decompression is wider than the higher lamina necessarily. The above procedure is performed with diamond burr of a diameter of 6.5 mm. Any ragged or obstructing LF to the operation field may be removed, although keeping LF till the last as much as possible is better. Identifying dura mater is the aim of the laminectomy of rostral side on midline (width long). For width of laminotomy of caudal side

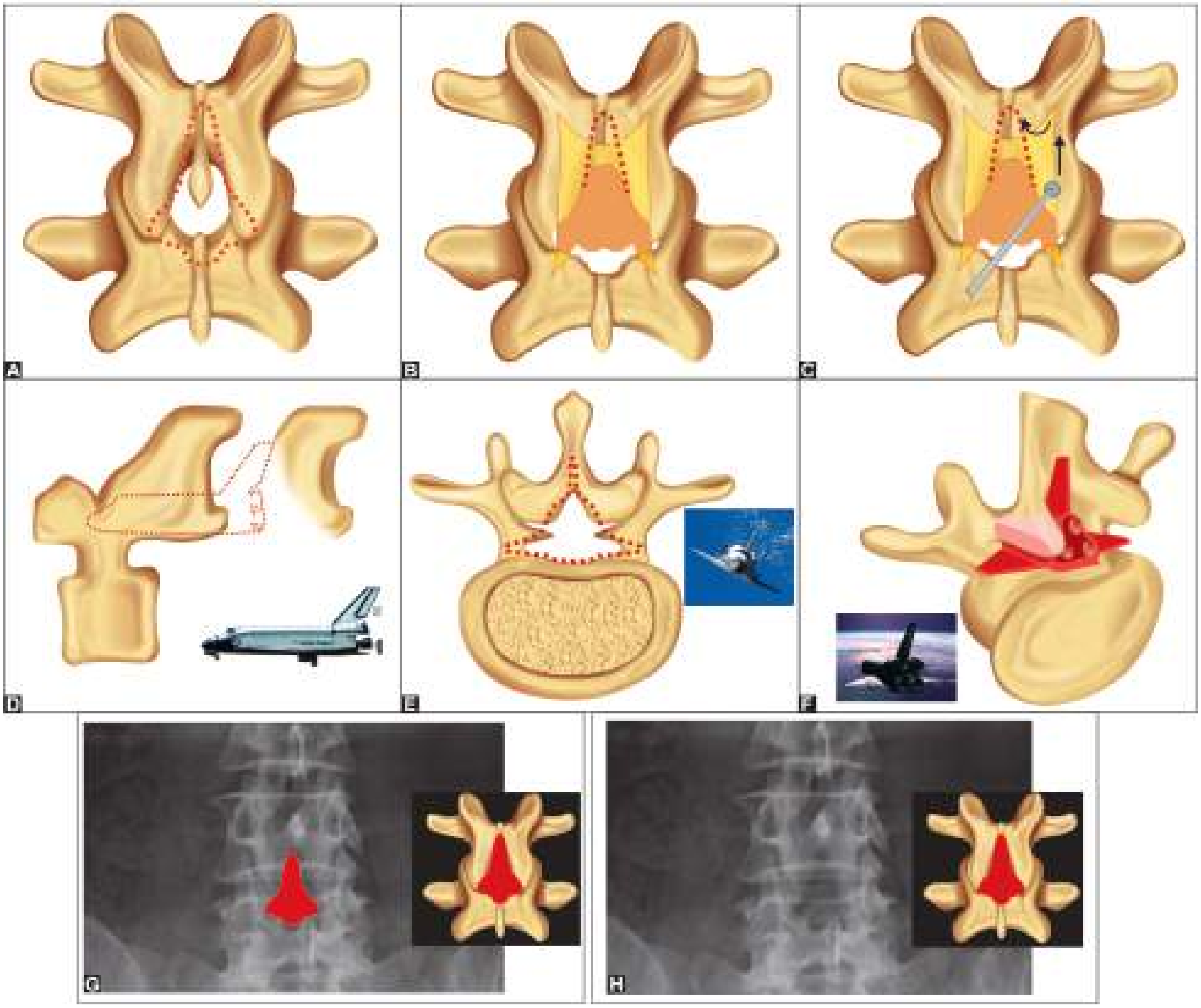


**Figs 42.1A to D:** (A) Normal one-level spine of schematic image; (B) Ligamentum flavum (LF) of medial portion. Pale yellow shows LF under lamina; (C) Combine medial portion and lateral portion of LF; (D) Schematic image of axial section of LF

lamina (if it level is L4-5, its mean is L5 side lamina), 16 to18 mm is enough. Therefore, we need attention because dura mater crops out just after laminotomy. With this procedure, the silhouette of laminotomy when viewed from back side is like "Space Shuttle" (Figs 42.2A to H). Subsequently meticulous decompression with diamond burr of a diameter of 3.0 mm is carried out. The medial side of inferior facet is drilled off with diamond bar. The operator must stand on the opposite side during this procedure. While inclining the visual axis of the microscope, it is pushed forward toward the medial side of superior facet (so-called, lateral recess). When the diamond bar gets closer to lateral recess, LF is floating naturally. At this point, LF should be kept as much as possible, because LF can protect the dura mater. This drilling off procedure is continued in the direction of "rear fender of the Space Shuttle". The most lateral fibers of LF extend toward pedicle, laminotomy is performed safely. The aim of the drilling off to "rear fender" is the point which LF gradually decline. At its point, diamond burr is turned to "the cock pit of the Space Shuttle" (Fig. 42.2C). There is no LF at the point of cock pit. Therefore, assistant of operator must pay attention without dural laceration during drilling off its point. This procedure is repeated in the reverse side, but sometime, the decompression of one side should not be performed at a stretch if narrow canal is very severe. Step by step decompression about each side is safely. If one side is decompressed, it is easier to decompress the other side. With multiple levels stenosis, MISSL is performed on each segment.

From Figures 42.3A to C are case presentations of MISSL. MISSL can protect bilateral facet joints.

Minimally invasive space shuttle laminotomy, it is laminotomy against caudal side of lamina, however, it is "spinous proctectomy" of base of spinous process against rostral side in the strict sense.



**Figs 42.2A to H:** (A) Silhouette image of Space Shuttle laminotomy from dorsal; (B) Dotted line shows "dome laminotomy" of cock pit of the Space Shuttle; (C) Drilling off with diamond bar over lateral portion of LF. LF protects dura mater; (D) Silhouette image of Space Shuttle laminotomy from lateral; (E) Axial section silhouette image of Space Shuttle laminotomy; (F) Three dimensional image of Space Shuttle laminotomy; (G) Postoperative X-p of L4-5 interlaminotomy; (H) Image of Space Shuttle laminotomy

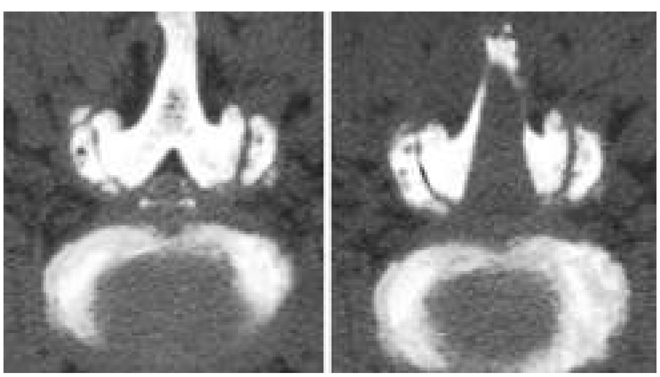


**Fig. 42.3A:** In spite of vertical facet joint, spinal canal decompression is complete

**Fig. 42.3B:** Lateral recesses were decompressed completely

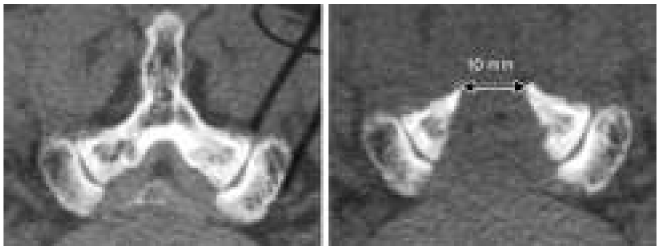



**Fig. 42.3C:** For width of laminotomy of rostral side lamina are 10 mm (arrow)

## Conclusion

Minimally invasive space shuttle laminotomy on having known the anatomy of LF well is a safe operation without complications using microsurgical technique.

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# Section 6

# Complications in Surgery for Lumbar Disc Herniation

## Section Outline

43

# Diagnosis and Management of Discitis Following Lumbar Disc Surgery

*Kourosh Karimi Yarandi, Abbas Amirjamshidi*

## Introduction

Spinal infection, spontaneous or postoperative, is relatively uncommon. Potential infections that can occur after spinal surgeries include superficial wound infections, deep infections (below the fascia), spondylodiscitis, epidural abscess, and meningitis. "Discitis" is defined as an inflammation of vertebral disc often related to infection. Postoperative discitis was first described by Turnbull in 1953[1] and Ford and Key in 1954.[2] When secondary involvement of the cartilaginous endplate and vertebral bone occurs in association with discitis the whole clinical picture will be called "spondylodiscitis". Discitis is one of the most common infectious complications of spinal procedures. It may be encountered after almost every open and minimally invasive surgical approaches to the lumbar spine including chemonucleolysis and automated percutaneous nucleotomy.[3-9] Also, it is reported following diagnostic procedures such as discography and myelography[7,10] and is assumed to be the most common complication following discography.[11] Discitis can be expected even following procedures like epidural corticosteroid injection and lumbar puncture.[12,13] Although not so prevalent in general, discitis and spondylodiscitis are potentially devastating and debilitating events. Spondylodiscitis is particularly a serious complication which is capable of producing long-lasting or permanent morbidity.

## Epidemiology

Spontaneous discitis is more prevalent among children. On the contrary, postoperative discitis mostly occurs in adults. Post-procedural discitis represents almost 30 percent of all cases of pyogenic discitis.[3] Also, 20 to 30 percent of all cases of pyogenic spondylodiscitis actually occur postoperatively.[14] There is a preponderance of lumbar involvement among the different regions of spine. The exact incidence of this complication is somewhat difficult to ascertain. The complication may be underestimated and missed in a considerable number of cases who only experience a mild self-limiting course of symptoms. Postoperative discitis occurs in about 0.1 to 5 percent of patients after conventional or minimally invasive open lumbar discectomy.[3,4,10,11,15-19] The incidence of postoperative spondylodiscitis ranges between 0.21 to 3.6 percent.[14,20] It is more frequently encountered after procedures like spinal instrumentation and grafting and the risk is lower following discectomy and laminectomy without fusion.[14]

## Pathophysiology

In children, discitis often develops spontaneously. On the other hand, in adults, spontaneous discitis is rare and this phenomenon mostly appears as a complication of surgical interventions such as discectomy. Infrequently, discitis can occur through hematogenous spread in the IV drug abusers or severely debilitated adults. According to the symptoms and laboratory investigations some of the researchers have classified postoperative discitis into two distinct categories: septic form (caused by infectious agents) and aseptic form (resulting from inflammatory and chemical reaction).[3,21] Others have categorized this complication into three types: type I: acute septic, type II: subacute septic, and type III: aseptic or chemical discitis.[15,22] Many of the investigators criticize such classifications and basically contradict the existence of the so-called aseptic or chemical discitis. They suggest that these cases are actually caused by less virulent easily-controllable infections or very few organisms.[6,23] Others have challenged the previous concept that discitis occurring after procedures like discography is mainly a result of chemical reaction to the contrast material instead of infection. It is hypothesized that infection can play a detrimental role (at least as an initiator) in every case of discitis following discography.[24] Currently, bacterial contamination and direct inoculation during the procedure is the main accepted etiologic hypothesis for postoperative discitis and spondylodiscitis. Some patients may only experience mild, spontaneously resolving symptoms while in others fulminant sepsis and abscess formation may occur. Evidence of bacterial contamination can be found in 45 to 88 percent of the cases.[15,18,25] The risk of postprocedural discitis is more among the elderly and immune-compromised individuals[3,14] Previous or concurrent infection can be another risk factor for postoperative discitis and spondylodiscitis.[14] Nonetheless; predisposing factors (including diabetes mellitus and previous bacteremia) are less frequently present in the cases of postoperative spondylodiscitis in comparison with the patients with spontaneous spondylodiscitis.[14] The exact pathogenic germ responsible for disc space infection is unknown in many cases. Even computed tomography (CT) guided needle aspiration or open biopsy may fail to identify the causative organism. In both adults and children, gram-positive cocci, including Staphylococcal species are the predominant pathogens responsible for discitis.[11,15,16] Skin flora, commonly *Staphylococcus aureus*, are the most common causative agents.[3] *Staphylococcus epidermidis* is another common pathogenic organism. Streptococcal species and anerobic bacteria can also frequently cause discitis. Coagulase-negative *Staphylococcus* and anaerobic bacteria are more frequently responsible for infection in postoperative spondylodiscitis than in spontaneous form.[14] *Escherichia coli*,[3] *Pseudomonas aeruginosa*,[4] *Mycobacterium tuberculosis*,[16] and unusual germs such as Fungi,[4] *Propionibacterium acnes*[3,16] and *Corynebacterium*[11] have been reported as the pathogenic organisms in some cases of postoperative discitis. Direct extension of discitis can cause further complications including epidural abscess and osteomyelitis. An abscess located anterior to the dura is often originated from discitis or vertebral osteomyelitis. A common belief is, since the vascular supply to the adult disc is not adequate, the immune system of the patient lacks the appropriate ability to control the infection within the disc space. However, the infected disc becomes vascularized and swollen and this may propose at least minor accessibility of the disc space to the immune system. If the infection spreads into vertebral body, where the blood supply is abundant, the infection can be more available to the immune system.

## Diagnosis

In many cases, early diagnosis is of crucial importance. Discitis may be hard to identify and should remain paramount in the differential diagnosis especially in patients with worsening clinical status and laboratory findings. The diagnosis can be achieved based upon combination of clinical, laboratory, and imaging data.

## Clinical Findings

Postoperative discitis and spondylodiscitis present insidiously. Since discitis can progress into osteomyelitis, early detection of this complication and proper management can be of vital importance. The paucity of findings in physical examination necessitates a high index of suspicion in any case of intensifying back pain following invasive spinal procedures. The diagnosis of these complications is frequently delayed. Several reports have cited the underestimation of the symptoms and misdiagnosis of the clinical picture as conversion disorders and overreaction. This may happen especially because some of the patients may confuse the new pain and discomfort with their original primary symptoms and complain of recurrence of preoperative problems. The diagnosis is often established based on the history, physical examination, laboratory studies, and imaging workups. There may be no significant clinical signs, while severe symptoms exist. Low back pain (often severe), painful ambulation, muscle spasm, and mild fever are among the most common reported signs and symptoms associated with discitis. The initial relief of the symptoms, i.e. radiculopathy, is generally achieved in the immediate postoperative period. The onset of new symptoms is usually 1 to 4 weeks after the surgical intervention and the symptoms gradually increase. The back pain is disproportionately severe when analyzed according to the physical examination and may accompany radiating pain into buttocks, thighs, and abdominal region. True sciatica may also be present. Although mild fever, fatigue or malaise are occasionally present, chills and sweats or significant elevation of body temperature are rarely encountered and may be of value in alerting the physician to the possibility of aggressive infection. Physical examination is often unable to clarify the situation more. Evolving neurological signs are discovered in less than 15 percent of the patients. The most common finding in physical examination is severe pain during assessment of lumbar range of motion. Normal process of wound healing is almost always seen in these cases.

## Paraclinical Evaluations

### Laboratory Studies

White blood cell (WBC) count is slightly elevated in 42 percent of the cases of spondylodiscitis.[26] Erythrocyte sedimentation rate (ESR) is a sensitive but not very specific[14] test (78–82% sensitivity and 38–62% specificity[3]) for diagnosis and follow-up. Customarily, the ESR levels rise in the immediate postoperative period and peak in the fourth to sixth postoperative days.[27,28] Afterwards, the level of ESR returns to normal baseline values within 2 to 3 weeks after uncomplicated surgical interventions[6,29] and it is unusual to exceed 25 during the total postoperative period of such procedures.[29] A more prolonged process of elevation and normalization of ESR levels following uncomplicated extensive procedures like conventional discectomies and various fusion techniques is expected.[30] According to the results of a report, slightly elevated ESR levels can be expected even twelve weeks after laminectomy.[28] Persistent elevation of ESR and C-reactive protein (CRP) levels strongly suggests the probability of discitis.

When measured two weeks after the surgery, an ESR level of more than 50 in the presence of relevant clinical symptoms strongly suggests discitis.[23] The level of CRP peaks on the second or third day after uncomplicated surgeries and returns to baseline numbers by the fourteenth postoperative day.[22,28] Since the level of CRP rises and returns to normal values sooner than ESR, it may be beneficial in early diagnosis of infection. CRP is reported to be the most sensitive clinical marker for diagnosis and assessment of therapy in discitis (64-100% sensitivity and 62-95.8% specificity).[3,31] As mentioned earlier, there are some cases of slight elevation of ESR levels even after 12 weeks following surgery.[28] Although the CRP value is also unspecific, it is more conclusive than ESR and less false-positive increases can be attributed to it.[28,31] Nevertheless, there is a well recognized variability in CRP levels among different individuals which may complicate diagnostic evaluations. Accordingly, measuring CRP levels can be more conclusive when baseline values are obtained in every individual and many of the investigators recommend routine preoperative assessment of both the ESR and CRP for postoperative comparison.[3,23] In conclusion, it is strongly suggested that ESR and CRP levels should be checked in every patient with low back pain following discectomy during the second postoperative week.[23]

### Imaging Studies

Plain radiography, magnetic resonance imaging (MRI), computed tomography and radionuclide scanning have been used to diagnose postprocedural discitis.

Plain radiography is ordinarily the first imaging study performed after the surgery. It is usually obtained to confirm satisfactory alignment of the spine and desired position of the inserted hardware. Regretfully, it is often difficult to diagnose discitis according to plain radiography and findings of infective discitis are not apparent until 2 to 8 weeks after the initial symptoms.[19] Loss of intervertebral disc space height and clouding of the vertebral endplates adjacent to the infected disc space can propose discitis in plain radiographs. There may also be an abnormal psoas shadow as a sign suggestive of paraspinal soft tissue involvement. Absence of this feature, however, does not exclude the diagnosis.[19]

Computed tomography (CT) scan is superior to X-ray in detecting early bony changes such as erosive and destructive lesions. CT findings highly suggestive of infective discitis include; anterior paravertebral soft tissue swelling with obliteration of paravertebral fat planes, fragmentation or erosions of vertebral endplates and paravertebral fluid collections.[19] The entire infected disc space can enhance in CT scan after intravenous injection of contrast material.[32]

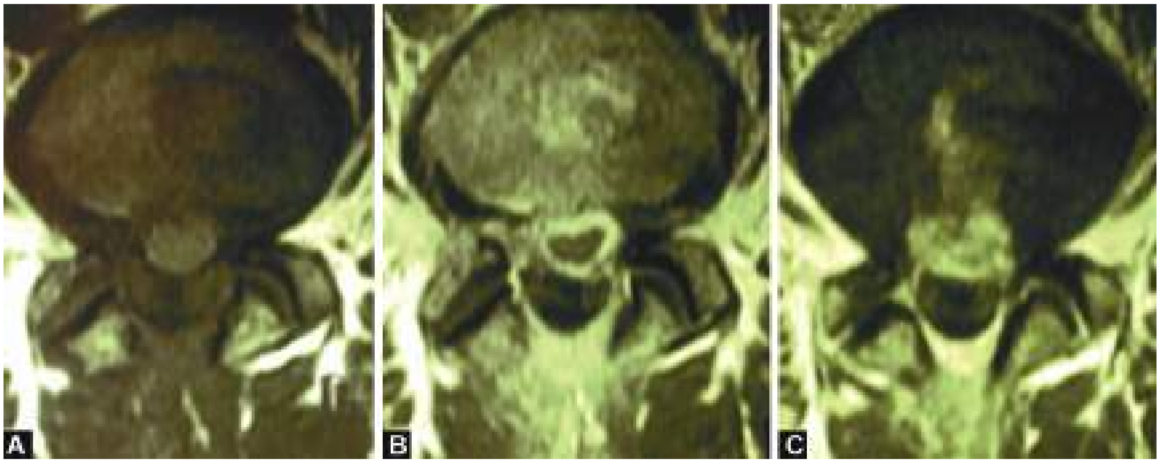
Magnetic resonance imaging (MRI) is the imaging modality of choice in diagnosis of spinal infection and many of the investigators believe that the most sensitive and specific diagnostic modality in detecting discitis and assessing the efficacy of treatment is contrast enhanced MRI (93% sensitive and 97% specific).[3,14,19] It provides better definition of the paravertebral and epidural spaces and allows assessment of the compression upon the neural elements. In the early postoperative period (3–5 days after surgery), decreased signal intensity of nucleus pulposus in T1-weighted images and increased intensity in T2-weighted images can suggest discitis as a possible diagnosis (Figs 43.1A and B). Increased signal intensity in T2-weighted images of adjacent vertebral bodies may also represent reactive edema or osteomyelitis. Contrast enhancement can also alert physician to the possibility of discitis or spondylodiscitis (Figs 43.2A to C). Absence of low signal on T1-and high signal on T2-weighted images in the marrow adjacent to the disc makes septic spondylodiscitis highly unlikely; the same holds true for absence of contrast enhancement of the intervertebral disc space.[10,33] An enhancing soft tissue mass surrounding the affected spinal level in the paravertebral soft tissues and epidural space is highly suggestive of septic spondylodiscitis, and indicates further investigation (Figs 43.3A to C).[10] It should be noted that contrast enhancement and signal changes in the intervertebral disc or the vertebral endplates are not specific for spondylodiscitis. Such changes can also be noticed in asymptomatic patients as well and can yield false-positive results.[10,33] Thus, it seems reasonable to use clinical and laboratory evidence as complementary data to verify the MRI results.[10] It can be concluded that although MRI is very useful in the postoperative settings, the results should be analyzed cautiously and this modality seems to be more useful for exclusion rather than confirmation of spondylodiscitis.[33]


**Figs 43.1A and B:** Postoperative MRI of a 66-year-old female who underwent laminectomy of L2 to L5 vertebrae and discectomy of L2/L3 level. Increased intensity in T2-weighted images can suggest discitis as a possible diagnosis

Focal nonspecific areas of increased uptake can suggest discitis in radionuclide (gallium 69 and/or technetium 99) imaging studies. The same pattern of tracer uptake also frequently occurs after uncomplicated surgeries and can persist even for up to one year following surgery.[23] Since the sensitivity and specificity of radionuclide studies is inferior to MRI examinations[3] it is not routinely used for diagnosis where MRI is available.

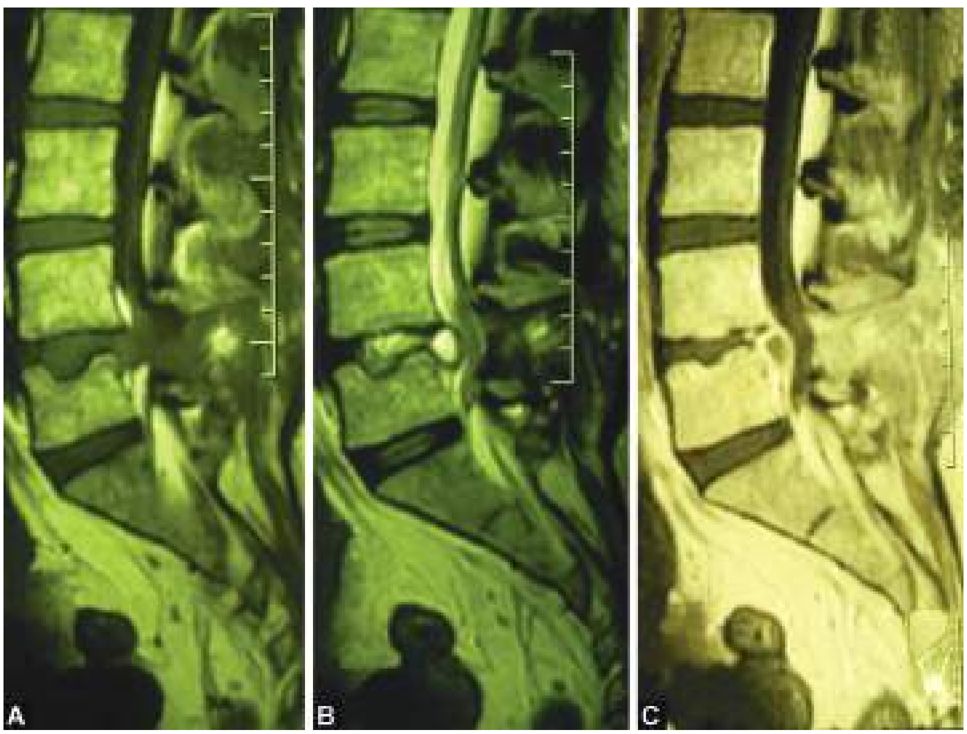
## Biopsy and Culture

When an infection is suspected a blood culture should be drawn. If no organism can be identified according to the blood culture,




**Figs 43.2A to C:** Axial MRI of a 43-year-old male performed 15 days after laminectomy and L4/L5 discectomy. (A) T1-weighted image without contrast shows an extradural mass anterior to thecal sac; (B) The same slice, T1-weighted image with administration of contrast material. Enhancement of the cartilaginous endplate can propose spondylodiscitis. The extradural mass also enhances peripherally which is suggestive of epidural abscess; (C) A view of disc space in T1-weighted image with administration of contrast material in the same patient. Abnormal enhancement of the disc should alert the physician of the possibility of discitis.

It should be noted that contrast enhancement and signal changes in the intervertebral disc or the vertebral endplates are not specific for spondylodiscitis. Such changes can also be noticed in asymptomatic patients as well and can yield false-positive results. Accordingly, it seems reasonable to use clinical and laboratory evidence as complementary data to verify the MRI results




**Figs 43.3A to C:** Sagittal view of a 37-year-old female performed 19 days after laminectomy and L4/L5 discectomy. (A) T1-weighted image without contrast shows an extradural mass anterior to thecal sac; (B) The same slice, hypersignal view of the disc space in T2-weighted image should raise suspicion of discitis. The contents of extradural mass are also hypersignal; (C) Sagittal T1-weighted image with administration of contrast material. Enhancement of the cartilaginous endplate can propose spondylodiscitis. The extradural mass also enhances peripherally which is suggestive of epidural abscess.

It should be noted that contrast enhancement and signal changes in the intervertebral disc or the vertebral endplates are not specific for spondylodiscitis. Such changes can also be noticed in asymptomatic patients as well and can yield false-positive results. Accordingly, it seems reasonable to use clinical and laboratory evidence as complementary data to verify the MRI results

CT-guided percutaneous biopsy should be considered. Although CT or fluoroscopy guided biopsy is often beneficial, the result of biopsy and blood culture can be negative in 20 to 50 percent of the cases.[11,14] Prior antimicrobial therapy is one of the main reasons for these negative results.[34] Since fine-needle aspiration is often negative in septic spondylodiscitis, biopsy with a larger bore nucleotome[10] or biopsy through percutaneous lumbar discectomy[25] is also advocated by some authors.

## Management

There are some variations in the management of discitis among different physicians. Spinal immobilization of the patient (bed rest), analgesic therapy, and a prolonged course of intravenous therapy followed by oral consumption of appropriate and organism-specific bone-penetrating antibiotics are the mainstay of treatment in the primary stage of postoperative discitis and spondylodiscitis. Generally, rigid immobilization is not necessary. Some of the authors believe that only bed rest and close follow-up would suffice in the treatment of discitis and the administration of antibiotics is unnecessary and inefficacious, especially because these drugs when administered systemically cannot penetrate the disc space in an appropriate fashion.[35] On the other hand, some researchers recommend addition of surgical treatment to antibiotic therapy as a routine initial approach exactly for the same reason.[14,18] In contrast, a large body of literature supports medical therapy with antibiotics as the sole primary treatment[3,15,36] and propose that when no instrumentation and bone graft is placed, little devascularized tissue or foreign material exist in the surgical field. In such cases, excellent antibiotic penetration into the surgical bed is anticipated and the aforementioned treatments are successful in the majority of the patients.[11]

The exact duration of antibiotic therapy may be variable among clinicians, clinical scenarios, and laboratory follow-up assessments. A period of 12 weeks (six weeks of intravenous therapy followed by six weeks of oral therapy) is suggested for spondylodiscitis but shorter durations of treatment (even for four weeks) have also been proposed with acceptable success rates according to the situation of the patient. If no organism can be identified through biopsy and cultures, broad spectrum antibiotics with anti-staphylococcal coverage should be instituted.[36] The patients should be followed by serial cultures or assessment of ESR and CRP and weekly examination.

The definite indications of surgical intervention for iatrogenic discitis and spondylodiscitis are yet to be defined. As mentioned, some authors recommend surgical treatment in every case[14,18] while many others believe operative intervention may only be necessary in cases who fail to respond to conservative treatment or when neurological deterioration occurs.[3,14,17] Non-responsiveness is defined as worsening of the clinical symptoms or laboratory markers during the conservative management. Open surgical biopsies are positive in many of the cases.[3,14,18] Surgical intervention is usually aimed to acquire biopsy specimens, debridement of the necrotic and infected bone, removal of the involved disc, and reconstruction with autograft followed by instrumentation in the same stage or in a delayed fashion. Autograft fusion often occurs appropriately in the presence of adequate immobilization. Application of a closed suction-irrigation system to deliver antibiotic to the wound[11,18] or augmentation of local bacterial control at the surgical site of grafting by implanting a kind of material that releases antibiotics locally over an extended period[3] are also suggested. Large sizes of postoperative fluid collection and paraspinal abscesses can also necessitate surgical debridement. Surgical debridement can be performed through a minimally invasive fluoroscopic or CT-guided technique.

Management of postsurgical discitis and spondylodiscitis in the presence of instruments can be challenging. When anterior instrumentation is performed, removal of the hardware and debridement of all necrotic and infected tissues followed by autologous bone graft reconstruction is proposed.[3] Autograft bone is the optimal material for fusion in these instances and the use of synthetic bone grafts is not advised. When autologous bone graft is not available, allograft bone can be used as the next option. The use of allograft bone material has the potential disadvantage of host immune reaction which can lead to aggravation of inflammation.[3] In case of posterior instrumentation, whether alone or along with anterior instruments, leaving the posterior instrumentation in place and performing anterior debridement and grafting can be another option.[3] When osteomyelitis is present, the situation will be more complex. Some propose removal of pedicle screws and performing a stabilization procedure with other types of instruments such as hooks,[3] while others suggest extending the fusion to the adjacent levels[3] or debridement of the wound and removal of the loose bone graft and devitalized tissue with retention of the implants when significant instability exists.[11] Delayed infections which are manifested several months after the initial operation probably result from intraoperative contamination of the instrumentation by organisms that multiply slowly. In such situations the instrumentation is usually coated with "glycocalyx". Glycocalyx is made of avascular exopolysaccharide produced by bacteria and prevents the body's immune mechanisms and antibiotics from eradicating them. Additionally, in the presence of glycocalyx, organisms won't detach from the instrument in sufficient numbers to be detected by simple aspiration and culture. Because such infections usually occur late, removal of the instruments may not compromise the bony fusion. Thus, it is strongly suggested to remove the hardware to eradicate the glycocalyx and thereby the nidus of the infection. Adequate debridement and intravenous antibiotics for about 4 weeks is also proposed in such cases.[11]

## Prophylaxis and Prevention

The treatment of discitis is not always easy and successful. Thus, following several essential principles for prevention seems to be justified. The indications and the modalities of antibiotic prophylaxis for "clean" surgical procedures, including spinal surgeries, are still open to discussion. Many of the specialists in infectious diseases recommend antibiotic prophylaxis only when there is a clear risk of sepsis. Nevertheless, a large amount of antibiotics is used in hospitals for surgical prophylaxis, often for several days. Accordingly, the effect of antibiotic prophylaxis in preventing postoperative lumbar spondylodiscitis is still controversial in medical, ethical, economic, and legal terms. Although the concentration of antibiotics is reported to be insufficient and poorly sustained in the disc space after systemic administration, the rate of discitis has decreased following judicious use of prophylactic antibiotics before the surgery.[3] The results of two studies assessing the impact of intravenous administration of cephazolin on prevention and treatment of discitis in ovine cases demonstrated that the incidence of discitis can be reduced by prophylactic injection of the drug. However, once discitis was established, cephazolin was incapable of preventing endplate destruction and progression of the inflammation.[37,38] The rate of penetration of intravenous antibiotics into the disc space is still open to debate. Walters et al. (2006) and Fraser et al. (1989) confirmed distribution of antibiotics throughout the ovine disc space by biochemical assay. The concentration of the drug was higher in the annulus fibrosus than nucleus pulposus according to their report.[37,38] The results of a recent human study further confirms the penetration of the intravenous antibiotics into the disc space. According to this report the time when antibiotic concentration reaches its peak level varies among different individuals. Detectable level of cephazolin can be found in more than 70 percent of the disc samples, although only half of the sampled discs contain antibiotic concentrations higher than minimum inhibitory level required for *Staphylococcus aureus*.[39] In contrast, some other reports can be found in the literature emphasizing that no antibiotic can be detected by bioassay or high-pressure liquid chromatography (HPLC) in nucleus pulposus or annulus fibrosus following intravenous injection of antibiotics such as flucloxacillin and cephradine.[40] Ultimately, according to current literature, prophylactic administration of intravenous antibiotics is advised before discectomy. Its beneficial effect in reducing the risk of postoperative discitis is supported by class III level of evidence.[37-39,41,42] Meanwhile, there is no enough evidence to support the routine use of prophylactic antibiotics to prevent discitis before discography.[43] The ideal protocol for prophylaxis before discectomy is not identified yet. In a recent study comparing the effectiveness of two different protocols no significant superiority was discovered. The first approach consisted of single intravenous administration of cefazoline 1g at induction of general anesthesia and generous washing with saline solution and irrigation with a solution containing rifamicin at the end of microsurgical procedure. The second proposed prophylactic strategy included single dose of intravenous ampicillin 1000 mg and sulbactam 500 mg at induction of anesthesia and generous irrigation with saline solution at the end of microsurgical procedure.[41]

Intradiscal prophylaxis has been widely used in order to decrease the risk of postoperative discitis. Placement of anti-microbial agents such as gentamicin-impregnated collagen sponge in the disc space or addition of bacitracin to the irrigating serum is claimed to be of benefit in reducing the risk of postoperative spondylodiscitis.[3,11,20] The rate of intraoperative contamination of disc space during standard discectomies is reported to be as high as 17 percent. It is suggested that the routine application of local antibiotic or antiseptic solutions into the disc space at the end of the operation could decontaminate the operative site and prevent clinical infection despite positive culture findings.[20,44]

It has been suggested that the technique of traditional laminectomy and discectomy may also pose a greater threat of postoperative discitis in comparison with microsurgical minimally invasive approaches for discectomy. Accordingly, when possible it can be proposed to use such techniques for discectomy instead of the traditional practice.[45] Currently, there is no conclusive evidence that the use of surgical microscope can enhance/prevent the risk of discitis.[3]

## Prognosis

The prognosis in noncomplicated cases of discitis, especially following surgeries without instrumentation, is good and proper treatment leads to resolution of all symptoms and eradication of infection and a good long-term outcome.[3,11,17] According to the results of one of the studies, ninety percent of the patients will be pain free after resolution of the infection and fusion. The fusion occurs in the form of bony ankylosis or fibrous union, in 75 percent of the cases after two years of infection.[36] Although a higher incidence of chronic low back pain and vocational handicap is reported following discitis,[46] most of the patients are reported to return successfully to their former works.[17] In contrast, some recent reports of considerable rates of complications can also be found in the literature. Sixty four percent of the patients with discitis who were treated nonoperatively experienced residual back pain.[26]

Generally, the prognosis of spondylodiscitis is worse.[12] The percentage of patients who are unable to resume their former work despite adequate therapy for the postoperative spondylodiscitis varies between 66.7 percent and 87.5 percent.[17,20,35,47] Also, 54.8 percent of cases of postoperative spondylodiscitis suffer from severe functional sequelle.[14] Early diagnosis, identification of the causal organism, and initiation of the treatment in proper time can improve prognosis by shortening the course of hospitalization and reducing the severity of the sequels.[10,14] Higher levels of leukocytosis, higher ESR, discitis in immuno-compromised cases, and presence of paravertebral abscesses are associated with poor outcome.[12,14] The prognosis of discitis managed by operative approaches is generally reported to be good.[18,26,48] Relapse of the infection or death is rare[14] and immunocompromised patients may be at higher risk of death.[12]

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# 44

# Failed Back Surgery Syndrome in Lumbar Disc Herniation

*Deepak Ranade*

## Introduction

Good results in spinal surgery depend on:

1. Understanding the biomechanics of the spine
2. Correct assessment and diagnosis of the compression/instability
3. Validation of the clinical findings with imaging findings
4. Adopting the appropriate surgical strategy to decompress the nerve root
5. The technical competence of the surgeon.

Figure 44.1 shows large disc prolapse compressing the nerve root.

*Surgical intervention:* In the lumbar spine is broadly directed to achieving:

1. Decompression of neural structures (root or of the thecal sac) (Fig. 44.2)
2. To restore the motion segment dynamics and load transmission on the segments involved
3. Stabilization (immobilizing the affected motion segment) when necessary.

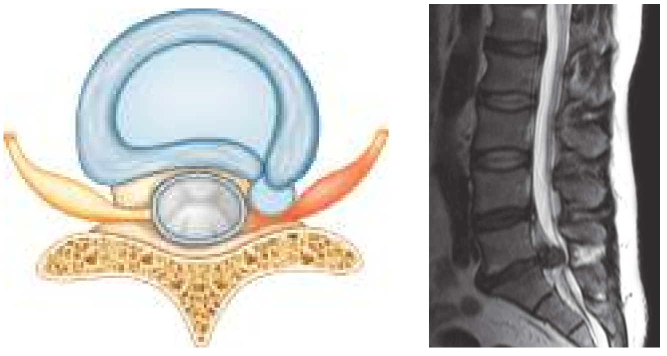


**Fig. 44.1:** Large disc prolapse compressing the nerve root

**Fig. 44.2:** MRI of lumbar spine. This axial (cross-sectional) contrast enhanced T1 weighted image through the L4 level shows exuberant enhancing epidural fibrosis (postoperative scarring) in the laminectomy defect and surrounding the thecal sac

Several factors can contribute to failed back surgery syndrome. It can occur when:

1. The decompression is incomplete, decompression is done at wrong level, or when the bony compression (lateral recess, foraminal stenosis) is not adequately removed.
2. Instability is created following surgical intervention.
3. The structural and functional integrity of the "spinal columns" is not maintained
4. Neural injury is caused during surgical intervention, a foreign body like gauge piece is left behind as secondary fibrosis cause further compression
5. Inadequate stabilization.

## Classification of Failed Back Surgery Syndrome Based on Time of Occurrence

1. Immediate—postoperative failed back surgery syndrome (FBSS)
2. Within two weeks of surgery—perioperative FBSS
3. Two to eight weeks—reactionary FBSS
4. Beyond eight weeks up to three years—delayed FBSS.

After what appeared to be a successful operation for excision of herniated lumbar intervertebral disc the pain persists or recurs. The symptoms are severe enough to indicate reoperation and the results are not always successful.[1-6] About 5 to 8 percent of the patients who have undergone surgery for herniated lumbar intervertebral disc present with failed back surgery syndrome (FBSS).[1,6,7] In some, the recurrence is inevitable for example the operation is done at the wrong level.[8] This sometimes happens in spite of best intentions of the surgeon. At times the herniated portion of the disc is removed incompletely and the remaining part causes symptoms to persist or recur soon. At times a double disc protrusion has been overlooked. In the past, in absence of proper imaging facilities, many surgeons routinely explored lowest two disc spaces to overcome this complication but now with the use of CT scan, MRI and C or O arm operative imaging the incidence of such mistakes has come down significantly.

Complications like inadvertently leaving behind a foreign body like a piece of gauze,[2,7] formation of postoperative arachnoid cyst on the root,[9] disc space infection,[10-12] arachnoidits,[13-15] fibrosis around the nerve roots[1,4,7] can all lead to persistence or recurrence of pain. In the past presence of dye (myodil) in the subarachnoid space caused arachnoiditis resulting in recurrence of symptoms (Fig. 44.3).[4,5]

### Proper Selection

O'Brien (1978)[16] felt that before doing surgery there has to be corrected anatomical localization of pain. Inadequate work up, inadequate localization of pain, inadequate conservative treatment and negative explorations[7,8] are important causes of postdiscectomy syndrome.[16-18]

The surgeon has been blamed when he has operated upon a wrong level.[8] However, the symptomatology could at times be confusing, for example, far laterally herniated nucleus of 5th disc can compress upper exiting L5 root. Lateral recess stenosis compressing the upper root can produce symptoms of that nerve root rather than the lower root compressed by the prolapsed disc. A sequestrated 4th lumbar disc can produce SI root compression when it migrates on the body of L5.

**Fig. 44.3:** Postoperative chronic adhesive arachnoiditis

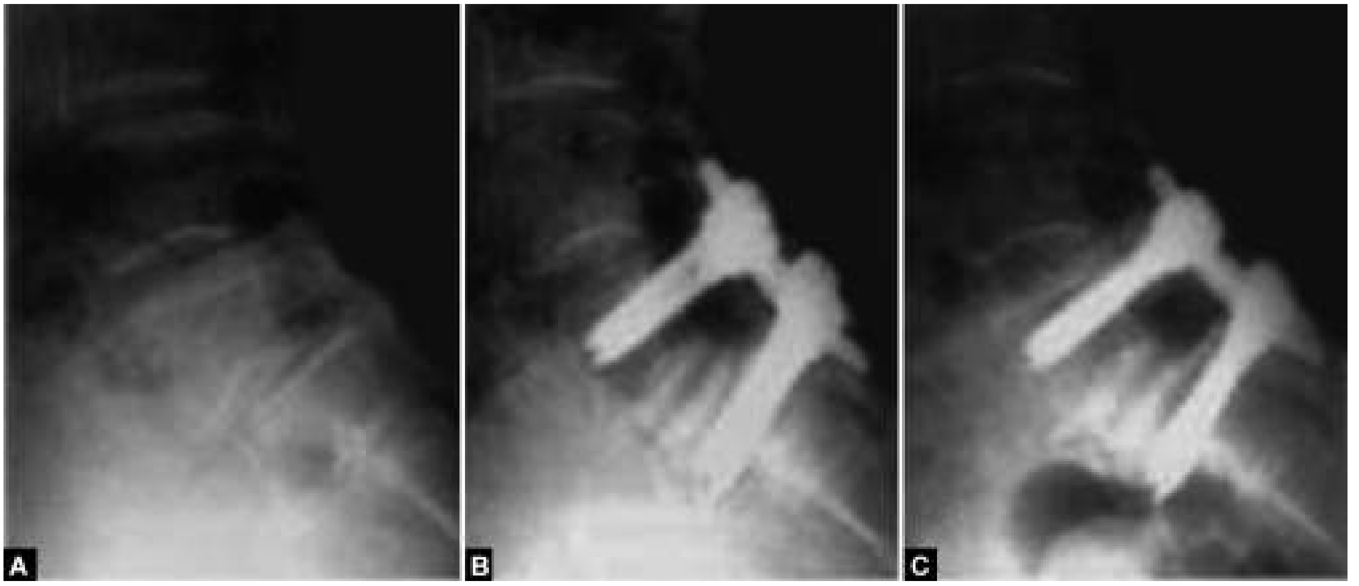
The period of pain relief enjoyed by the patient has been found to be important in understanding the mechanism of failure. For example, if the sciatic pain is felt by the patient immediately after he wakes up from anesthesia either a wrong level has been operated upon or the herniated portion has been removed incompletely. At times the burning paresthesiae of damaged nerve root[19,20] is misinterpreted by the patient as persistence of pain. The latter is an important cause of persistence of paresthesias and burning pain. If the pain recurs three months after surgery, it is likely to be due to neurectomy effect. During surgery tissues are denervated by the exposure. They are renervated and start causing pain. This will also help to explain the source of discogenic pain. Reassurance and rest with symptomatic treatment helps to get relief.

### Late Presentation

At least one year after surgery, the patients start getting symptoms following trivial sprain. Usually instability is produced by previous surgery[17,18] and he will obviously need surgical help by way of stabilizing procedure (Figs 44.4A to C). Late failure five years after surgery is also common (Fig. 44.5). Long-term follow-up of operated patients may not always be encouraging[21-23] although in a recent study by Ramani the recurrence of symptoms 10 years after surgery was seen only in 4 percent of the patients.[24] But in the past during laminectomy days literature indicated significant disablement in 40 to 50 percent of laminectomy patients.

Lewis et al.[23] in a perspective study found that at the end of 5 years 93 percent of the patients were back to their work, and 96 percent of the patients were pleased that they had submitted themselves for surgery.

The indications for re-operation are judged by the sufferings of the patient and his disability.[3-5] For example, if the patient can cope with day-to-day activities with some amount of medication




**Figs 44.4A to C:** Failed back corrected by doing PLIF, pedicle screws and plates

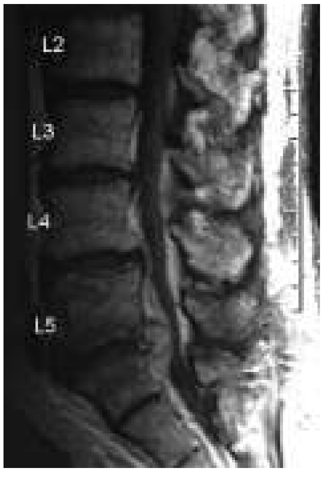



**Fig. 44.5:** Recurrent disc herniation

and life is tolerable then surgery is not considered. On the other hand, if he has severe disabling pain, cannot attend to his work and has to take medicines continuously then benefits from second surgery, should be given to him.

## Surgery

Merely re-exploration and decompression of the roots, from adhesions, however, meticulous it may be, does not come up to patient's expectations on several occasions. It is now generally felt that in presence of degenerative changes in the spine, a good stabilizing procedure will give more and long lasting comfort to the patient. Fusion has to be done at one or two levels.

The failed back surgery syndrome (FBSS) is a misnomer. If is the surgery that has failed rather than the back itself. The fault, most often, lies with the surgeon, not so much in his technical competence as in his selection of patients. Finneson[25] in a careful review of 94 patients with failed low back syndrome considered that the original surgery was not indicated in 76 (81%) of these patients. In a retrospective study, there is always the hindsight. But the percentage of failure in those days was so high that the procedure had, at one time, become unpopular. Long et al. (1988)[21] studied exhaustively 78 patients seen in the John Hopkins pain program. The results emphasized that the iatrogenic factors played an important role in the development of FBSS. Of these 43 patients were subjected to surgery when they had failed to respond satisfactorily to conservative treatment although they did not fit into the category for operative intervention. Two-thirds of 1541 patients admitted to the pain treatment program had undergone three spinal operations and six myelograms. Even the experience of surgeons seeing patients in a standard neurosurgical clinic is not much different. The author's impressions are similar to those of Finneson (1988) when patients were referred for second opinion after the first operation had failed. All the patients had surgery for backache and sciatica from herniated lumbar intervertebral disc.

### First Surgical Intervention is Crucial

The very first surgical procedure is most crucial. If it fails for any reason, it is not always easy for someone seeing the patient for the first time several months after the original surgery to distinguish readily the symptoms and signs that the patient first presented with and those that have developed later. However in the majority, there is a common pattern in which the original symptoms have persisted with little or no relief. The improvement, if at all, has been transient and incomplete. While discussing the symptomatology of this syndrome, one cannot do justice without reference to some of the etiological factors. When subjected to surgery for the first time, the etiological factors must be correctly judged.

### Surgeon's Outlook

It is important to know some of the concepts of the surgeon, which might have contributed to the syndrome of FBSS.

Iatrogenic cutting of pars can lead to instability.

- The belief that most low back and sciatic pain is from prolapse of an intervertebral disc.

  The impact of a joint publication by neurosurgeon (Dr William Jason Mixter) and an orthopedic surgeon (Dr Joseph S Barr) on the 2nd August 1934 in the New England Journal of Medicine was so impressive that it dominated all the thinking on the subject of backache and sciatica. It was only when faced with frequent failures after repeated surgeries on the back was any attention paid to alternative explanations and hypothesis. As early as in 1911 Goldthwait had suggested that pathology in the facet joints may cause sciatica. V Putti in 1927 had referred to anomalies in the posterior articulations producing localized arthritis which may irritate or compress the adjacent nerve root.[26] The concept of referred pain has also to be considered in the differential diagnosis of backache and sciatica. There is ample literature to describe referred pain and to differentiate it from the sciatic pain of nerve root compression. It helps to keep the mind open rather than be locked in a fixed concept.
- Uncritical acceptance of the traditional teaching that failure to respond to conservative treatment is an indication for surgery without thinking carefully, if the proposed operation will deal with the patient's symptoms.
- Blind faith in the reliability of any diagnostic imaging as being superior to clinical judgment.

  In the past myelography and later CT scans on the spine did not give accurate information about the extent of herniation of the severity of nerve root compression. Co-relation with patients complaints was more arbitrary. On plain X-rays, changes of degeneration in the disc space is as common in patients suffering from backache as it is in patients without backache. No one disputes the importance of radiological imaging but it must be clinically corelated. MRI scanning on the spine can pick-up most of the pathology and is the investigation routinely done in all patients.

## Common Clinical Problems

### Failure to Recognize the Instability

In the second opinion, the clinic group, where subtle instability has not been recognized, consists of maximum number of patients. The patient is having instability from spondylolysis at one or the other pair of joints in the given segment without spondylolisthesis. This has not been recognized. The patient is operated upon for a prolapsed lumbar intervertebral disc by doing laminectomy. The instability has increased and progressively the patient now starts developing forward slip of the upper vertebra (spondylolisthesis) resulting in more pain, discomfort and neurological signs. A sub group of this section consists of patients, who have subtle instability without any structural changes associated with disc prolapse (degenerative) Such instability can only be demonstrated by dynamic flexion extension X-rays. This has not been recognized and the patient is subjected to the surgery of discectomy without getting relief from symptoms.

### Iatrogenic Instability

This forms the second largest group. The surgeon is concerned about the compression on the nerve roots. He is also convinced that the roots must be well decompressed by removing laterally placed bone. While doing so, inadvertently, the pars interarticularis is cut resulting in the starting of instability and the morbidity associated with it. In an attempt to do wide lateral decompression, it is a common mistake to go very laterally and create instability.[17,18]

### Posterolateral Fusion

This is not a very adequate procedure by itself in the treatment of instability arising from spondylolistheis. It was done when better and more scientific alternatives were not available. Now with better understanding of biomechanics and load bearing characteristics of the spine one appreciates the ineffectiveness of such a procedure. Posterolateral fusion also produces spinal stenosis [27] and there is a high incidence of pseudoarthrosis. Not many centers practice posterolateral fusion anymore.

### Disc Space Infection

These are unfortunate patients, who develop the infection in spite of all the best efforts of the surgeon. There are two important criteria of this wound infection.[10] After being all right for first five days after surgery on the 6th day patient gets a chill and fever. Shivering is usually associated. Patients are then treated for malaria. The fact that there could be deep seated infection is ignored and from this beginning the infection starts getting worse and worse.

The second mode of presentation comes two weeks later after the patient is discharged.[11,12] After being all right and in good spirits, he starts getting uneasy feeling which quickly spreads to become unbearable pain and stiffness in the muscles. He is bedridden once again. He cannot turn from side to side. He shouts with excruciating pain and the ESR and CRP are raised. This patient should immediately be admitted to the hospital. The pus, if any should be liberally drained and sent for microbial culture and antibiotic sensitivity. Till the report comes, the patient should be treated with antibiotics covering both gram positive and negative bacteria. The correct antibiotic regimen should start on receiving the sensitivity report and the course should continue for a much longer period parenterally and then orally for few months. Disc space infection also calls for immobilization of the patient for six to eight weeks. Rarely as a late sequelae of infection with partial destruction of vertebral bodies patients present with instability and requires the corrective procedure of stabilization.

### Nerve Root Damage

Conditions like nerve root damage, cauda equina damage, unidentified CSF leak producing meningocoele, excessive bleeding during surgery causing fibrosis later on, incorrectly placed pedicle screws, slipped away harrigton rod destabilizing the spine again are not common.[19,20] But when they occur, it needs attention. Very little can be done for neurological damage but meningocoele can be repaired and the wrong screw can be replaced.

### Other Complications

Complications like abdominal blood vessel injuries, bowel injury or formation of AV fistula have been reported [28-30] High suspicion, timely intervention and speedy correction is the answer.

## Presenting Clinical Features

Pain is one symptom that cannot be assessed objectively nor can it be quantified. It has many variables. When pain is the main indication for operation, one has to spend time to elucidate what it means to the patient when he says he has pain. In fact, it is better to recognize patients with pain who will not benefit from surgery rather than those who will. While selecting the patients for disc surgery criteria agreed by American Association of Neurological Surgeons and American Academy of Orthopedic Surgeons (1982) will provide basis for selection.

## Criteria

- Radicular pain following a dermatomal pattern
- Failure of 2 to 4 weeks of appropriate conservative treatment
- Limited straight leg raising with reproduction of radicular pain
- Sensory loss in the area of dermatome to which the leg pain radiates
- Motor loss in the clinically affected nerve
- A depressed tendon reflex appropriate to the pain, motor and sensory loss.

According to the author's experience the most important parameter is the mechanical sign. Absence of neurological deficit should not be in itself a reason not to operate. Disappointment often awaits a patient following surgery, who has a disc prolapse associated with facet joint arthritis when the patient may not get the desired benefit from surgery.

## Unhappy Patient

At every stage of the doctor-patient encounter, there may be warning signs that the patient may never be happy with any form of treatment. Either he has his own motives or he is waiting for certain issues to be settled. For the doctor, it means that the patient will be unrewarding for treatment. The expression on the face of the patient, while in pain, gives some indications. The patient shuffles in wincing pain at every step of examination but his SLR is negative. Inappropriate symptoms suggest a functional component. Inappropriate signs form the base for conclusion.

Wadell (1980) has given criteria for such patients.

- Persistent unrelenting pain with lack of pain free interval
- Pain crossing normal anatomical boundaries
- Pain affecting the whole leg
- The feeling of whole leg giving way
- Numbness in the whole leg
- The ability to sit on couch from lying down position when SLR is restricted
- Over reaction during examination like exquisite tenderness, hypersensitivity etc.

Many patients, who have become addicted to drugs and who have no initiative will have continuing pain after surgery purely because of subconscious craving for drugs. The addiction at times may be so severe that further surgery for elimination of significant causes of pain is certain to fail. Circumspection and care before the very first surgery is the best way to reduce the prospects of failure in such a situation.

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# 45

# Recurrent Disc Herniation

*Mehmet Zileli*

## Introduction

Recurrent herniation after a discectomy is defined as a lumbar disc herniation at the same level as the one previously operated on, with a pain-free interval of at least 6 months after surgery.[45] Recurrent disc herniation is a major cause of failure after surgery for lumbar disc herniation. This manuscript will try to explain the reasons of recurrence, risk factors, treatment options and measures to avoid a recurrence.

## Etiology

For some authors, recurrence of disc herniation is because of micromotion of laxity or degenerative instability of the motion segment. This argument considers a fusion surgery in case of recurrence.

Laus et al.[30] has observed that early recurrences within first year of operation are formed by disc tissue, whereas late recurrences are caused by mechanical collapse of fibrocartilaginous tissue that has developed after discectomy. Besides, preserved disc height has been claimed to be responsible for the recurrence.[50]

## Epidemiology

In general, the reported rate of herniation recurrence ranges from 1 to 20 percent.[2,14,15,29,44] It is 15 percent in series of White et al.[49] and 13 percent in Asch et al. series.[2]

In general, recurrence develops most commonly during the 1st year (one-third of the total) after operation.[10] The frequency of recurrrence depends on the duration of the follow-up. Davis[10] stresses that follow-up period must be at least 4 years, otherwise one-third of the recurrences will be overlooked. He has found a 6 percent recurrence rate and the mean time of recurrence is 4.3 years, and has reported that 50 percent of recurrences are at the same level and the same side as the original disc herniation.[10]

Keskimäki et al.[28] have examined the results of disc surgery in finnish population and found that 12.3 percent of 25,359 surgical patients with herniated lumbar discs underwent subsequent lumbar operations. The reoperation risk was higher if the regional disc surgery rate was higher. Besides, neurosurgical patients had a higher reoperation risk than orthopedic patients. The risk has not varied between sexes, but patients aged less than 50 years had a somewhat higher risk of reoperation than the older patients. They also report that the risk of reoperation systematically increased during the study years.

Suk et al.[45] have reported that young age, male gender, smoking are the risk factors for recurrence.

Ipsilateral herniation occurred in approximately 40 percent of the recurrences, with the rate of contralateral herniation ranging from 18 to 45 percent.[7,39,41]

Reoperation due to recurrence may be accepted as a failure of the primary surgery.[27,47] Besides, the rate of reoperation is a measure of surgical success. The rate of a recurrence surgery after primary discectomy ranges between 4 and 18 percent.[7,13,17-19,32,44,45] Asch et al.[2] report most of these reoperations were within 1 year after the initial surgery. We must consider that the reoperation rate after lumbar disc surgery is between 10 and 20 percent.

There is a report that risk of a repeat operation after a lumbar disc surgery is 10 time greater compared with the general population.[4] The risk significantly increases when the follow-up increases from 5 year (5%) to 10 year (7%).[4]

The reason of higher recurrence rates in recent years may be explained by differences in treatment strategies of lumbar disc herniation, particularly in attitudes toward surgery on smaller, protruding discs. We must consider that if reoperations are high in a community, it is potentially reflecting looser criteria for surgical indications. However, it does not mean that nonoperated patients have been pain-free or operated patients have been more disabled even they need repeat surgeries.

## Diagnosis

The diagnosis of recurrence bases mostly on clinical symptoms (i.e. recurrence of sciatica) and radiology. Best radiological imaging method for recurrent disc herniation is MR examination and Gadolinium-enhanced magnetic resonance imaging represents the "gold standard" for recurrent disc herniation identification.

## Treatment

Similar to the primary disc herniation, nonoperative treatments must be applied before considering surgery. There are mainly two surgical options when recurrence happens and conservative treatment fails: repeat discectomy or fusion. However, there is no consensus which approach is better.

### Discectomy Only

Standart discectomy, whether with conventional techniques or with minimally invasive fashion is still the preferred management technique among the majority of spine surgeons. Those surgeons believe that repeat discectomy is the treatment of choice in case of lumbar disc recurrence, and they have reported good clinical results similar to the primary procedure.[6,12,13,16,17,19,23,31,38,43-46,48,50]

Guo et al.[22] have examined long-term results of repeat discectomy with a minimum follow-up period of 10 years, and obtained 70.6 percent good and excellent results with discectomy alone. Cauchoix et al. have examined 60 patients with recurrent disc herniation[5] of which only 9 patients required fusion surgery.

If there is a significant fibrosis at the recurrent disc site, the results are poorer.[26] However, the quantity of scar tissue may not affect the outcomes.[6] Cinotti et al. believe that the epidural scar does not cause residual radicular pain and removal of the herniated disc tissue is sufficient. In case of significant epidural fibrosis, the dissection should be meticulously done in order not to injure the dura and root. It is not necessary to remove all the fibrotic tissue.

### Fusion

Some spine surgeons believe that fusion is necessary for treating recurrent disc herniation.

Rational for fusion surgery after recurrence come from biomechanical studies. Some conditions have been claimed as risk factors for recurrence: type of annular incision (crossed or circular), quantity of excised tissue in the discectomy.[20,40] Both of these conditions may influence the stability of the motion segment. Disc excision itself may cause weakening of the posterior annulus and hence stability. Incision into the annulus fibers may reduce the stiffness of the specimen. This destabilization effect is even worse if the excision for the partial or repeated discectomy is excessive. For that reason, repeated discectomy requires more disc removal and effect the stability.[6]

For the reasons mentioned above, fusion to treat or prevent segmental instability after recurrence is reasonable choice in cases of recurrent disc herniation, and this concept is strongly supported by many spine surgeons. However, the controversies over fusion or no fusion in treating recurrent disc herniation and whether it has to be performed after the first or the second reoperation are still ongoing.[36]

There are some radiological findings which may be considered as signs of instability and supporting fusion surgery are: Modic type 1 changes at the recurrent disc herniation level (reduced T1 single intensity and increased T2 single intensity),[35] vacuum phenomenon in disc, wedged disc, lateral slipped segment, kyphosis in flexion films, preservation of the disc height, a high-intensity zone[1] shown on magnetic resonance imaging (high T2 signal in the posterior midline outer annulus), a positive provocative test during discography.

There are different fusion techniques studies to be applied after discectomy: posterolateral fusion (PLF), posterior lumbar interbody fusion (PLIF), anterior lumbar interbody fusion (ALIF), transforaminal lumbar interbody fusion (TLIF) are among most applied fusion techniques.

In a study comparing the results of disc excision with and without posterolateral fusion[19] excellent or good clinical outcomes were obtained in 78.3 percent of patients with discectomy alone and in 83.3 percent of patients with posterolateral fusion.

Since application of a cage is risky because of scar tissue, Niu et al.[36] have proposed to apply a single diagonal interbody cage from the virgin side after unilateral facetectomy combined with unilateral pedicle-screw fixation in treating recurrent lumbar disc herniation. However, they recommend to use bilateral pedicle-screw fixation in case bilateral facet joints must be destroyed during surgery.[36]

I personally recommend an interbody fusion surgery if the new disc herniation causes more back pain than leg pain, or if the patient had back pain episodes after primary surgery. Flow chart 45.1 summarizes a personal surgical preference in cases with recurrent lumbar disc herniation (Figs 45.1A to H).

## Complications

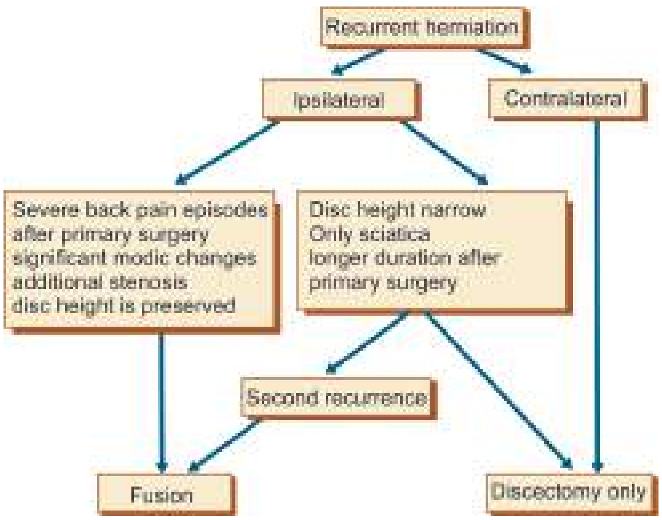
A revision operation is typically associated with a higher complexity, poses more complications than primary surgery. This is mainly related to scar tissue, i.e. epidural fibrosis, and dural tear, root injury and infection are somewhat higher.

## Outcome

Many reports give good and excellent outcomes similar to primary discectomy. Guo et al.[22] have examined the results of 51 recurrence disc herniations who were operated by a simple


**Figs 45.1A to H:** A 51-year-old lady came with left sciatic pain. Her complaints have started in 1988 and since then she had 5 discectomies at L4-L5 level. When she applied to our clinic her left sciatic pain did was still severe. Fat injections and root blocks have not helped. We operated her in 2007 and applied PLIF with short segment pedicle screw fixation. Her back pain and severe leg pain resolved, however, she is still using pregabalin for remaining neuropathic pain

**Flow chart 45.1:** Algorithm for surgery of recurrent lumbar disc herniation




discectomy. A good outcome was achieved in 70.6 percent of the cases, however, 8 patients (15.7%) have failed and needed another reoperation. Dvorak et al.[14] have reported that 35 percent of the patients with recurrences were disabled.

Factors associated with a fair and bad outcome are smoking, isolated trauma or injury, fibrosis, duration of the remaining or recurrent primary postoperative symptoms, and psycho-sociological signs.[22]

## Avoiding Recurrence

Some surgeons try to remove all disc tissue during discectomy to avoid recurrence.[3,8,34] However, a complete removal of all disc material is not possible, since there is no clear cleavage between annulus fibrosus and nucleus pulposus.[24] Some surgeons[24] believe that a complete removal of the intervertebral disc especially deep to the posterior longitudinal ligament would prevent the recurrence. The curettage of the intervertebral space by taking out remaining degenerated disc tissue has been a strategy for some surgeons to avoid recurrence.[8,34] However, there is a general trend that the curettage of vertebral endplates may increase the risk of postoperative spondylodiscitis.[42]

Mastronardi and Puzzilli[34] have proposed to pack intervertebral spaces with "Oxidized Regenerated Cellulose" at the end of microdiscectomy to prevent recurrences. In a series of 158 patients using this technique and a minimum of 18 months follow-up, they have reported only 2 (1.34%) recurrences.

## Conclusion

Recurrence of a lumbar disc surgery occurs in 10 to 20 percent of cases. Recurrence rate increases if the duration of the follow-up is longer. Recurrence rate in regions/communities having higher rate of disc surgeries is also high. This is possibly due to large indications of primary surgery.

If nonoperative treatment fails, a repeat discectomy or discectomy with fusion are surgical options. There is no consensus for which technique should be preferred. It is the author's choice to perform fusion surgery if there are instability signs such as significant Modic changes, if the disc height is preserved, if there were severe back pain episodes after primary surgery, if there is additional stenosis at the level of recurrence, if it is a second recurrence.

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# Complications in Surgical Management of Lumbar Disc Herniation: Past and Present

*Cumhur Kilincer*

## Introduction

Discectomy is indicated in selected patients with leg pain due to lumbar disc herniations that fail to resolve with conservative therapy or in patients with prominent neurological deficits. Because of the epidemic problem of low-back pain, lumbar discectomy has become one of the most common neurosurgical and spinal procedures worldwide.[1,2] Many studies suggest that outcome of lumbar discectomy is favorable, and it improves pain and physical function in the majority of patients.[3] However, in the long-term, its superiority over conservative management is debatable and recurrence continues to be a major problem.[4] Moreover, although lumbar disc surgery is generally considered as a benign and safe procedure, catastrophic complications are possible. This chaper aims to outline the complications of this extremely common operation, and how to avoid them.

## Scope of the Chapter

As a part of degenerative spinal process, disc herniations are generally accompanied by other structural problems such as lateral recess or spinal canal stenosis, and/or spondylolisthesis. These pathologies may require use of a combination of various surgical decompression techniques such as discectomy, foraminotomy, and laminectomy. These techniques may be employed through traditional open surgery or smaller incisions under visual assistance of microscope or endoscope. Thus, surgical management of lumbar disc herniation (and subsequent complications) is greatly affected by accompanying degenerative pathologies and actual surgical technique used. Complicating the issue further, many patients suffer from instability caused by degenerative changes or surgical decompression itself (iatrogenic), thus requiring some sort of stabilization procedure. Traditionally, stabilization has been achieved by posterolateral or interbody fusion whether it is instrumented or uninstrumented. Later on, nonfusion stabilization techniques such as disc arthroplasty and dynamic stabilization techniques have been emerged. As might be expected, complications of a particular surgery heavily depend on the underlying pathology, and the surgical methods/technology used. Complication rate and type of a single discectomy procedure greatly differs than that of a wide decompression plus interbody fusion accompanied by pedicle screw fixation surgery. Outlining the complications of all types of lumbar disc surgery (anterior and posterior, instrumented or uninstrumented, alone or accompanied by other degenerative changes) is far beyond the scope of this chapter. Instead, this chapter primary deals with complications of a simple discectomy procedure performed by traditional posterior approach.

## Evolution of Lumbar Discectomy

Although the pathology is universal, the approaches to handle the problem and the details of surgical techniques employed vary considerably. Because complications heavily affected by the technique used, it is wise to look the historical perspective and evolution of surgery for disc herniation.

Sciatica describes pain originating in the back, radiating into the buttocks and legs, and is the hallmark of lumbar disc herniation. Recognition of sciatica as being the result of an insult to the sciatic nerve goes back to 1764, which was described by

Domenico Cotugno. However, the association between disc herniation and lower extremity symptoms could not be defined for a very long time. In 1913, Elsberg reported 60 consecutive laminectomies.[5] However, he did not believe disc pathology was responsible for the symptomatology in these patients. Alajouanine reported on two patients who underwent laminectomy and discectomy in 1928.[6] In 1929, Walter Dandy published two cases presenting with cauda equina symptoms caused by "loose cartilage from intervertebral disk" by his definition.[7]

In 1934, a neurosurgeon, William J Mixter of Harvard College, and his orthopedic colleague, Joseph Barr, published their breakthrough study.[8] The authors described symptoms of 16 cases that they suggested were caused by degenerative changes in the intervertebral disk which might be relieved by surgical intervention. This publication is generally credited as the first paper elucidating the pathophysiology of sciatica. Their technique involved a wide laminectomy and removal of offending disc through an intradural approach. In 1939, Love described the extradural approach to disc herniation.[9] That procedure became standard and was widely practiced until less invasive surgical dissection techniques were introduced in the late 1960s.

Like all other medical conditions, technological advancements revolutionized the care of spinal disorders. Evolution of diagnostic techniques such as X-ray, myelography, computed tomography (CT), and magnetic resonance imaging (MRI) greatly facilitated diagnosis and treatment of disc herniation. A Turkish neurosurgeon, Mahmut Gazi Yaşargil was the first person introducing the microscope to the surgical field in 1972.[10] In 1977, Yasargil[11] and Wolfhard Caspar[12] independently described the use of the operative microscope for removal of a herniated disc. Use of microscope enhanced surgical safety by increasing visibility of tissue details. Better lightning conditions made possible working within narrow tissue corridors through smaller incisions.

Refinement of surgical techniques resulted in shortened hospital stays, less surgical morbidity, and a faster return to work for the patient. Use of microscopic technique began to be more and more popular in the late 1980s. In the 1990s, many spinal surgeons passed to the routine practice of microdiscectomy, abandoning traditional naked-eye "open" discectomy. Microdiscectomy has been considered the "gold standard" of surgical treatment for lumbar disc herniations. As of the second decade of 21st century, microdiscectomy is the preferred method by the vast majority of spinal surgeons.

Not only the technique of discectomy, but also the extent of disc removal evolved by time. Traditionally, discectomy included removal of disc tissue as much as possible by use of rongeurs and curettes (complete discectomy). Over time, to decompress the affected nerve root, removal of only a portion of the offending disc tissue and loose fragments inside the disc interspace (i.e. limited discectomy), or just the offending disc fragment (fragmentectomy) is adopted. Although there is still debate on the issue of the extent of disc removal, there is a trend toward the preference of limited discectomy. Extent of disc removal is important in terms of complications. For example, it is expected that vascular/visceral complications may be lowered by adoption of limited discectomy instead of complete discectomy. This issue will be revisited below.

Advancement in technology led to new ideas and establishment of different, less invasive ways to decompress nerve roots. In 1960, Nachemson demonstrated bulging of the annulus associated with increased intradiscal pressure under load.[13] To decrease intradiscal pressure, percutaneous endoscopic and nonendoscopic techniques came into use. In 1963, Smith et al.[14] were the first to inject chymopapain into a herniated nucleus pulposus for the treatment of sciatica. Then, this treatment was given to tens of thousands patients worldwide. Although there is still controversy, published results of chemonucleolysis are good, unless patient selection criteria and technical details were violated.

Although, it was not published at that time, Parviz Kambin was the first to perform annulus fibrosus fenestration and mechanical nucleotomy using a biopsy cannula placed dorsolaterally in 1973.[15] In 1975, Hijikata et al.[16] published a case of percutaneous nucleotomy under local anesthesia by utilizing arthroscopic techniques adopted from orthopedic practice. In 1985, Onik et al.[17] reported use of an automated percutaneous nucleotome for mechanical resection of nuclear tissue.

Despite its promising rewards, percutaneous intradiscal techniques were not commonly performed partly due to excellent results of microdiscectomy. In the 1990s, by the advent and progressive use of magnetic resonance imaging (MRI), as well as histopathological/immunochemical studies of disc tissue, it was demonstrated that herniated disc material may decrease in size, or disappear within a few weeks or months. This led to a paradigm shift towards more conservative approaches, and revival of percutaneous decompression and intradiscal procedures.

The last two decades witnessed emergence of transforaminal endoscopy. This technique seems to be a safe and reliable method, provided the surgeon is experienced enough. However, endoscopic transforaminal discectomy has a steep learning curve, and prone to increased rate of complications in inexperienced hands.

## Success and Complication Rates of Discectomy

Despite existence of many alternative methods, microdiscectomy is still the standard method of surgical treatment due to its straightforward nature, relatively low rate of complications and high percentage of satisfactory results. Success rates of microdiscectomy are generally reported between 88 to 98.5 percent in various series. It should be noted that disc herniation is a part of degenerative process. Thus, even though the immediate result of a surgery is good, ongoing degenerative changes may affect long-term outcome negatively. In fact, recent studies suggest that a success rate of 70 to 80 percent may be the more realistic expectation in the long-term follow-up.[18-21]

Complications of disc surgery include failure to relieve the symptoms (which is called Failed Back Surgery Syndrome, FBSS) and any new problem resulting from the surgery itself. These complications can usually be treated successively, but may require a longer hospitalization or additional surgery.

Reported complication rates of lumbar discectomy vary between 1.5 and 15.8 percent in the literature.[21-23] These complications can be classified as general complications, position-related

**Table 46.1:** Complications of lumbar disc surgery

| |
|---|
| **General complications** |
| Thrombophlebitis, pulmonary embolism, anesthesia-related complications |
| **Position-related complications** |
| Vision loss |
| **Surgery-related complications** |
| ***Intraoperative*** |
| Wrong-site surgery |
| Dural tear/CSF leakage |
| Vascular injury |
| Bowel injury |
| Ureter injury |
| Neurologic injury |
| ***Early postoperative*** |
| Epidural hematoma |
| Ogilvie's syndrome |
| Infection |
| ***Late postoperative*** |
| Recurrent disc herniation |
| Textiloma/granuloma |
| Failed back surgery syndrome |

complications, and surgery-related complications. Surgery-related complications can be further subdivided as intraoperative, early postoperative and late postoperative. A list of complications of lumbar discectomy is presented in Table 46.1.

*General complications* of lumbar disc surgery include the complications which can be encountered in all patients undergoing some sort of surgery. These include thrombophlebitis, pulmonary embolism, and anesthesia-related problems. The frequency and severity of these problems mostly depend on the individual characteristics of the patients, and will not be detailed here.

*Position-related complications* include tissue damages due to pressure encountered while the patient lying on the operating table. The most important position-related problems occur in the eye, which are detailed below.

*Surgery-related complications* of lumbar disc surgery can be subdivided *intraoperative, early postoperative and late postoperative complications* according to the time period in which the problem occurred or noticed by the surgeon. *Intraoperative complications* (for example, a dural tear) occur during surgery, and should be noticed and treated intraoperatively at best. Failure to recognize an intraoperative complication may result in further problems in future (for example, pseudomeningocele). *Early postoperative complications* occur or recognized by the surgeon generally within the first or second postoperative week, although their roots and reasons can be traced into the surgery. *Late postoperative complications* are the ones which come into the surgeon's attention weeks, months, sometimes years following the surgery.

It should be noted that this classification is highly arbitrary, and transitions are possible. For example, an infection can be diagnosed very early or years after the surgery. A vascular damage, an intraoperative problem, cannot be diagnosed during surgery, and the patient may admit months or years after the surgery with symptoms of an arteriovenous malformation.

Below, the complications of lumbar disc surgery are outlined under their respective subheadings.

## Vision Loss

In patients treated in the prone position, the most common eye-related complication after spine surgery is corneal abrasion. Less frequent, but much more serious complication is postoperative vision loss (PVL). It was reported that spinal surgery is the leading cause of postoperative vision loss, replacing cardiac surgery.[24] The incidence of blindness after nonocular surgeries has been reported as 0.002 percent among all surgeries and reaches 0.2 percent among cardiac and spine surgeries.[25,26] It is estimated that 1 case per 100 spine surgeons annually will have a significant vision complication after surgery.[27] Due to an aging population and increase in number and duration of complex spinal surgeries, incidence of this problem may increase.

The exact pathogenesis of PVL is still unknown in many cases. The most important precipitating factors are prone position and subsequent direct pressure on globes, hypotension, and subsequent ischemia. Common diagnosis associated with postoperative vision loss is ischemic optic neuropathy.[27,28] Other causes include central retinal artery occlusion and cortical blindness.[27,28] Antihypertensive medication, arteriosclerosis and intraoperative hypotension are possible causes for the PVL. Intraoperative administration of catecholamines and Trendelenburg positioning for treatment of systemic hypotension might further compromise ocular perfusion.

In patients with comorbidities compromising arterial blood pressure, blood circulation and microcirculation, PVL must be considered as a potential complication. Additional metabolic diseases, prolonged duration of surgery in prone position and increased blood loss are other risks factors.

Direct pressure on the globes, perioperative hypotension or anemia, large amounts of crystalloid infusions, and changes in any perfusion-related medication shortly before surgery should be avoided. Some precautions are recommended to prevent PVL: 10 degrees of reverse Trendelenburg during prone surgery, lower transfusion threshold to keep hematocrit above 30 percent in at-risk patients, staging long spinal surgeries, maintaining mean arterial pressure at patient's baseline, postoperative visual exam in at-risk patients.

PVL following spine surgery may be reversible in the early stages. Thus, early diagnosis and prompt treatment is crucial. Although a simple disc surgery is not expected to have a prolonged surgery time or considerable blood loss, PVL still should be a concern, especially in at-risk population. Thus, it is recommended to inform patients about risk of vision loss and include it in the preoperative informed consent.

## Wrong-Site Surgery

When the spine surgeon experienced a negative exploration event (that means failure to find the expected pathology, such as a herniated disc fragment in the exposed level), three questions should instantly come into his/her mind: Could this be the "wrong patient", "wrong side", or "wrong level"? Indeed, wrong-level exploration is probably one of the most common, yet under-reported intraoperative complications of lumbar disc surgery.

If the surgeon identifies the problem of "negative exploration" and correct his/her fault by eventually reaching the right level/place to decompress, this does not harm the patient too much except having some unnecessary skin incision and tissue dissection (i.e. increased "collateral damage"), and prolonged surgical time. A much bigger problem arises when the surgeon does not recognize the problem of wrong level surgery. This may happen when an incidental, asymptomatic degenerative pathology (a bulged or herniated disc) is encountered at the explored wrong place. In this case, the surgery may be completed as if the correct level/place is decompressed. Postoperatively, sometimes after a considerable long time, the unresolved symptoms of the patient may dictate further evaluation, thus the wrong level problem is recognized. This scenario accounts for one of the reasons of FBSS.

Ammerman et al.[29] identified advancing patient age (>55 years) and pathology above the L5-S1 level as risk factors for wrong-level lumbar surgery. Mody et al.[30] suggested direct preoperative communication between the surgeon and patient, marking of the intended site, and the use of intraoperative verification radiographs to be useful in preventing wrong-site surgery (WSS).

WSS problem can be considered as a preventable error, and a systematic approach such as a standardized checklist can facilitate this process (Hsu-2011).[31] The North American Spine Society (NASS) has developed the SMaX protocol (sign, mark, and X-ray) to assist in preventing wrong-patient, wrong-surgery, or wrong-level errors. The American Academy of Orthopedic Surgeons offers a similar method known as SYS (sign your site).[32] Irace and Corona from Milan propose a 3-step method called as IRACE (intraoperative radiograph and confirming exclamation) for single-level lumbar decompressive surgery.[33] In this method, before skin incision, the surgeon places a wire in the spinous process and a lateral fluoroscopy is performed. Subsequently and also before skin incision, the assistant nurse provides oral confirmation of the level and side. Additional fluoroscopic control is performed before starting the laminotomy. By using this method, the authors report no case of wrong level or wrong side surgery, and only one case of an initial wrong level exploration in a series of 818 consecutive patients who had undergone lumbar microdiscectomy.[33]

The problem of an incorrect level or side in lumbar surgery is unresolved and prevention of this error remains a top priority. A recent survey-based study from US reported that nearly 50 percent of reporting surgeons have performed wrong-level lumbar spine surgery at least once, and >10 percent have performed wrong-side lumbar spine surgery at least once.[34] Nearly 20 percent of responding surgeons faced with at least one malpractice case relating to WSS. Regarding the methods to identify the operating level, most participating surgeons reported that they either routinely (74%) or sometimes (11%) obtain preoperative imaging for incision planning. Most surgeons indicated that they obtained imaging after the incision was performed for localization either routinely or most frequently before bone removal (73%), but occasionally after bone removal (16%). The study suggests that there is substantial heterogeneity in approaches used to localize operative levels, and existing safety protocols may not prevent WSS to the extent previously thought.[34]

Although it is not a deadly or prevalent complication, WSS can lead to significant morbidity, increased health care costs, and medical-legal consequences. There may be some unique challenges in spinal localization, especially in the thoracic levels (Hsu-2011).[31] However, for a single-level lumbar procedure, WSS is a preventable complication and mainly a matter of attention. Verification of the intended site of surgery by fluoroscopy is critical, and every surgeon should incorporate this verification step into his/her surgery protocol systematically.

## Dural Tear and Cerebrospinal Fluid Leakage

Incidental durotomies are very common. Its incidence varies by series and type of surgical procedure performed. Considering all type of lumbar spinal procedures, inadvertent dural tears occur in as many as 7.6 percent of lumbar spinal procedures and 15.9 percent of revision surgeries.[35] Of the patients with dural injuries, the overall risk was lower for younger patients and patients receiving lumbar discectomy. Conversely, the dural complication rate was greater with increased age and with procedures involving spinal stenosis or reoperations.[36] Tafazal and Sell reported a durotomy incidence of 3.5 percent for primary discectomy, 8.5 percent for spinal stenosis surgery, and 13.2 percent for revision discectomy procedures.[37]

### Mechanism and Risk Factors

Dural tear and subsequent cerebrospinal fluid (CSF) leak occur via several mechanisms. They often result from dissection of adherent fibrotic or calcified tissue from the dura of thecal sac or root. Bone removal during laminectomy/hemilaminectomy is another dangerous step: dura can be trapped between the bone and teeth of Kerrison rongeur or it may tear due to bone spikes. Eroded or thin dura, adhesions and fibrosis, or dural redundancy in patients with severe spinal stenosis are the risk factors. Epstein reported that ossification of the yellow ligament, synovial cysts, and postoperative scarring as the main risk factors for intraoperative durotomy.[38] Poor surgical technique and lack of surgical expertise are independent risk factors for dural injury and correlated inversely to the surgeon's experience.[39] Inability to identify the stretched nerve root dura (on a severely bulged disc interspace) or excessive traction may cause dural tear.

### Diagnosis

Detection of a dural tear may occur either intraoperatively or/and postoperatively. Intraoperative recognition of the dural dear is a lucky event, because prompt diagnosis and direct repair give the best chance to prevent a CSF leak. Intraoperatively, a clear CSF egress will typically be visualized directly through the dural tear. Unexplained excessive epidural bleeding or a collapsed thecal sac could be an indirect sign of an unnoticed dural tear.

Sometimes, the dural opening remains unnoticed intraoperatively, causing a late presentation. These late-presenting dural tears are much less common, having a frequency of 0,28 percent.[40] Reason for this may be either inability to recognize CSF leak intraoperatively, or an incomplete breech of the arachnoid membrane. In that case, the patient either will have a clear wound drainage (i.e. open CSF fistula), or a fluctuant mass under the incision (i.e. closed CSF fistula, or pseudomeningocele). Open CSF fistulas typically occur in the early postoperative period (1 to 7 days). If the nature of the liquid is suspicious, laboratory tests are indicated. Electrophoresis for β-2-transferrin has been shown to be a sensitive and specific test for CSF.[41] If a fluctuant mass is noted over the surgical site, the diagnosis of closed CSF fistula (pseudomeningocele) must be considered. Other possibility may be a liquefied hematoma. A careful, sterile puncture of the mass should reveal the diagnosis.

Although magnetic resonance imaging (MRI) is able to verify the presence of a CSF leak and may potentially locate the site of dural injury in most cases; cisternography, myelogram and myelogram/computed tomography (CT) scans, and gadolinium-enhanced MR cisternography may be required in selected cases.

### Clinical Implications

Intraoperatively, dural injury may complicate the surgical process. CSF loss may decrease the hydrostatic pressure, then turgor of the thecal sac. This may lead to increased epidural bleeding, because the natural tamponade of the local epidural veins is lost.[42] Dural openings are also associated with injury to the underlying nerve roots.

CSF overdrainage cause decreased CSF pressure. Caudal displacement of neural content stretches the meninges, thus resulting in a severe headache. Other symptoms include vertigo, blurred vision, and nausea/vomiting. Intracranial hypotension, tonsillar herniation, and subdural hematoma or hygroma are the reported complications.[43]

Open CSF fistula is a risk factor for infection. Fever, neck stiffness, or localized wound findings should warn the physician. A persistent fistula may cause meningitis, epidural abscess, delay of wound healing and infection.[44]

Many pseudomeningoceles remain clinically asymptomatic, and can be followed. However, if signs or symptoms after surgery persist, then additional treatment may be needed. Pseudomeningoceles may cause localized nerve root entrapment or adhesions, and subsequent radicular symptoms.[45] These collections may become calcified and result in neural compression.[45,46]

### Treatment

Most of incidental dural tears are detected intraoperatively, and repaired. Indeed, the best treatment for dural tears discovered intraoperatively remains prompt, watertight primary repair.[42] For this, adequate exposure of the tear and surrounding normal dura is necessary. Primary repair is typically obtained by 5-0 sutures. In addition to primary repair, adjuvant use of collagen matrix, fibrin glue or other tissue sealants can be used.[47] It should be noted that, none of the tissue sealants' strength is enough to fix dural edges together against hydrostatic pressure of the CSF.

If primary repair is not possible, the use of a patch graft is recommended along with a tissue sealant. Fat, fascial, and muscle grafts can also be used.[40,47] After repair, to check water-tightness, the table is bring into reverse Trandelenburg position to fill the dural sac, and a Valsalva maneuver is performed to increase intrathecal pressure. A tight fascial closure with nonabsorbable suture is important. The use of subfascial drain placement is debatable. Some authors do not recommend its use to avoid possible formation of fistulous tracts. Some authors suggest primary repair, a subfascial drain, and 1 to 3 days of bed rest.[35,40,47] Hughes et al. reported that a subfascial epidural drain can be used to successfully allow the dura to heal primarily with prolonged drainage.[48] The need for bed rest and its duration is also a controversial issue.

If there is late-presenting open CSF fistula, surgical reopening and repair of the durotomy may be considered for the definitive treatment.[48] Surgery should be considered in patients with a profuse CSF leak, a symptomatic pseudomeningocele, or those that failed conservative management.[49]

Conservative management is appropriate in most cases in an attempt to avoid a surgical revision procedure. Bedrest is the first step in the conservative management. Focal compression and abdominal binders and may be helpful in the pseudomeningocele cases.[50] Some studies have shown complete resolution of a CSF fistula with a watertight skin closure, bedrest, and some form of CSF diversion procedures.[51] By decreasing CSF pressure, closed continuous subarachnoid drainage was found to be successful in the treatment of open CSF fistulas and pseudomeningoceles. In 90 to 92 percent of cases, continuous lumbar drainage (of 120 to 360 mL/day for 3 to 5 days) achieved a complete resolution.[52,53]

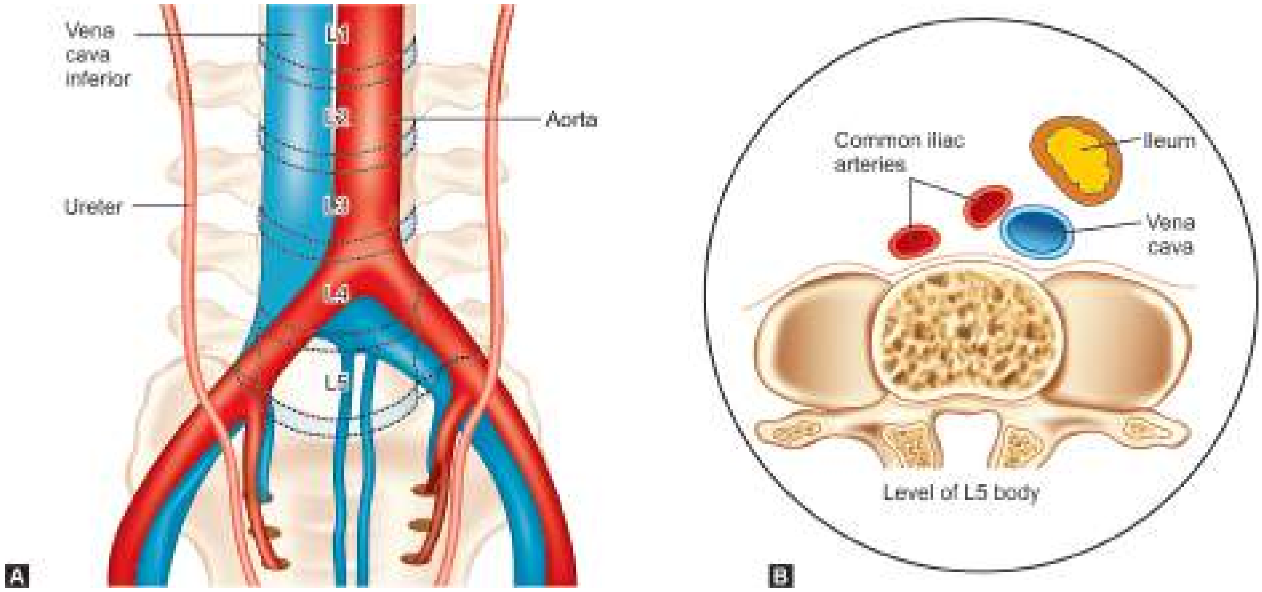
Epidural blood patching is frequently used for headache after lumbar puncture. It can also be used to treat postoperative CSF fistulas.[54] Patel et al. described success in three of six cases with postoperative CSF fistulas using a percutaneous fibrin sealant.[55]

### Outcomes

Saxler et al. found that dural tears were associated with long-term clinical sequelae such as increased rates of back pain and headaches, and worse outcomes regarding daily activity and return to work after lumbar disc surgery.[56] Goodkin and Laska found that incidental durotomy cases accounted for 23 of 146 lawsuits (16%), the second most common cited cause of malpractice lawsuits in spine surgery.[57] However, most studies reported no long-term problem when the patients were treated successfully for dural tears during surgery.[40,47,58]

## Vascular Injury

Iatrogenic vascular injury, although very rare, is considered as the most serious complication, "nightmare",[59] of lumbar surgery. When it occurred, it carries an overall mortality of 15 to 65 percent.[59,60] In the literature, more than 300 cases of vascular complications associated with discectomy have been reported,




**Figs 46.1A and B:** Schematic representation of great vessels and visceral structures in the neighborhood of the lumbar spine

usually as case reports, or in small series. The exact incidence of lumbar vascular complications associated with lumbar discectomy is not known, but reported between 0.01 to 0.17 percent.[61,62] However, its true incidence is probably higher than expected. Sometimes, it may occur in combination of injury to other viscera.

## Description and Pathophysiology

Vascular injury describes any alteration in the wall or lumen of a blood vessel leading to rupture, dissection, pseudoaneurysm, hematoma, narrowing, occlusion, and/or clot formation resulting in thrombosis or embolization. With the posterior lumbar approach, vascular injuries usually result from either inadvertent entrée to the prevertebral space or that cause adhesions between the spine and the viscera. It generally occurs by accidental slips of surgical tools (rongeur or curette) from the disc interspace to the abdomen. Risk factors include degeneration/defect in the annulus fibrosus or anterior longitudinal ligament (ALL), prior adhesion of prevertebral structures to the ALL, revision surgery, and aggressive exploration. The anterior portion of the annulus fibrosus generally is thicker than the posterior portion, and along with the ALL, might be expected to provide a strong barrier. However, anterior disc herniation due to perforation of the annulus and the ALL can occur with a higher prevalence rate of 29.2 percent in MR imaging study[63] emphasizes that this anterior barrier is not dependable.

Vascular injury during lumbar discectomy occurs most commonly at the L4-L5 level, followed by L5-S1. Topographic anatomical relationship of the spine and vessels (Figs 46.1A and B) dictates the injured vessel. The most common vascular injury is a tear of the left common iliac artery, which is just anterior to the L4-L5 lumbar disc space. Other reported vascular injuries have included the right iliac artery, the aorta, the inferior vena cava, iliac veins, iliac vessels' branches and bridging veins, and formation of arteriovenous fistulae (which are usually develop between the left common iliac artery and the left common iliac vein).

## Prevention

Reports of pre-existing defects in the integrity of the anterior annulus fibrosus and ALL highlight the fact that the surgeon cannot rely upon these structures as a barrier. Thus, the surgeon should be very careful when excising anterior part of the disc. Historically, some authors suggested radical disc removal (all fragments up to the anterior annulus fibrosus, using curettes and pituitary rongeurs) to reduce recurrence rates,[64,65] and many surgeons followed this principle. It is clear that vascular injury occurs when the surgeon tries to excise the disk, and forced attempts to evacuate all disc interspace may increase the risk of violation of anterior annulus and ALL. Thus, some authors warned against a radical approach, because of potential risk of a vascular injury.[66] However, it should be remembered that, a mishap may occur even during a partial discectomy. Birkeland and Taylor[67] stated that "not infrequently during the course of disc removal a rongeur may slip through the ALL without causing intra-abdominal injury." The amount of disc material removed from the disc space is the surgeon's choice. We believe that there is a trend towards limited discectomy today.

It is necessary that the surgeon be constantly aware of the depth to which instruments are inserted into the disc space, particularly the pituitary rongeurs. It has been recommended that instruments used within the disc space be marked with "safe-depth-or-death markings."[68] This depth, although it differs level by level, is between 2.5 and 3 cm. Also, anatomical data regarding the size and configuration of the patient and patient's disc should be considered and this information should be a part of the surgical plan.

### Clinical Findings and Diagnosis

Clinical course of vascular injuries are highly variable depending on the extension of trauma and can be divided into acute, subacute and chronic. Bass et al.[69] described six categories of vascular complications associated with lumbar discectomy:

1. Laceration of the aorta or vena cava with immediate hypovolemic shock.
2. Lacerations of the iliac vessels with or without immediate shock.
3. Partial avulsion of a vessel wall with delayed hemorrhage or thrombosis.
4. Injury incident to pre-existing vascular disease such as an abdominal aortic aneurysm or atherosclerotic vessel walls.
5. False aneurysm and infected hematoma, and
6. Arteriovenous fistula.

While arterial lacerations are detected rapidly, detection of venous bleedings and arteriovenous fistulas may be difficult. Unexplained bleeding from the disc space not caused by epidural or bone bleeding, findings of fat, visceral or vessel wall in the specimen (between the teeth of rongeur) should warn the surgeon. Diagnosis is relatively easy when there is profuse bleeding from the disc interspace, and/or early signs of hemodynamic instability and/or retroperitoneal hemorrhage. Excessive or atypical bleeding as observed by the surgeon or hypotension during surgery may prompt a communication between the surgeon and the anesthesiologist, which may result in earlier detection and intervention. In an attempt to help to detection, Shevlin et al.[70] described the escape of saline from the disc space as a test indicating that a perforation of the ALL had occurred. However, lack of this sign does not prove the integrity of ALL.

Only one-third of the vascular injuries are diagnosed in the operating room.[71] Delayed hypotension, swelling and engorgement of the lower extremities or delayed unexplained abdominal symptoms may be present in the remaining patients. The patients may show flank pain, fever, and ileus. Thus, communication between the surgeon and other members of surgical care team is essential to diagnose this problem. Informing the anesthesiologist and the recovery room staff about the findings associated with this complication may cause a nurse or resident to consider this severe complication in the differential diagnosis. The diagnosis may be missed even for weeks or years when there is a pseudoaneurysm or an arteriovenous fistula formation. Arteriovenous fistulas and pseudoaneurysms may cause regional venous hypertension with swelling and pain in the abdomen and leg.

For acute injury with rapid clinical decline, diagnostic imaging is neither warranted, nor feasible. Emergent surgical exploration is indicated. If the patient hemodynamically stable, imaging is performed. A radiogram or CT scan may show free air in the peritoneal cavity leading to the diagnosis. CT scan also demonstrates the presence and size of any hematoma. Angiography provides the complete assessment for vascular tree, and sometimes provides opportunity for intravascular repair.

### Management

If a vascular or visceral injury is highly suspected and blood transfusions/fluid replacement do not restore the patient's blood pressure, then lumbar wound should be packed or closed and an exploratory laparotomy should be performed urgently with the necessary assistance of a general and/or vascular surgeon. Even there would be some negative intra-abdominal explorations could be encountered by that way, the patients still should be treated as if she/he had a vascular injury until proven otherwise, because the exploration can be life-saving. As stated by Hildreth "No guilt or charge should result from a negative retroperitoneal exploration" when a vascular injury is suspected.[72] Aorta and vena cava inferior lacerations are preferably repaired by lateral suturing. This approach is sometimes challenging to perform if the injury is located at the posterior wall. Therefore, suturing from inside after arteriotomy or graft interposition are alternative procedures.[60]

For those cases in which the diagnosis is in question and the patient is stable, angiography, CT scan, or ultrasonography can be used to guide treatment. Significant advances in endovascular techniques have changed the treatment of vascular injuries associated with lumbar spinal procedures in hemodynamically stable patients. Endovascular stenting with or without coil embolization is highly successful for arteriovenous fistulae and pseudoaneurysms.

Repair of an arteriovenous malformation should always be elective. In fact, the development of a collateral circulation is an advantage, since ligation of vessels may be necessary. However, when cardiac insufficiency or pulmonary embolism developed, a quicker intervention may be necessary.[73]

### Importance of Informed Consent

It was noted that all such complications went to litigation and a settlement or verdict was rendered in all cases.[71] Although a potentially catastrophic complication, vascular/visceral may not be mentioned in obtaining an informed consent because of its presumed rarity. Informing the patient of this risk is unlikely to alter the patient's decision to proceed with surgery; however, this effort may provide some medico-legal protection to the surgeon.

## Bowel Injury

Bowel or ureteral injuries during discectomy are even less common than vascular injuries. Nearly 20 case reports describing isolated bowel injury during lumbar discectomy have been published to date.[74-77] Vascular injuries in conjunction with bowel or ureteral injury have also been reported. Even though determining its incidence is difficult, a large scaled study reported 1 case of bowel injury in a series of 68,329 patients (0.0015%).[78]

This complication usually occurs during surgery at the L5-S1 level. An inadvertent penetration with an instrument into the peritoneal cavity is more likely to cause a prominent injury, if the intra-abdominal contents are compressed against the spine, as in prone position of obese and short patient. Anatomically, since the root of the mesentery of the small bowel arising in front of the vertebral column extends obliquely from the second lumbar vertebra to the right sacroiliac joint, the small bowel is more likely to be injured than the large bowel. Thus, intestinal injury most frequently involved the ileum, followed by the sigmoid colon and appendix.

Bowel injuries create a management challenge because they are uncommonly recognized in the operating or recovery rooms. Postoperatively, patients typically complain of acute abdomen, abdominal tenderness and rebound with distension over the course of several days. In these cases, plain radiographs or abdominal CT scans confirm free air in abdominal cavity and the anterior portion of the spine at the surgical level. In cases of acute abdomen after discectomy, the treatment includes emergency laparotomy, bowel resection and anastomosis, or simple suture of the perforated area.

In a few instances, the diagnosis was made months to years later after mature, intra-abdominal abscess formation.[79] Chronic wound infection and discitis can be seen in these cases. Persistence of a wound infection especially when the culture grows intestinal flora is another indication of bowel injury.

Although the prognosis of bowel injury after lumbar discectomy is not worse compared to that of vascular injury, the fatal course may be led by generalized peritonitis, septicemia, and shock[75] or concomitant vascular injury possibly induced by chronic infection. Considering delay in diagnosis is associated with a high morbidity and mortality rate after bowel injury, exploratory laparotomy following prompt diagnostic evaluation should be performed to repair the injured intestine.

## Ureter Injury

Iatrogenic ureteric injury is a serious complication having the risk of kidney loss. It is occasionally encountered during abdomino-pelvic surgeries. In a review, hysterectomy was responsible for the majority (54%), followed by colorectal surgery (14%), pelvic surgery (8%), and abdominal vascular surgery (6%).[80] As a complication of lumbar disc surgery, ureter injury is very rare.

Similar to vascular or bowel injury, ureteral injuries are caused by perforation of the anterior annulus and ALL by a rongeur. Anatomically, the lower lumbar ureter is located lateral to the aorta on the left and the vena cava inferior on the right, between the anterolateral aspects of the vertebral body and psoas muscle at the L4-L5 level. It crosses the common iliac artery and vein ventrally and appears medial to these vessels at the lumbosacral junction. Because of this close proximity, ureteral injuries are sometimes associated with combined arterial or venous injuries. The ureter is surrounded by a protective retroperitoneal fat. In obese patients, a cushion of perivertebral fat elevates the ureter away from the spine, achieving greater ureteral mobility in the retroperitoneal space and less chance of injury during spine surgery. Thus, ureter may be more susceptible to injury in thinner patients. Retroperitoneal adhesions are also another risk factor. The injured ureter is generally contralateral to the side of discectomy because of the oblique direction of the instrument.[81]

Early signs and symptoms of injury are nonspecific and consisting of abdominal pain, fever, vomiting, ileus, leukocytosis, a tender or distended abdomen. There may be significant leakage from the drain site. Persistent hematuria, anuria, or even urinary fistula may be observed. Lack of intraoperative abnormalities and nonspecific symptoms may lead to delayed detection. The length of time until diagnosis ranged from 3 days to 6 weeks after surgery.[82] Computerized tomography, retrograde or antegrade pyeloureterography are used for definite diagnosis. Exploration may be necessary ruling out associated vascular and visceral injuries. It should be noted that exploration of the abdominal cavity may miss the ureteral injury.

Once the diagnosis is established, there are several alternatives for repair including simple stenting, ureteroureterostomy, or autotransplantation. The most often used technique is the end to end anastomosis, especially if there is a complete ureter injury. In most cases the final outcome is good. An early diagnosis is essential in order to avoid further complications such as kidney loss or sepsis.[83]

## Neurologic Injury

Immediate neurological deterioation after a disc surgery may be seen in forms of radiculopathy or cauda equina syndrome. The spectrum of neurological loss varies between a mild and transient increase at the pre-existing radiculopathy (a transient increase in pre-existing leg pain, sensory disturbance, or weakness) and a complete cauda equina syndrome in a previously neurologically intact patient. Therefore, the true incidence of neurological injury is very hard to determine, if even the small deficits are included. The incidence of cauda equina syndrome after lumbar disc surgery has been reported to vary between 0.2 and 1 percent.[84,85]

When there was a clear intraoperative problem or surgical mishap such as root avulsion, excess retraction of root or dura, inability to perform discectomy and decompression, etc. the reason for neurological injury is appreciable. In this setting, neurological decline is predictable, and the measures to correct the problem are obvious, if any. In addition, prevention methods are well described and generally include conforming competent surgical techniques.

The problem arises when the surgery seemed to be straight-forward and fine, at least from the surgeon's view. What is the reason for a newly developed deficit after a relatively straightforward disc surgery? Several mechanisms have been suggested to explain postoperative neurological deficits. These include adverse effects of anesthetic agents, vascular complications, compression of a fat graft, a retained operation sponge, and venous stasis secondary to inadequate decompression.[86-90] Henriques et al.[91] reported 5 patients who developed cauda equina syndrome after seemingly uneventful disc surgeries. Postoperative MRI confirmed that the initial operation was performed at the correct level, and no obvious cause of the complication was evident. However, the authors noted that there was marked narrowing of the spinal canal as a result of the initial relative stenosis and postoperative edema at the level of surgery. All patients underwent decompressive surgery within 48 hours of index operations. At reoperation, the surgeon could not find a hematoma, remaining disc fragment, or any other causes of compression. Wide decompressions were performed. Two patients recovered fully, whereas the other three had varying degrees of sequelae. The authors concluded that preexisting relative spinal stenosis, either congenital degenerative, might contribute to the development of neurological deficit after surgery for lumbar disc herniation. This series demonstrates the importance of appropriate bony decompression during discectomy, especially in patients with relative/borderline canal stenosis. We believe that a dazzling disc herniation may attract the surgeon's attention too much that he/she may neglect to treat stenosis. We suggest that not only cases with postoperative neurological decline, but also many cases with persisting pain (i.e. FBSS) caused by inadequate bony decompression. In other words, many cases has dual pathology: while the primary pathology (the recent reason that brings the patient to the surgeon) is disc herniation, there may be a secondary pathology, spinal canal or foraminal stenosis, which should also be treated appropriately to optimize results.

## Epidural Hematoma

Collection of blood in the epidural space after lumbar surgery is very frequent. Asymptomatic postoperative epidural hemorrhages are found in 58 percent of patients undergoing lumbar surgery. Symptomatic ones are much infrequent, and found in 0.17 percent of patients.[92] Epidural hematomas located at the operative defect, and extend cephalic and/or caudal directions. These hematomas reduce the cross-sectional area of the canal by an average of 32 percent (range, 12–56%).[93]

Disruption of the epidural veins during surgery and decreased coagulation ability lead to enlarging hemorrhage. Risk factors for spinal epidural hemorrhage include coagulopathy, international normalized ratio (INR) greater than 2.0 within the first 48 hours after surgery, use of nonsteroidal anti-inflammatory medications, and multilevel spinal procedures. Other factors include posterior versus anterior surgical approach, previous surgery at the same site, and large intraoperative blood loss.[93]

Patients with symptomatic epidural hemorrhages usually present within 24 hours after surgery. The patients experience intense sharp pain at the surgical site, followed by dysesthesias, radicular symptoms, and, finally, motor weakness. Sometimes, a symptom-free postoperative interval (average, 3.8 days) may be observed.[92] In symptomatic cases, postoperative imaging (MRI) is indicated. In the acute phase, the epidural hemorrhages shown as dorsally situated well-defined lentiform masses with heterogeneously variable signal intensity. In the subacute period, increased signal intensity is observed on both T1- and T2-weighted images. In sagittal view, they often show variable thickness with an undulant anterior border. Seromas, especially partially hemorrhagic seromas may have similar appearance but often have lower, more homogeneous signal intensity.[93] Seventy-one percent of patients improve after surgical evacuation of the hematoma.[92]

### Gelfoamoma

In preventing postoperative hematoma, meticulous hemostasis is recommended. The hemostatic materials used to overcome this problem, indeed, may rarely cause further problem by their mass effect. Dry absorbable gelatin (Gelfoam®) absorbes fluid and swells as it becomes wet. Absorbable gelatin pads placed onto dura that are incompletely soaked may swell within the spinal canal after surgery, leading to compression of the nerves. Friedman and Whitecloud reported one patient who underwent 4 levels of lumbar decompressive laminectomies and received a Gelfoam pad over the exposed dura experienced pain and neurological decline after surgery.[94] After removal of this material, the patient quickly recovered. The authors called this situation "gelfoamoma" and concluded the problem may be caused by swelling and the mass effect of gelatin sponges. We believe there may be also some biocompatibility issues. It was suggested that absorbable gelatin sponge might promote fibrosis to a significantly greater degree in a rat model comparing to other forms of absorbable hemostatic agents.[95]

## Ogilvie's Syndrome

Acute colonic pseudo-obstruction (also known as Ogilvie's syndrome) is characterized by clinical and radiological evidence of acute large bowel obstruction in the absence of a mechanical cause. The condition usually affects elderly people with underlying co-morbidities. To date, four cases of Ogilvie's syndrome following lumbar spinal surgery have been reported in the literature.[96] This syndrome should be differentiated from a bowel injury. The patients show persistent abdominal distention and lack of bowel sounds. Plain radiography and ultrasonography reveal dilatation of the colon. Treatment includes nasogastric decompression, parenteral correction of fluid or electrolyte imbalance, and withdrawal of narcotic medication. Intravenous administration of neostigmine, an acetylcholinesterase inhibitor, may achieve colonic decompression.[97] If the cecal diameter continues to increase, colonoscopy or laparotomy may be needed to prevent perforation of colon.

## Infection

Infection is an uncommon but serious complication of disc surgery. It is generally accepted that discectomy and laminectomy have reported incidences of infection less than 3 percent. Surgeries that require extensive soft tissue dissection, longer operative time, greater blood loss, significant soft tissue retraction, or the creation of dead space have an increased infection rate. Infection rates in patients undergoing discectomy alone and those undergoing discectomy and fusion showed infection rates of 1 percent versus 6 percent, respectively. Specifically, lumbar discectomy has had a reported incidence of 0.7 percent, and using a microscope for the procedure increases the incidence to 1.4 percent.[98]

Patient risk factors play the most important role in influencing postoperative infections. Some of these risk factors are modifiable. These include smoking, obesity, surgical length, prolonged indwelling catheter use, length of hospital stay, and malnutrition. Significant improvement in the ultimate outcome can be achieved if these problems could be addressed. In general, diabetic patients have increased complication rates, particularly with posterior lumbar surgery. Careful preoperative attention to tight blood glucose control and an assessment for other related factors may limit the risk of local infection and systemic morbidity in diabetics.

Although there is still some debate on the necessity of antibiotic prophylaxis, most would agree that prophylactic antibiotic is indicated for routine spine surgery. In order for antibiotics to be effective, they must have antimicrobial action against the most common bacteria encountered and must be present in tissues adjacent to the surgical site during surgery. Currently, it is suggested that antibiotic administration should begin 30 minutes to 1 hour preoperatively to ensure adequate antibiotic levels at the surgical site at the time of skin incision. Some authors recommend repeating the dose of antibiotics after 4 hours of surgery, because serum and tissue antibiotic levels decrease with prolonged operative time. Because of their good coverage against the common bacterial agents encountered in spine surgery, its limited side effect profile, and advantageous pharmacokinetics, cephalosporins are generally used for prophylactic antibiotics. Cefazolin continues to be the most commonly administered prophylactic antibiotic because it provides appropriate antimicrobial coverage, is relatively inexpensive, and reaches peak serum concentrations rapidly.

The most common presenting symptom for postoperative infections is pain. Patients generally have a pain-free interval of 1 to 2 months, and then subsequently develop increasing pain over several weeks. Suspicion of a postoperative infection is frequently raised as the result of a change in the patient's clinical postoperative course from pain free to painful. Worsening back pain (often accompanied by paravertebral muscle spasm) may be a strong indication of infection. The pain is classically out of proportion to what would be expected. Infection after a lumbar disc surgery can be superficial or deep. Attention to physical examination findings at the surgical site can be informative to help to distinguish between superficial and deep infections.

Superficial wound infections generally present within 2 weeks of surgery with local pain, erythema, edema, tenderness to palpation, heat, and drainage. These infections in the early postoperative period that are not accompanied by increasing back pain or systemic findings can be treated with local wound care and oral antibiotics for approximately 2 weeks. If a wound continues to drain after local care or if the patient develops increasing back pain with the development of constitutional symptoms, it must be assumed that there is an underlying deep infection. The consistency and timing of the drainage also provides insight into the nature and depth of the infection. Clear, yellowish serous drainage might indicate an underlying seroma, whereas more purulent drainage indicates infection. However, deep infections may have relatively mild superficial findings, confounding the diagnosis. Systemic symptoms must also be taken into consideration when evaluating a wound infection. Infection may be associated with high temperatures, chills and sweats. Fever is the most common constitutional symptom seen in these patients, although many patients with deep infections have no systemic symptoms. Late infections (presenting more than 2 months after surgery) may present without obvious symptoms and can be difficult to diagnose.

Laboratory studies are useful to diagnose postoperative infection. The initial blood workup should consist of a complete blood count (CBC) including while blood cell count (WBC) with differential, erythrocyte sedimentation rate (ESR), and C-reactive protein (CRP). When used alone, many of these laboratory markers may be of little use, because they may not be either an absolute indicator of infection (such as WBC) or may elevate following surgery and not normalize until several weeks postoperatively (such as WBC, ESR, and CRP). However, when taken together and repeated over time to display a trend, these markers measure severity of infection and allow the clinician to monitor the response to treatment. As with ESR, CRP values rise sharply during the initial postoperative period. It peaks on the third day postoperatively. However, CRP decreases to baseline levels more rapidly (within 10–14 days), unlike ESR. Thus, CRP is a more sensitive indicator of infection and a more useful diagnostic tool when determining the presence of infection.

The identification of offending microorganism is a critical step in the treatment of a postoperative infection. Cultures obtained from the superficial wound are often contaminated with skin flora and can obscure the correct diagnosis. If there is a fluctuant mass, it should be aspirated. If a fluctuant mass is absent, computed tomography (CT) or fluoroscopic guidance can be used to obtain a deep culture from the affected area. If the patient is in septic condition, blood cultures can reveal the responsible organism.

MRI, with and without intravenous gadolinium contrast is the most important imaging modality when evaluating postoperative spinal infections. It can identify, with high sensitivity and specificity, postoperative osteomyelitis, discitis, and epidural abscesses. MRI findings typical of discitis include hypointensity on T1 and hyperintensity on T2-weighted images.

The fundamental principles involved in the management of a postoperative infection include prompt diagnosis with isolation of the specific organism, if possible, and initiation of appropriate medical and surgical management. For any significant superficial or deep infection, a minimum of 6 weeks of IV antibiotics followed by 6 weeks of oral antibiotics are required. ESR and CRP measurements are used to monitor the response to treatment. In most patients, medical treatment with extended courses of antibiotics can treat the infection, although surgical debridement may be necessary if the infection does not respond to antibiotics. Surgical treatment of postoperative infections includes debridement of each layer of the wound. At each layer, assessment of tissue devitalization and possible communication with underlying planes must be assessed. In addition, appropriate specimens for staining and cultures (aerobic, anaerobic, fungal, and acid-fast) should be taken from each layer before the initiation of intraoperative antibiotics. When involved with the infection, the deep fascial layers should be opened and all loose tissue and foreign material should be removed. Sometimes, multiple subsequent débridements may be required until the tissues appear clean and operative cultures are negative.

## Recurrent Disc Herniation

After discectomy, there is a risk that another fragment of disc will herniate at the same level and cause similar symptoms in future, due to already disrupted anatomy. This is a so-called recurrent disc herniation, and the rate of this complication after lumbar discectomy is 5 to 15 percent.[99-101] It should be noted that, for the diagnosis of recurrent disc herniation, there should be a brief pain-free interval after discectomy. Otherwise, it should be accepted as a case of residual disc fragment, instead of recurrence. The mean interval for recurrent pain associated with recurrent herniated discs is 18 months, longer than that for *de novo* disc herniations or symptomatic epidural fibrosis.[102] The strict definition of recurrent disc herniation is "the presence of herniated disc material at the same level, ipsi- or contralateral, in a patient who has experienced a pain-free interval of at least 6 months since surgery". However, this duration of pain-free interval (6 months) has been chosen arbitrarily. It may be shorter in some cases.

There are some risk factors for disc recurrence. Higher recurrence rates and poorer outcomes have been documented in patients with diabetes.[103] Carragee, et al.[100] divided disc herniations into four groups according to the size of the disc fragment and annular tear:

1. Fragment/fissure herniations (extruded disc fragment and small anular defect)
2. Fragment/defect herniations (extruded disc fragment with >6 mm anular tear)
3. Fragment/contained discs (incomplete anular tear and subanular disc fragment)
4. Anular prolapse (incomplete annular tear and absence of subanular fragment).

In the authors' series, the fragment/fissure type herniations were associated with the lowest rate of persistent symptoms, reherniation, and reoperation rates (1.1% each). These rates were respectively 27.3 percent, 27.3 percent, and 21.2 percent in the fragment/defect type herniations; and 37.5 percent, 12.5 percent, 6.3 percent for anular prolapses. These numbers indicate that existence of a large anular defect (>6 mm) is highly correlated with increased risk of recurrence.[100]

## Textiloma/Granuloma

The terms of textiloma (or gossypiboma) are used to define a retained surgical sponge or cottonoid and its surrounding foreign-body reaction. They can frequently occur after thoracic or abdominal and surgeries. Depending on their location and composition, they may cause severe complications or remain silent.[104] Olnick et al.[105] has classified textilomas into acute necrotic forms and chronic forms. In the acute form, exudative reaction causes abscess formation and skin fistulas. This form becomes symptomatic in the early postoperative period. In the chronic form, encapsulated aseptic foreign body granuloma is observed and may remain asymptomatic.

Regarding spine surgery, most cases are related to surgical sponges left in between the paraspinal muscles. These lesions are not expected to create any neurological problem. However, if a small cottonoid is left in the epidural area, it may cause radicular pain due to mechanical compression of the foreign body and/or the epidural scarring. In these patients, the symptoms may persist or recur after the operation depending on the location and size of the textiloma; degree of decompression at the previous operation; and severity of the epidural scarring induced. In patients admitting persisting or recurring symptoms after a lumbar procedure accompanied by some atypical MRI findings, a textiloma should be considered in the differential diagnosis along with recurrent disc herniation and epidural fibrosis. CT and MRI appearances of the textilomas may be highly variable and confounding.

To prevent such a complication, use of X-ray detectable sponges and cottonoids (containing radiopaque barium sulfate markers) are recommended. Cottonoids used in the epidural space should have ribbons, and care should be taken always to keep the integrity of ribbons during surgery.

## Failed Back Surgery Syndrome

Also called as Failed Back Syndrome (FBS). By definition, FBSS is persistent or recurrent pain after at least one previous lumbar surgery. Being one of the complications of lumbar disc surgery, FBSS should be separated from others: FBSS caused by a variety of other complications of surgery. For example, an unnoticed wrong-site surgery (WSS) will result in unresolved symptoms, i.e. FBSS. Similarly, infection or iatrogenic instability will result in persistent or new pain. Thus, FBSS generally results from other complications of lumbar surgery which have been poorly managed. From this point, FBSS could be taken as "complication of another complication". Another difference of FBSS from other complications is its heterogeneous nature. FBSS may results from various reasons as detailed below. Sometimes, finding the underlying reason may be puzzling, and requires a systematic approach. Each possible reason should be carefully reviewed and eliminated. On the contrary, other complications of lumbar surgery are easier to identify. Because of this reasons, FBSS is different from other complications of lumbar surgery, and may require a whole dedicated chapter. The current text will review FBSS with its main features only.

### Incidence

Most patients undergoing discectomy find relief of much, if not all, of their symptoms. However, the success rate of discectomy is around 85 to 90 percent, meaning that 10 to 15 percent of patients who undergo a discectomy will still have persistent symptoms, i.e. FBSS.

### Etiopathogenesis

FBSS may result from diverse reasons. By their nature, these can be classified into the three groups:

1. Diagnosis/indication-related
2. Surgical mistakes
3. Surgery/degeneration-related.

*Diagnosis/indication-related FBSS* caused by the poor preoperative evaluation and planning phase due to lack of enough knowledge, experience, or attention. Sometimes, the planned surgery is not likely to achieve the desired result, or even not indicated. Thus, it is expected that the symptoms would persist even after a technically perfect surgery. Sometimes, the surgeon fails to identify the actual problem responsible for symptoms, and aim to correct another structural problem which is asymptomatic or unrelated with symptoms.

*Surgical mistakes* which can potentially cause FBSS are many and include insufficient decompression, excessive bone and/or ligament removal (causing subsequent instability), failure to identify and address intraoperatively detected instability, and direct nerve damage.

*Surgery/degeneration-related reasons of FBSS* include adverse events triggered or facilitated by surgery. Because every surgery cause some unintended injury to the peripheral tissue (collateral damage), and postoperative mobility may weaken muscles, spinal operations may cause a deconditioned spine. Gejo et al.[106] proposed that surgical disruption of the paraspinal muscles caused by stripping the muscle from the laminae resulted in loss of muscular support and contributed to development of the FBSS. Thus, deconditioning may contribute to the surgery/degeneration related reasons of FBSS. These include *recurrent disc herniation, epidural fibrosis, arachnoiditis, and infection.* Unlike the first two group of FBSS reasons (indication or surgical-technique related), these may be unavoidable reasons of FBSS, although the surgery can be modified somehow to decrease risk of their occurrence. *Recurrent disc herniation* and *infection* will not be detailed here, because they have been mentioned under their respective subheadings.

### Epidural Fibrosis

The formation of a scar tissue adjacent to the dura matter may be an unavoidable consequence of any procedure which requires entering into the epidural space. Thus, certain amount of epidural fibrosis can be accepted as a normal response of the body to surgery. The reported incidence of epidural fibrosis ranges from 10 to 75 percent.[107-110] The formation of this scarring is thought to be the result of the invasion of the postoperative hematoma by dense fibrotic tissue. This fibrotic tissue originates from the fibrous layer of the periosteum and the paravertebral musculature.[111] This scarring is clinically silent in most patients. Coskun et al.[112] reported no relationship between the occurrence of epidural fibrosis and unfavorable postoperative pain and disability scores. However, the problem may arise when this scarring prominently extend into the neural canal and adhere to the dura mater and nerve roots. In some patients, the mechanical tethering of the dura and nerve roots by the epidural adhesions may contribute to persistent back and leg pain following lumbar laminectomy, the so-called "postlaminectomy syndrome."

The exact factors causing development of severe and symptomatic epidural fibrosis has not been established. As a fibrogenic stimulus, persisting cotton debris from sponges,[113] and dust from the lower quality surgical tools[112] used during surgery were blamed. Cabukoglu et al. studied the effect of postlaminectomy lumbar column sagittal plane deformity on postlaminectomy epidural fibrosis formation in a rat model and identified kyphosis and consequent traction of the lumbar spine as a risk factor for increased epidural fibrosis.[114] The authors postulated that establishment of lordosis and relaxation of the lumbar spine may decrease the scar formation. There should be many host- and procedure-related factors affecting the risk of occurrence and amount of epidural fibrosis after surgery.

Although the exact role of epidural fibrosis on occurrence of FBSS is debatable,[115] it has been well documented that it significantly increases the hazards of revision surgery, in particular, the increased risk of dural tears, root injury, and bleeding.[116] Epidural fibrosis also causes difficulty in the management of FBSS because its differentiation from recurrent/residual disc herniations may be problematic. Therefore, prevention of epidural fibrosis is an important area of research. To limit the formation of scarring, modifications of surgical technique, some medications, and the use of biologic or synthetic tissues, serving as a mechanical barrier between dura and overlying tissue, have been employed.[117-121] While their use in animal models demonstrated some success, the clinical success is limited.

### Arachnoiditis

Arachnoiditis (adhesive arachnoiditis) means inflammation of the arachnoid membrane. When this inflammation is severe enough, it leads to the formation of scar tissue and adhesions which can cause clumping the nerve roots and vessels of the cauda equina. It is a debilitating condition characterized by severe burning or sharp pain and neurological deficits.

Arachnoiditis may be caused by adverse reactions to chemicals, infection, spinal trauma, surgery, and chronic compression of spinal nerves. Its true incidence after lumbar spine surgery and clinical importance is not known. Fit and Stevens reported that 4.6 percent of patients develop lumbar adhesive arachnoiditis radiologically after lumbar disc surgery.[122] Clinical importance of this finding is not fully acknowledged. As with epidural fibrosis, arachnoiditis is held responsible for FBSS, without strong evidence. The diagnoses of epidural fibrosis and arachnoiditis are generally made when other causes of FBSS are excluded and radiological findings of these conditions are detected.

For treatment, pain medications, physical therapy, or spinal cord stimulation are employed to control the pain. Although some release procedures has been tried, surgery is not recommended for arachnoiditis because there is further risk of more scar tissue after intervention.

## Conclusion

Surgery for lumbar disc herniation has nearly 80 years of history, and showed significant evolution in this period. Surgical results can only be improved by use of better patient selection criteria, meticulous surgery, and preventing complications. Although lumbar disc surgery is generally considered as a benign and safe procedure, many complications are possible, including catastrophic ones. Complications of lumbar disc surgery heavily depend on the patient's characteristics, the surgical methods/technology used, and the surgeon's expertise. This chapter outlined the most significant complications of lumbar disc surgery.

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Section

7

# Follow-up

## Section Outline

# 47

# Short-term Results of Microlumbar Discectomy for Herniated Lumbar Intervertebral Disc

*Sumeet Pawar, Adil Chagla, PS Ramani*

## Introduction

In 1974, Caspar[1] developed a microsurgical technique for prolapsed lumbar discectomy. Yasargil[2] and Williams[3] independently and without the knowledge of each other's work reported on microlumbar discectomy procedure. Past decade has seen the emergence of less invasive surgical procedures. The surgical microscope with its high intensity light source and varied magnification has provided more accurate interpretation of pathological anatomy.

The surgical procedure of microlumbar discectomy is the procedure of choice for a given case of posterolateral lumbar disc prolapse. The technique involves minimum retraction and disruption of tissues causing minimum discomfort to the patient. The herniated disc material causing nerve root compression is removed in minimum time with hardly any blood loss (less than 25 cc.) and without significant operative complications. The technique can be easily mastered once the surgeon has familiarized himself with basic microsurgical technique.

## Material and Methods

Two hundred and fifty consecutive patients of posterolateral lumbar disc herniation operated upon by minimally invasive micro-operative technique by the senior author over a period of four and half years from January 1990 till May 1994 have been used to evaluate short-term (one year) follow-up results.

### Criteria for Selection (Figs 47.1A to D)

1. Patients presenting with sciatica without neurological deficit not responding to treatment with conservative methods within a reasonable period of 6 months.
2. Younger patients were operated even earlier, after three months of conservative treatment.
3. Typical root pain with neurological deficit suggestive of involvement of nerve root.

Age was not considered as a limitation for surgery. The youngest patient operated upon was a male 13 years old table-tennis champion in his school and the oldest patient was 78 years female with severe left sided L4 root pain due to posterolateral L3/4 disc prolapse. The overall age incidence of patients considered for microlumbar discectomy has been described in Table 47.1.

Majority of the patients were in the age group between 21 and 50 years (213 = 85.2%). This is in accordance with the overall incidence of lumbar disc prolapse. The incidence of prolapsed lumbar intervertebral disc is more common in males. In this series, 170 (68%) were males and 80 (32%) were females.

### Division of Patients (Based on Criteria for Selection)

Two hundred and fifty patients have been divided into five groups:

**Group I (60 patients = 24%) No. definite neurological deficit:** Conservative treatment had failed and they were relieved of the

This follow-up was carried out while Prof PS Ramani worked at LTM Medical College and Hospital in 1994. Even today, this procedure is considered as gold standard to compare other minimally invasive surgical techniques


**Figs 47.1A to D:** Posterior lumbar lateral disc prolapse ideal for microlumbar discectomy

**Table 47.1:** Age incidence

| Age group | No. of patients | Percentage |
|---|---|---|
| 0-10 years | | |
| 11-20 years | 15 | 6 % |
| 21-30 years | 66 | 26.4% |
| 31-40 years | 80 | 32% |
| 41-50 years | 67 | 26.8% |
| 51-60 years | 14 | 5.6% |
| 61-70 years | 6 | 2.4 % |
| 71-80 years | 2 | 0.8 % |

pain by doing microlumbar discectomy. The pattern of prolapsed disc has been outlined in Table 47.2. Six patients requiring bilateral microlumbar discectomy were operated upon through a midline incision over the spinous processes. The incidence of prolapsed disc requiring surgery but without neurological deficit is more common at L4/5 level. Table 47.2 below gives the pattern of disc herniation in this group of 60 patients.

**Table 47.2:** Group I patients

| Pattern of prolapsed disc in patients with backache and sciatica without neurological deficits | Total no. of patients (60) |
|---|---|
| Lateral disc protrusion L4-5 | 41 |
| Medial disc protrusion L4-5 | 6 |
| Disc protrusion at L4-5 and L5-S1 | 4 |
| Lateral disc protrusion L5-S1 | 9 |

**Group II (98 patients = 30.2%) 5th lumbar disc prolapse:** This group presented with depressed or absent ankle jerk with or without wasting and weakness in the calf muscles. Fifteen patients (15) have been operated at two levels unilaterally with purely neurological signs of S1 root compression but MRI showing significant 4th lumbar disc prolapse along with 5th disc prolapse.

**Group III (70 patients = 28%) 4th lumbar disc prolapse:** There were seventy patients in this group (28%). L4/5 is the most common level to be operated upon. All patients were operated at a single level except two cases. They presented either with weakness in extensor hallucis longus (most common) or weakness in tibialis anterior (less common) or with numbness with appreciable sensory loss in the region of great toe (least common). Six cases presented with associated depressed ankle jerk and they have been grouped separately. Six patients operated upon bilaterally have been at the level of L4 to L5.

**Group IV (7 patients= 2.8%) 3rd lumbar disc prolapse:** There were seven patients in this group (2.8%). They presented with severe and typical root pain with depressed or absent knee jerk and with or without weakness and wasting in the quadriceps muscles. All the seven patients were operated upon at one level unilaterally. The oldest patient being a 78 years old female with severe root pain on the left side. Four out of seven patients were elderly above the age of sixty. They had bearable backache in the past. X-ray and definitive investigations showed spondylotic changes which were more widespread. However, more recently (within a year) they were getting severe shooting unbearable root pain. They were operated only for the root pain without considering their problems of backache and they were satisfied with the procedure. The incidence of 3rd lumbar disc prolapse is higher in patients with advancing age.

**Group V (15 patients = 6%) Table 47.3 Multiple levels disc prolapse:** They had unilateral sciatica. Definitive investigation (MRI studies of the lumbar spine in all cases) showed two level discs. All have been operated upon at two levels. Two patients with signs suggestive of L5 root compression have been included in Group III. Seven patients with signs suggestive of S1 root compression have been included in Group II. Of the six patients with two level unilateral disc prolapse the signs of compression of two roots were present in two patients while four patients presented with sciatica without any neurological deficit, these four patients were young of which three were females. All the 15 patients in this group have been operated upon at two levels. In six patients with two root signs the procedure is justified, however, in the remaining nine patients with one root involvement operated at two levels based on MRI findings the decision to operate may be questioned.

**Table 47.3:** Unilateral sciatica with two consecutive disc prolapses

| | Group V | |
|---|---|---|
| 1. | Patients presenting with L5 root compression | 2 |
| 2. | Patients presenting with S1 root compression | 7 |
| 3. | Patients presenting with compression of both roots | 2 |
| 4. | Patients presenting with backache/sciatica, no neurological deficit | 4 |
| | **Total** | **15** |

N.B. : All the 15 patients have been operated upon at both levels on one side.

### Pattern of Patients Selected for Microlumbar Discectomy

In this series L4/5 was the most commonly operated level (46%) followed by L5/S1 level (42.8%). In all, 271 disc spaces in 250 patients were explored. In six patients, the same level was explored from both sides as patient had pain in both legs. All the six patients were at L4/5 level. However, not a single patient at L5/S1 level was explored bilaterally in this series. Fifteen patients were operated at two consecutive levels on one side being L4/5 and L5/S1. Of the fifteen patients, nine had signs of one nerve root compression but two discs as seen on MRI were removed. Patients generally are extremely worried to undergo surgery a second time. This decision was taken in an attempt not to submit the patient for a second surgery in case symptoms developed in future from the asymptomatic disc prolapse after discussing the issue with the patient and his relatives. Similarly, in this series, four patients were operated upon because the pain in the legs had persisted in spite of conservative treatment. In such situations, we have excised both the prolapsed discs as seen on MRI. A definite pattern seemed to evolve when the level of disc prolapse was analyzed in relation to age. Fifth lumbar disc prolapse was most common in younger age group. Fourth lumbar disc prolapse was common in middle age group and third lumbar disc prolapse was common in older age group. It is possible that in young people, the whole spine is elastic and the maximum stress is at L5/S1 level. Changes of arthritis developing with advancing age possibly produces stiffness and ankylosis at the level of maximum stress and then the maximum load bearing force shifts upwards to L4/5 level and with further advancing age higher levels are subsequently affected.

### Radiological Criteria

Most cases were investigated with survey radiographs followed by MRI Studies of the lumbar spine. T2-weighted images are more impressive as they look similar to the myelogram.

## Operative Technique

In our department, we use Carl Zeiss Pentero operating microscope (Fig. 47.2).

The table is kept horizontal and the patient is positioned on two bolsters 26 inches in circumference. The leg end of the table is then bent to flex the legs by 45 degrees both at hip and knee joints. Pillows are used to support the feet and rings are kept under knee joints. An indwelling urinary catheter is not used. Kidney bridge is not used to avoid pressure on the abdomen and venous congestion.

**Fig. 47.2:** Carl Zeiss OPMI Pentero operating microscope

Skin incision is one inch (25 mm) long taken paramedially curvilinear 1.5 cm away from midline. The incision should be exactly between the spinous processes of L5 and SI for 5th lumbar disc prolapse. The 1/2 inch of incision should be in the upper part of L4/5 interspace and the remaining half should be over the lamina of L4 for 4th lumbar disc prolapse. The incision should be parallel to the spinous process of L3 vertebra for 3rd lumbar disc prolapse. The variable placement of the incision is in keeping with the obliquity of the laminae of the lumbar spine from below upwards. The correct level should always be checked with an check X-ray or image intensifier. The paravertebral fascia is then incised along the line of incision. The medial flap is reflected up to the midline and retracted with two stay sutures. The paravertebral muscles are separated from the spinous processes and the lamina using electrocautery.

The microlumbar retractor (Fig. 47.3) consists of two types of blades (Dr PS Ramani).

**Fig. 47.3:** Microlumbar retractor designed by the senior author

The medial blade is a hook which is anchored between the spinous processes on the interspinous ligament. The lateral one is a blade and it is positioned against the reflected paraspinal muscles. The retractor has a ratchet and it can retract the muscles forcefully. Using a No. 11 blade with its cutting edge directed upwards the ligamentum flavum is incised vertically into medial and lateral halves. The lateral half of the ligamentum flavum is excised in one piece and preserved to be replaced in the window after discectomy. No portion of lamina is removed in this procedure. However at L3/4 level, the undersurface of the junction of lamina with the facet may need to be undercut to expose the prolapsed disc. The epidural fat is exposed and excised using bipolar coagulation and microscissors. The root is then exposed. It is a tubular structure and appears glistening white under the microscope with blood vessels of the root running over it.

Usually, the root is displaced medially by the prolapsed disc. Meticulous hemostasis of the epidural blood vessels under vision is carried with bipolar coagulation and cut with microscissors. The prolapsed intervertebral disc is exposed. We prefer to use two small cottonoids on either side of the disc to retract the root. This technique helps to retract the root satisfactorily leaving the left hand of the surgeon free. Very occasionally a no.4 dissector may be used intermittently for retraction. The prolapsed disc looks glistening white and fibrous under magnification if the posterior longitudinal ligament is intact. It looks white but not fibrous and may not be glistening if it is sequestrated. Around 5 mm long horizontal incision is made in the posterior longitudinal ligament parallel to the rims of the vertebral bodies. The prolapsed disc is then removed using microlumbar discoidectomy forceps. The disc is removed piecemeal meticulously with patience. The policy is to remove a little more disc tissue from the disc space after the prolapsed portion has been removed. The disc space is not curetted. Once the discectomy is completed, the root is checked to be lying free. Hemostatic material or minivac drain is not used. The piece of ligamentum flavum excised earlier is replaced back in the window. Muscles are not sutured back. The fascia is approximated with three interrupted sutures; four interrupted subcutaneous sutures are used and the skin edges are approximated with subcuticular monocryl. The monocryl is pulled out on the sixth day (Fig. 47.4).

**Fig. 47.4:** Microlumbar discectomy in progress


**Figs 47.5A and B:** (A) Patient of acute disc prolapse; (B) Six hours following microlumbar discectomy

## Postoperative Management

Four doses of antibiotics (Inj. cefotaxime sodium 1 gm IV) are administered. One dose is given prior to surgery and three doses after surgery at 12 hourly interval. Oral medication with tablets consisting of a combination of ibuprofen and paracetamol (one three times a day) is administered for two weeks.

Patient is allowed to get out of bed and walk up to the toilet on the day of the operation (Figs 47.5A and B). He moves about in the ward on the first postoperative day and is discharged home on the second postoperative day. He is not allowed to ride a two-wheeler or drive a car for three weeks. The patient is taught a set of exercises to carry out at home with the intention to keep the back strong and mobile without any stiffness or restriction of lumbar spinal movements. Lumbosacral belt is not used.

## Complications

There were no significant complications in this series. Possible complications in this procedure are wound infection, discitis, dural tear and CSF leak, and neurological deficit due to damage to root during the procedure either directly or by retraction. It is understandable if there were no serious complications in this series. The whole ligamentum flavum is not removed. Only the lateral half covering the root is removed. Much of the dural sac is not exposed. Generally, the CSF leak occurs inadvertently while excising the ligamentum flavum with a knife. Secondly dural tears can occur at the time of manipulation of nerve root in the presence of fibrosis. Usually the tear is at the junction of root sleeve with the dural sac. Rarely, one encounters a tear over the dura of the root which need meticulous closure.

There was no infection in this series although we have accepted 2 percent infection in standard laminectomy. Silvers (1988) had 0.7 percent infection in his series of 270 cases. Williams[3] and Yasargil[2] do not enter the disc space at all. Silver's and our technique involved entering the disc space for what can be called subtotal discectomy. A little more portion of the disc tissue is removed from the disc space. The whole nucleus pulposus is never removed. Curettes are not used in this procedures at any time. Disc tissue is removed only with micro disc forceps. This series and Williams[3] did not have disc space infection and Silvers[4] had just one patient who had developed some disc space infection whereas Wilson[5] has reported 2.3 percent disc space infection. It is not clear from his technique if he used the curette or not. Our disc space infection rate of standard laminectomy is 1 percent.

Our technique of retraction of the root is as follows. Two cottonoids or two pieces of surgical are used one above and one below lateral to the root to retract it medially. This is quite adequate. No other retractor is used. At the most during discoidectomy sometimes the root needs to be gently retracted medially using No.4 dissector intermittently. The retraction is not maintained all the time.

## Recurrence

Six patients (2.4%) from this series of 250 patients required to be reoperated. Two patients did not leave the hospital after first operation. They complained of the same pain as before. They were re-explored after waiting for six days. In one case, the wrong level was operated. He was operated one level above the pathological disc. The second patient, the level was correct but adequate disc tissue was not removed. The disc tissue had sequestrated and was compressing the root tightly in the foramen. It was missed during the first surgical procedure. One patient, a 45-year-old diabetic male was quite all right after the surgery and was able to drive his car and travel long distances within Maharashtra in pursuit of his business. He got severe backache while in Pune, admitted locally and operated. X-ray of the lumbar spine revealed that he underwent a laminectomy. This case has also been included in our recurrences. The 4th patient came after three years with recurrence of same pain. Following MRI studies he was explored. There was no disc prolapse but calcification had developed in the posterior longitudinal ligament at the site of the previous surgery exactly over the disc space causing bulge like prolapsed disc. The calcification was excised using 3 mm osteotome. Two patients were operated again at the same level, one after 11 months and one after one year and ten months. Besides the above mentioned cases, no patient of microlumbar discectomy has required disc surgery subsequently in this series. One rather overweight 36 years female presented with pain on the right side suggestive of right L5 root compression. She had earlier undergone left L5 microlumbar discectomy.

# Results

Early results were assessed at the end of one year. VAS, Oswestry disability score and overall satisfaction of the patient were used as parameters to assess the results. The details of these criteria are discussed in our chapter on long-term results of microlumbar discectomy published in this text book. Overall, 96 percent of the patients were satisfied with the procedure and had returned back to their original work within 3 weeks after surgery. Within 2 months, eligible patients had engaged in sports activities like swimming, jogging, climbing, playing table tennis, badminton, athletics and were able to lift heavy weight exceeding 30 kg. None fitted into the category of poor result in this series.

## Discussion

Microlumbar discectomy is a less invasive, less painful and more specific procedure giving maximum comfort to the patient. The operation is like hitting a target in the dart game.[3] The idea is to relieve the compression on the root and relieve the patient of sciatic pain along with relief of neurological deficit if any.

Microlumbar discectomy is not the answer for all prolapsed discs requiring surgery. The criteria for selection have to be rigid for best results with this procedure. Posterolateral disc prolapse causing only a root cut out on the myelogram is the best case for microlumbar discectomy. Younger the patient, more likely that he will have only sciatic pain due to prolapsed disc. Such patients should be encouraged to get the operation done early so that within a very short period he can go back to his games instead of spending time in conservative approach. This rationale of thinking comes from the fact that the procedures itself is less invasive with minimum discomfort to the patient.

We operate upon a large number of patients between the age of 51 to 65 years for prolapsed lumbar discs. Backache and sciatica is common at this age. However, there is a sharp decline in a number of cases subjected to microlumbar discectomy at this age group. In our series, there were only 19 patients out of 250 in this age group. Most of them are managed by alternative methods. At this age hour glass deformity on myelograms due to facet hypertrophy,[2] lateral recess stenosis at one or multiple levels is common.

Taking away adequate portion of laminae and a part of the medial portion of facet and then doing a good discectomy with the help of magnification from operating microscope is a modification of interlaminar approach and does not constitute microlumbar discectomy. In the later procedure no bone is touched except at the level of L3/4 where the undersurface of the junction of lamina with facet need to be undercut.

The hospital stay in microlumbar discectomy is extremely short. The patient should be able to resume most of the duties within two weeks. Patients doing hard work are advised not to resume duties for three to four weeks.[5]

There was no case of dural tear or infection in this series. In the operative procedure, only the nerve root is exposed. Dural tear usually occurs at the junction of dural sleeve with theca. Bright illumination and magnification allows meticulous haemostasis. Not much part of the disc space is entered in this procedure. Wilson[5] has reported discitis in 2.3 percent of cases in his series. Williams[3] does not enter the disc space and hence there is no question of discitis but Silvers[4] using similar technique had one case of discitis in his series of 270 cases. The pathogenesis of discitis is uncertain. Teng[6] felt that discitis is caused by surgical trauma to the cartilaginous endplate. It is not uncommon for a piece of bone to be curetted while curetting out the disc, if the procedure is done too vigorously.[7,8] The piece of bone is in fact a piece of bony end plate with a portion of bone on its vertebral surface. It is our experience that discitis occurs when a portion of bony end plate is inadvertently curetted out during discectomy. There was no case of discitis in this series.

The short exposure in this procedure causes minimum trauma, minimum dissection and minimum manipulation goes a long way making postoperative period comfortable and thus increasing the confidence of patients in such procedures.

The lateral portion of the ligamentum flavum which is earlier excised in one piece is preserved. This piece is replaced back in the window at the end of the procedure. The laser can be run along its edges to stick it together if felt necessary or one can put a few 5/0 sutures (three) to hold the piece in position and assure that it is not displaced. It is not a tissue with a vascular pedicle, however, the cells will survive and have potential for regrowth. Its undersurface, which comes in close contact with the root, is smooth and may prevent fibrosis around the nerve root.

One point in operative technique needs to be stressed. The operating table is kept horizontal without even creating kidney bridge. The patient is positioned prone on the operating table. We find it convenient to turn the table sideways by 15 degrees toward operator so that the lateral recess containing the prolapse disc is better visualized. This point has not been mentioned in the literature.

### Recurrence

Six patients from this series have been operated upon again for prolapsed disc giving a recurrence rate of 2.4 percent, of the six patients two patients were not true recurrence as in one there was technical error of missing the correct level and in the other patient, a piece of disc compressing the root in the foramen was missed. Four patients (1.6%) had truly recurred to need re-exploration. Our technique involves subtotal disc excision. Williams[3] who removes only the protruded portion without even opening the posterior longitudinal ligament. (He makes a hole in the ligament and widens the hole with No.4 with the idea that the fibers are stretched but not cut so that once the procedure is over, the fibers will come together and the hole will seal again naturally) had a recurrence rate of 9 percent requiring a repeat surgery at the same level in his earlier series. This high recurrence rate is related to the technique of removing only the protruded portion. Silvers[4] who also uses the same technique as used in this series has had 3.3 percent recurrent rate and Wilson[5] has 4 percent recurrent rate. It can be concluded from these figures that recurrence of the same disc prolapse can occur but its incidence should be kept low by using proper techniques and it should be kept below 5 percent. The technique of subtotal excision of the disc appears rational rather than excising only the protruded fragment. It is just possible that other loose fragments lying underneath may subsequently cause root compression and become symptomatic.

Williams[3] does not excise epidural fat. He feels this is very important to protect the nerve root. Our technique is slightly different. The root and the prolapsed disc should be properly visualized since one is using high magnification. It is necessary that all the epidural fat coming in the way is meticulously excised. There is no clinical indication in our series that fibrosis has occurred or there has been recurrence due to fibrosis due to lack of fat around the nerve root.

## Conclusion

The operative technique of microlumbar discectomy is designed to minimize to the minimum the alterations in the architecture of the lumbar spine. The incision is small. Paravertebral muscle dissection is minimum and no trauma is inflicted on laminae or facets. The operative procedure is short, postoperative recovery more quick, the patient leaves the hospital early and the overall results are much superior in comparison to standard laminectomy. All these facts make microlumbar discectomy the procedure of choice for selected patients of lumbar disc herniation.

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# Long-term Follow-up of Surgical Patients of Microlumbar Discectomy

*PS Ramani, Shradha Maheshwari, Sudhendoo Babhulkar, Sumeet Pawar*

## Introduction

Microlumbar discectomy was first described independently by Yasargil[1] and Caspar[2] in the same year 1977 for herniated lumbar intervertebral disc. Since then, this procedure has been accepted worldwide as the standard treatment for a given case of prolapsed lumbar intervertebral disc. Since 1985 we have adopted this procedure to treat patients with prolapsed disc. With 3D magnified and well illuminated image in the operative field enables the surgeon to use a much smaller incision causing least morbidity to the patient resulting in shorter stay in the hospital (Table 48.1), early return to work and definitely better outcomes in comparison with the procedure originally described by Mixter and Barr.[3] The procedure is much superior to macrosurgery.[4-6]

**Table 48.1:** Comparative analysis of hospital stay

| Hospital stay | Present series (2008) | Ramani series (1996) | Gold series (1978) | Gold series (1980) | William series (1978) |
|---|---|---|---|---|---|
| Days (mean) | 2 | 2 | 3 | 3 | 3.1 |

Our early results of microlumbar discectomy[7] have been good. In the present study we have retrospectively reviewed long-term results (more than 5 years and up to 11 years) of our patients. All patients were operated upon by one surgeon using the same technique under ideal conditions in the operating theater in one hospital.

## Methodology

This is a correspondence analysis and it includes salient features like patient's personal information and habits, duration of symptoms before surgery, their occupation and the outcome after surgery and their functional and economic status at the time of evaluation. The data was statistically analyzed using software "Epi Info, version 3.5.1 (CDC, Atlanta, USA).

## Material

Over a period of 6 years from 1998 to 2004, 221 cases were operated upon in this department by the single senior surgeon. The form (questionnaire) was posted to the patients. Twenty-seven forms were returned back to us probably due to change in residence. 146 patients responded to our questionnaire equivalent to 75.25 percent response.

We have used following criteria before selecting the patient for surgery:

### Inclusion Criteria

i. Clinically determined sciatic pain
ii. Persistent pain despite conservative management for at least six weeks
iii. Neurological deficit
iv. Cauda equina syndrome
v. Positive imaging study for herniated disc, i.e. MRI.

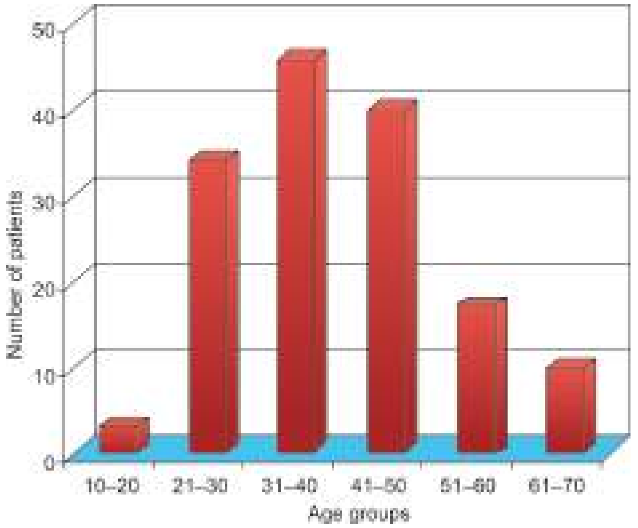


**Fig. 48.1:** Age distribution of patients

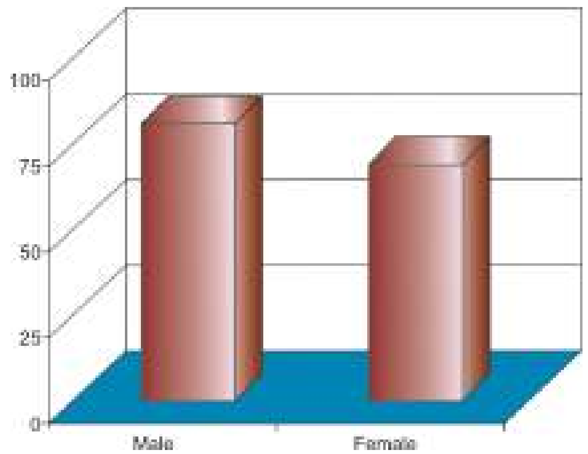


**Fig. 48.2:** Sex distribution of patients

## Exclusion Criteria

i. Patients with failed back surgery syndrome
ii. Psychosocial disorders.

### *Clinical Data Obtained from Patient's Records in the Hospital*

The patients operated upon were in the age group ranging from 23 to 83 years (Fig. 48.1). Of the 146 responses that were received by us, 94 were male patients and 52 were females (Figs 48.2 and 48.3). The duration of symptoms (Tables 48.2 to 48.5) ranged from 0.25 to 108 months.

Ninety-five percent confidence limit for sciatica was present in 91.1 percent of the patients (85.3–95.2).

On few occasions, we have operated two level disc prolapses which were at different levels mostly at L4/5 and L2/3 but in this series there was none with different levels.

All patients with two levels, the disc prolapse was ipsilateral.

**Table 48.2:** Lateralization of sciatica

| | | |
|---|---|---|
| Right lateralization | 43 | 29.4% |
| Left lateralization | 76 | 52.05% |
| Both lateralization | 14 | 9.59% |
| No true sciatica | 13 | 8.9% |

**Table 48.3:** Level of disc prolapse (single), n = 135

| Single level | L5-S1 | L4-L5 | L3-L4 | L2-L3 |
|---|---|---|---|---|
| Protrusion posterolateral | 37 | 20 | 4 | 1 |
| Sequestrated | 13 | 18 | 0 | 0 |
| Central bulge | 5 | 11 | 1 | 0 |
| Bulge diffuse | 8 | 7 | 0 | 0 |
| Far lateral | 1 | 9 | 0 | 0 |
| Number of patients | 64 | 65 | 5 | 1 |
| Percentage | 47.40% | 48.15% | 3.7% | 0.74% |

**Table 48.4:** Level of disc prolapse (double), n = 11

| Levels | L5-S1, L4-5 | L4-5, L3-4 | L3-4, L2-3 |
|---|---|---|---|
| Number of patients | 10 | 1 | 0 |
| Percentage | 90.90% | 9.1% | 0 |

**Table 48.5:** Motor power involvement

| Motor | Number of patients | Percentage |
|---|---|---|
| Normal | 106 | 72.6% |
| Grade IV | 30 | 20.5% |
| Grade III | 03 | 2.05% |
| Grade II | 7 | 4.8% |

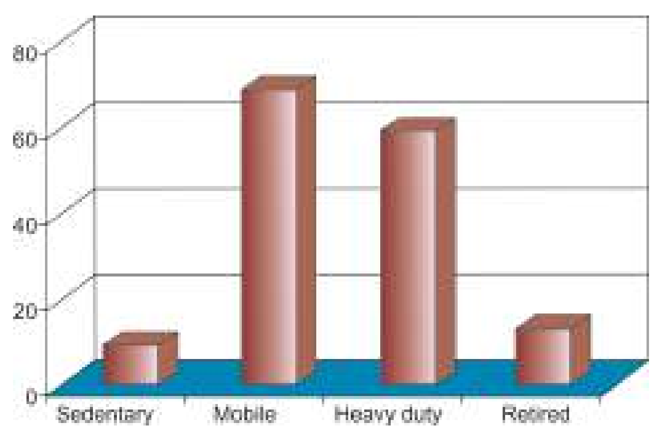


**Fig. 48.3:** Graph showing type of work

Statistically, 95 percent confidence limit of patients without motor loss was 72.6 percent (64.6–79.7%).

At times, we see a patient with foot drop with 0/5 power in TA and EHL, but in this series, there was no patient with such motor power recording.

### Clinical Data Obtained from the Questionnaire

Mean age was 48.30 years with a standard deviation (SD) of 13.25.

Ninety-five percent confidence limit for females varied from 27.9 to 44.0 percent and for males from 56.0 to 72.1 percent.

## Patients Seen with Recurrent Disc Prolapse

In this series, we have included 14 patients who were operated upon elsewhere but their symptoms had not improved and required surgery at the same level.

There were 9 cases in this series that required to be operated upon again, giving a recurrence rate of 6.16 percent. The age ranged from 40 to 83 years and 5/9 were above the age of 60 years. Six were male patients and three females. Eight out of nine have improved after second surgery and one patient who has been included in the unsatisfactory group is relieved of sciatic pain but complains of back pain.

At the time of long-term follow-up, 6/9 patients continue to remain asymptomatic, 2 patients take occasional analgesics and 1 patient requires regular analgesics.

Only 1 smoked, 3 patients had diabetes, 1 diabetic patient had hypertension and 1 nondiabetic, nonhypertensive patient had arthritis and IHD indicating that associated factors, including age did not have any influence on the recurrence. Similarly, profession also did not seem to influence the recurrence as 3 were housewives, 3 sedentary workers and remaining 3 mobile by profession. None was involved in heavy work indicating that the nature of profession did not influence the recurrence. However, 6/9 patients had presented with bilateral leg pain as against unilateral pain in the first instance, indicating more diffuse bulge of the recurrent disc. All these, 6 patients were subjected to laminectomy rather than microlumbar discectomy according to the protocol in the department.

Functionally, 6/9 patients were normal, 7/9 patients were able to continue in the profession that they were doing before without change in economic status. One patient categorized in the unsatisfactory group, could still pursue his previous occupation in the government office albeit with some restrictions but without loss in economy. These findings indicate that recurrent lumbar disc surgery did not pose any problem to pursue activities as before surgery.

Geographical distribution also did not seem to influence the recurrence as these patients came from north, south, central and western India.

None of these patients were operated upon for adjacent level degeneration.

## Analysis of Data (Tables 48.6 to 48.16)

In this study of 146 patients, the youngest patient was 23 years old and the oldest patient was 89 years old, with a mean age of 48.3 years. There were 94 males (64.4%) and 52 females (35.6%) suggesting a higher prevalence of disc herniation in male patients.

Although smoking has been suggested as a risk factor for prolapsed disc, our series had only 9 patients who were smokers and 14 patients who were tobacco chewers, which was

**Table 48.6:** Age; n = 146

| Age groups | n | Percentage |
|---|---|---|
| 10–20 | 3 | 2 |
| 21–30 | 11 | 07.53 |
| 31–40 | 26 | 17.8 |
| 41–50 | 47 | 32.2 |
| 51–60 | 31 | 21.2 |
| 61–70 | 26 | 17.8 |
| 71–90 | 4 | 2.7 |

**Table 48.7:** Sex distribution

| | | |
|---|---|---|
| Male | 94 | 64.3% |
| Female | 52 | 35.7% |

**Table 48.8:** Duration of symptoms

| | |
|---|---|
| Range | 0.25–108 months |
| Mean | 20.6 months |
| Standard deviation (SD) | 26.29 |

**Table 48.9:** Backpain

| Backache | Frequency | Percentage | Cumulative percentage |
|---|---|---|---|
| No | 132 | 90.4% | 90.4% |
| Yes | 14 | 9.6% | 100% |
| Total | 146 | 100% | 100% |

**Table 48.10:** Motor involvement

| Motor | Frequency | Percent | Cumulative percentage |
|---|---|---|---|
| No | 106 | 72.6% | 72.6% |
| Yes | 40 | 27.4% | 100% |
| Total | 146 | 100% | 100% |

**Table 48.11:** Sensory

| Sensory | Frequency | Percent | Cumulative Percent |
|---|---|---|---|
| No | 85 | 58.2% | 58.2% |
| Yes | 61 | 41.8% | 100% |
| Total | 146 | 100% | 100% |

**Table 48.12:** Type of work

| | | |
|---|---|---|
| Sedentary | 11 | 7.5% |
| Mobile | 103 | 70.55% |
| Heavy duty | 19 | 13.01% |
| Retired | 13 | 8.9% |

**Table 48.13:** Tobacco habits

| Tobacco | Frequency | Percentage | Cumulative percentage |
|---|---|---|---|
| None | 123 | 84.2% | 93.8% |
| Chew | 14 | 9.6% | 9.6% |
| Smoke | 9 | 6.2% | 100% |
| Total | 146 | 100% | 100% |

**Table 48.14:** Associated illness

| Associated illness | Frequency | Percentage | Cumulative percentage |
|---|---|---|---|
| No | 104 | 71.2% | 71.2% |
| Yes | 42 | 28.8% | 100% |
| Total | 146 | 100% | 100% |

**Table 48.15:** Level of surgery

| Level of surgery | Frequency | Percentage | Cumulative percentage |
|---|---|---|---|
| Multi | 11 | 7.5% | 7.5% |
| Single | 135 | 92.5% | 100% |
| Total | 146 | 100% | 100% |

**Table 48.16:** Past surgery

| Past Surgery | Frequency | Percentage | Cumulative percentage |
|---|---|---|---|
| No | 132 | 90.4% | 90.4% |
| Yes | 14 | 9.6% | 100% |
| Total | 146 | 100% | 100% |

statistically not significant. The most common associated illness in our patients was diabetes mellitus followed by hypertension, arthritis and IHD, which were seen in 42 patients.

The duration of symptoms ranged from 0.25 to 108 months, with a mean of 20.6 months with a standard deviation (SD) of 26.3. Fourteen patients had undergone previous surgery.

Of the responses received by us, only 9 patients had undergone repeat surgery (Table 48.17).

**Table 48.17:** Repeat surgery

| Repeat surgery | Frequency | Percentage | Cumulative percentage |
|---|---|---|---|
| No | 137 | 93.8% | 93.8% |
| Yes | 9 | 6.2% | 100% |
| Total | 146 | 100% | 100% |

## Evaluation of Data

*Surgical outcome:* Table 48.18 gives the overall surgical outcome.

**Table 48.18:** Surgical outcome

| Surgical outcome | Frequency | Percentage | Cumulative percentage |
|---|---|---|---|
| Better | 120 | 82.2% | 82.2% |
| Improved | 20 | 13.7% | 95.9% |
| Same | 4 | 2.7% | 98.6% |
| Worse | 2 | 1.4% | 100% |
| Total | 146 | 100% | 100% |

Surgical outcome is evaluated in terms of back pain, sciatic pain, numbness and the motor weakness.

140/146 (95.9%) are relieved of sciatic pain. Four patients did not have significant difference and 2 patients were not happy in the surgical outcome. Both these patients who were not satisfied with the surgical outcome were reoperated. One patient 83-year-old with arthritis and IHD but otherwise in good health was operated upon again as MRI showed persistence of the prolapsed disc causing compression on the nerve root. The other patient without diabetes or hypertension and below the age of 50 years was also re-explored resulting in relief of sciatic pain (Table 48.18).

Of 4 patients who were same, 3 were males and 1 was female. 2 patients (1 male and 1 female) had bilateral nerve root exploration at the same level. Only 1 patient who was a housewife was subjected to repeat surgery with relief of sciatic pain but has to take regular analgesics for back pain while doing the household work. The other 3 patients have returned back to their previous professions and not taking any analgesics, demonstrating the fact that their sciatic pain is not very severe. In spite of the fact that the profession of these 3 patients is in the mobile category.

61 (41.8%) patients had some sensory deficit and 40 (27.4%) patients had motor deficit. 57/61 (93.4%) patients were better with improvement in motor and sensory deficits. In 4 patients there was no significant improvement. Of these 4 patients, 3 patients had numbness and 1 patient had genuine motor deficit. Two patients who complained that they were worse in their outcome had numbness as their preoperative complaint and felt that they were in fact worse after surgery but there was no genuine sensory deficit.

Figure 48.4 shows overall surgical outcome which shows that 92 percent of the patients fall in the excellent and good category.

*Functional status:* This is shown in Table 48.19.

Functionally, 109/146 (74.67%) patients expressed complete recovery, 18 patients (12.3%) with complete recovery had recurrence of low back pain while pursuing their profession. None of these patients were reoperated but had settled with conservative therapy. Interestingly 6/9 patients who underwent resurgery are among the 109 patients. While at active work, they had developed recurrent symptoms, were operated upon and have shown complete recovery once again. 2/9 patients in the category of mild to moderate pain were operated upon again with recurrence 1 patient remains in the unsatisfactory group

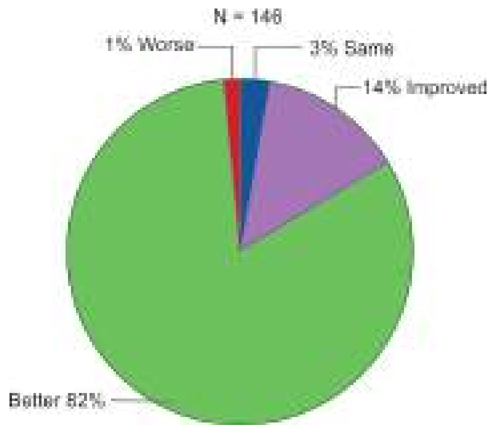


**Fig. 48.4:** Surgical outcome

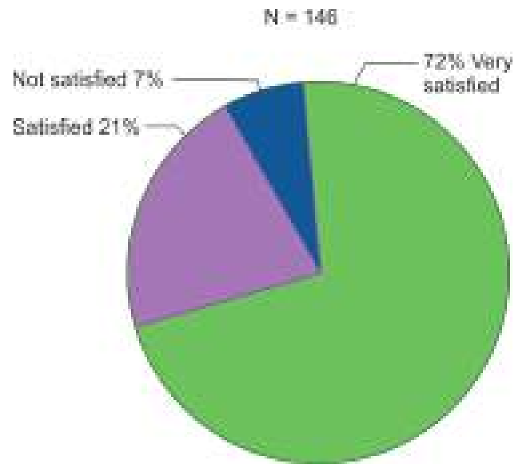


**Fig. 48.5:** Patient satisfaction

and 1 patient is happy with the mild pain. And 1/10 patients in the category of low level of pain underwent resurgery continues to engage in his activities except sports as before.

**Table 48.19:** Functional status

| Functional Status | Frequency | Percentage | Cumulative percentage |
|---|---|---|---|
| Mild-to-moderate pain | 9 | 6.2% | 6.2% |
| Low level of pain | 10 | 6.8% | 13.0% |
| Pursuing same job with restrictions | 18 | 12.3% | 25.3% |
| Complete recovery | 109 | 74.7% | 100% |
| Total | 146 | 100% | 100% |

*Economic outcome:* This is outlined in Table 48.20.

Economically, 133/146 patients (91.1%) have not suffered any economic loss and are able to perform their previous occupation without any restriction. 9/146 patients (6.2%) are still able to pursue their original profession but are not undertaking additional responsibilities.

Overall 97 percent of the patients have not sustained any economic loss as a result of the surgical procedure.

*Overall satisfaction:* This is the most important point of this study and has been outlined in Figure 48.5.

**Table 48.20:** Economic status

| Economic status | Frequency | Percentage | Cumulative percentage |
|---|---|---|---|
| 2 | 2 | 1.4% | 1.4% |
| 3 | 2 | 1.4% | 2.7% |
| Pursue their original profession without overtime | 9 | 6.2% | 8.9% |
| No economic loss | 133 | 91.1% | 100% |
| Total | 146 | 100% | 100% |

Table 48.21 shows patient's satisfaction tabulated in figures.

**Table 48.21:** Patient satisfaction

| Patient satisfaction | Frequency | Percentage | Cumulative percentage |
|---|---|---|---|
| Not satisfied | 10 | 6.8% | 6.8% |
| Satisfied | 31 | 21.2% | 28.1% |
| Very satisfied | 105 | 71.9% | 100% |
| Total | 146 | 100% | 100% |

Overall the long-term follow-up results ranging from 5 to 11 years, show that 136 patients or 93.2 percent patients showed that they are happy to have undergone the surgical procedure of microlumbar discectomy for a given case of prolapsed lumbar intervertebral disc. Rate of satisfaction is slightly less than the short-term results of our earlier study.

Our results compare favorably with the results in other studies.

## Discussion

The assessment of long-term results of surgically treated prolapsed lumbar intervertebral disc patients is not new. Weber[2] had studies the long-term results in details and his results were in keeping with the world literature reviewed by Sprangfort.[8] In fact, the clinical findings were even similar as reported by Laasonen et al.[4] But the publications of Laasonen and Sprangfort are old, much before microlumbar discectomy was evolved. Even the article by Weber was published in 1983 when microlumbar procedure was just being popularized. Weber spoke about macrolumbar discectomy. But the interesting fact about the Weber series is the fact that 26 percent of his patients in the conservative treatment group had to be operated upon for failure of conservative treatment. In today fast moving world, 26 percent is a significantly high number and at the end of one year statistically significant better results were obtained in surgically treated group with 73 percent patients being completely relieved of sciatica. His long-term results even after six years were as good as at one year. At the end of 10 years 62 percent had complete relief from back pain and complete relief from sciatica. His overall improvement results at the end of 10 years were 86 percent. Sixteen percent of patients developed sciatic pain and 18 percent of this group required surgery.

Howe and Frymoyer in the past[9] had studied the long-term results by questionnaire and had found 60 to 97 percent satisfactory results. Questionnaire results depend on the complexity of the questionnaire form. The more complex it is and includes objectivity the results are likely to be showing lower percentage of satisfactory results. Our questionnaire was complex and detailed and had the advantage of background of early results studied in the department in the past.

Prolapsed lumbar intervertebral disc is a common problem and in our department on an average 150 patients are operated upon every year. With such massive number of patients it is extremely difficult to carry out prospective and particularly controlled trial over a 10 years period.

Microlumbar discectomy is minimally invasive, least morbid to the patient who is advised to return to his original work as quickly as possible.

It may be prudent to warn the patient with disc protrusion coming for microlumbar discectomy that this may be the initial episode in an ongoing degenerative process and that further surgery may be required in future.

All the same microlumbar discectomy is a safe surgical procedure. It shortens significantly patient's period of incapacity although it cannot guarantee recurrence of similar episode in the future. Ultimately the long-term outcome cannot be precisely predicted in advance by analyzing the factors which were possibly involved in the prolapse of lumbar intervertebral disc.[1,5,6,10-13] Clear magnified vision under microscope has distinct advantage over macrodiscectomy[13,14] Today, there are several procedures to surgically treat a given patient of prolapsed disc. However patients feel better if the procedure is performed through a limited approach.[14,15] This is in spite of the fact that there are several articles in the literature reporting 70 to 95 percent success rate with macrodiscectomy.[10,11,14,16] However their very long-term results (more than 10 years) have been less successful.[17,18] Today, it is generally believed that 1 and 2 years results are definitely better with microdiscectomy.[3,8,19] One of the reasons for this could be decreased procedure related tissue disturbances. The overall long-term satisfaction in the present study has been 93.2 percent microsurgery group returned to work much quicker.[1,10,16,19] The figures compare favorably with return to work in our study. Requirement of narcotic analgesics is definitely less with microprocedure.

Shorter hospital stay reflects less muscle and soft tissue disturbances, less bone excision and less nerve root handling.[7,16,19] Our series had the shortest hospital stay as shown in Table 48.1.

Infection has not been a problem with us. However some have reported infection when microscope was directly positioned over the wound.[1,9,13] The limited space between wound and the objective of the microscope could be another factor for contamination.[14] The complication rate should not exceed 0.5 percent in this procedure.[9,20-22]

As far as the surgical outcome is concerned 95.7 percent (82% excellent and 13,7% good) are satisfied with the surgery on a long-term basis. Functionally 74.7 percent agree that they have total functional recovery while 12.3 percent agree to pursue the same profession with some reservations. Most satisfying has been the economic status of the patients. In all 91.1 percent confess to no economic loss, 6.2 percent agree to be happy in the same profession without doing any extra duties to gain more money.

Microlumbar procedure is being performed by innumerable surgeons round the world. Several reports are available in the literature concerning evaluation of results. Although the methods of evaluation and follow-up period has varied excellent or good outcome has been obtained in 85 to 92 percent of the patients.[2,4,7,9,10,12,14,16,18,19,23-25] In this study, the long-term overall satisfaction of the patients has been 93.2 percent. Besides early return to work, resumption of recreational activities and competitive games is an added advantage.

## Conclusion

Microlumbar discectomy is a useful surgical procedure, it is minimally invasive with least morbid. Sciatica due to lumbar disc prolapse is a common problem that can greatly compromise the quality of life. Microlumbar discectomy is the most common minimally invasive surgical procedure and it has that is being practised today. It allows the patient to lead a normal life, early return to work, less dependant on analgesics and resumption of recreational activities including competitive games. In this study the procedure has given 93.2 percent long-term overall satisfaction of the patients.

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# Long-term Results of Surgery for Lumbar Disc Herniation

*George Dohrmann, Nassir Mansour*

## Introduction

The most frequent spinal operative procedures performed by neurosurgeons are those operations for lumbar disc herniation. For over seventy-five years operations on lumbar disc herniations have been done, primarily for back pain radiating down the leg and sometimes associated with weakness and sensory deficit. Over the years, the most frequently performed procedure is what is now known as the 'standard open operation,' laminectomy/laminotomy with discectomy. Variations on that procedure are more recent and include a more limited, microscopic approach (microdiscectomy) and an endoscopic approach (microendoscopic discectomy). All of these operations serve to remove the laterally herniated lumbar disc and, thereby, decompress the nerve root(s). The overall results of these operative procedures are good but not as good as the results of operations for cervical disc herniation.[1-3] A question remains as to the long-term follow-up of patients having had operations for lumbar disc herniation and, specifically, the long-term results of standard open discectomy vs. microdiscectomy vs. microendoscopic discectomy.

The purpose of this chapter is to analyze the long-term follow-up of patients having had various operations for lumbar disc herniation and to compare the outcomes.

## Patient Selection

Patients, who had operations for lateral lumbar disc herniation to treat back pain radiating down the leg (with or without motor/sensory symptoms) were selected. The patients further were selected who had follow-up of at least two years postoperatively. Patients with good/excellent results (as per patient/surgeon) were identified.

**Table 49.1:** Location of lumbar disc herniations

| Level | Percentage* |
|---|---|
| L1-2 | 0.2% |
| L2-3 | 0.5% |
| L3-4 | 3.5% |
| L4-5 | 45% |
| L5-S1 | 50% |

* Numbers rounded to nearest tenth of a percent.

## Results

Of patients having been operated upon for lateral lumbar disc herniation and radiculopathy and followed for a minimum of two years, there were 5502 of such patients identified. As expected, 95 percent of the herniations were at the L4-5 and L5-S1 levels (Table 49.1). The mean time of follow-up was 7 years. Good/excellent results were seen in 77 percent of the patients in long-term follow-up (Table 49.2).

There were 1201 patients who had a microdiscectomy for lateral lumbar disc herniation. Mean follow-up was 6.5 years. Eighty percent (80%) of the patients had good/excellent results (Table 49.3).

**Table 49.2:** Long-term results of operations for lumbar disc herniation (5502 patients)

| Authors | No. of patients | Mean follow-up | Good/excellent results |
|---|---|---|---|
| Asch, Lewis, Moreland, et al.[4] | 212 | 2 years | 80% |
| Atlas, Keller, Wu, et al.[5] | 217 | 10 years | 69% |
| Bakhsh[6] | 39 | 10 years | 79% |
| Casal-Moro, Castro-Menendez, Hernandez-Blanco, et al.[7] | 120 | 5 years | 95% |
| Chang, Fu, Liang, et al.[8] | 26 | 3 years | Not given |
| Dewing, Provencher, Riffenburgh, et al.[9] | 183 | 2.1 years | 85% |
| Hsu, McCarthy, Savage, et al.[10] | 226 | 2 years | 82% |
| Jensdottir, Gudmundsson, Hannesson, et al.[11] | 134 | 20.7 years | 91% |
| Liu, Wu, Guo, et al.[12] | 82 | 6.4 years | 84% |
| Loupasis, Stamos, Katonis, et al.[13] | 109 | 12.7 years | 64% |
| Mariconda, Galasso, Secondulfo, et al.[14] | 201 | 27.8 years | 90% |
| Martinez Quinones, Aso, Consolini, et al.[15] | 142 | 5 years | 93% |
| Naylor[16] | 204 | 10–25 years | 79% |
| Nykvist, Hurme, Alaranta, et al.[17] | 197 | 12.9 years | 81% |
| Padua, Padua, Romanini, et al.[18] | 120 | 12.1 years | 77% |
| Parker, Xu, McGirt, et al.[19] | 111 | 3.1 years | 68% |
| Salenius and Laurent[20] | 695 | 6 years | 63% |
| Schoeggl, Reddy and Matula[21] | 672 | 6.3 years | 77% |
| Silverplats, Lind, Zoega, et al.[22] | 140 | 7.3 years | 70% |
| Vik, Zwart, Hulleberg, et al.[23] | 124 | 8.5 years | 81% |
| Weinstein, Lurie, Tosteson, et al.[24] | 245 | 4 years | 84% |
| Wu, Zhuang, Mao, et al.[25] | 1231 | 2.3 years | 77% |
| Yorimitsu, Chiba, Toyama, et al.[26] | 72 | 14.3 years | 87% |
| Total: | 5502 | Mean: 7 years | Mean: 77% |

**Table 49.3:** Microdiscectomy for lumbar disc herniation: long-term results

| Authors | No. of patients | Mean follow-up | Good/excellent results |
|---|---|---|---|
| Asch, Lewis, Moreland, et al.[4] | 212 | 2 years | 80% |
| Dewing, Provencher, Riffenburgh, et al.[9] | 183 | 2.1 years | 85% |
| Jensdottir, Gudmundsson, Hannesson, et al.[11] | 134 | 20.7 years | 91% |
| Schoeggl, Reddy, Matula, et al.[21] | 672 | 6.3 years | 77% |
| Total: | 1201 | Mean: 6.5 years | Mean: 80% |

**Table 49.4:** Microendoscopic discectomy for lumbar disc herniation: long-term results

| Authors | No. of patients | Mean follow-up | Good/excellent results |
|---|---|---|---|
| Casal-Moro, Castro-Menendez, Hernandez-Blanco, et al.[7] | 120 | 5 years | 95% |
| Chang, Fu, Liang, et al.[8] | 26 | 3 years | Not given |
| Liu, Wu, Guo, et al.[12] | 82 | 6.4 years | 84% |
| Wu, Zhuang, Mao, et al.[25] | 873 | 2.4 years | 79% |
| Total: | 1101 | Mean: 3 years | Mean: 81% |

Microendoscopic discectomy for lateral lumbar disc herniation was performed in 1101 patients. The mean follow-up time was 3 years. Grading of outcome as 'good/excellent' occurred in 81 percent of patients (Table 49.4).

In 3200 patients having the standard open discectomy for lateral disc herniation in the lumbar region, the mean time of follow-up was 8.7 years. Results of the operation were good/excellent in 75 percent of patients (Table 49.5).

**Table 49.5:** Standard open discectomy procedure for lumbar disc herniation: long-term results

| Authors | No. of patients | Mean follow-up | Good/excellent results |
|---|---|---|---|
| Atlas, Keller, Wu, et al.[5] | 217 | 10 years | 69% |
| Bakhsh[6] | 39 | 10 years | 79% |
| Hsu, McCarthy, Savage, et al.[10] | 226 | 2 years | 82% |
| Loupasis, Stamos, Katonis, et al.[13] | 109 | 12.7 years | 64% |
| Mariconda, Galasso, Secondulfo, et al.[14] | 201 | 27.8 years | 90% |
| Martinez Quinones, Aso, Consolini, et al.[15] | 142 | 5 years | 93% |
| Naylor[16] | 204 | 10-25 years | 79% |
| Nykvist, Hurme, Alaranta, et al.[17] | 197 | 12.9 years | 81% |
| Padua, Padua, Romanini, et al.[18] | 120 | 12.1 years | 77% |
| Parker, Xu, McGirt, et al.[19] | 111 | 3.1 years | 68% |
| Salenius and Laurent[20] | 695 | 6 years | 63% |
| Silverplats, Lind, Zoega, et al.[22] | 140 | 7.3 years | 70% |
| Vik, Zwart, Hulleberg, et al.[23] | 124 | 8.5 years | 81% |
| Weinstein, Lurie, Tosteson, et al.[24] | 245 | 4 years | 84% |
| Wu, Zhuang, Mao, et al.[25] | 358 | 2.6 years | 72% |
| Yorimitsu, Chiba, Toyama, et al.[26] | 72 | 14.3 years | 87% |
| Total: | 3200 | Mean: 8.7 years | Mean: 75% |

## Discussion

Of all neurosurgical procedures, lumbar discectomy is the one which is most often performed (>250,000/year) and the most frequent spine operation in the United States.[4,5] The main goal of such operations, are two: (1) relief of leg pain and (2) return of the patients to their usual activities.[6]

Success rates generally reported for herniated lumbar disc operations can be divided into two groups as detailed by Asch, et al. 75 to 80 percent and 90 to 95 percent.[4] However, analysis of the latter group shows that these studies usually have shorter periods of follow-up and the series tend to be smaller.

Although it has been reported[5] that surgical patients had better functional status and were more satisfied in 10 years follow-up than nonsurgical patients, the results of operation for lumbar disc herniation were inferior to results of operation for cervical disc herniation. This difference in outcome has been a significant reason for surgeons trying various operative approaches for lateral lumbar disc herniation to see if the outcome could be improved.

In long-term follow-up, the results are interesting in that there was no difference between the results of the standard open procedure, microdiscectomy and microendoscopic discectomy. Using the standard open procedure, the good/excellent results were 75 percent as compared to 80 percent and 81 percent for microdiscectomy and microendoscopic discectomy respectively. There is not a statistically significant difference in these outcomes. All follow-up times were sufficiently 'long-term' (mean: 7 years) and the number of patients was suitably large (over 1000 in each surgical group).

The most important part of each operation is whether the nerve root is decompressed/untethered, not as much with which operative technique it was done. The question still remains as to why the results of operations for lateral cervical disc herniation are markedly better than those for lateral lumbar disc herniation. Certainly, it is not related to the operative approach used to free the nerve root.

Except in emergency situations, lumbar disc herniation should be operated upon when conservative treatment has failed. The results of such operations usually are good but in long-term follow-up, the results as a percentage are in the mid to upper 70s. Results do not seem related to available technology or operative approach. Future efforts must be devoted to determining all the specific reasons that results of operations for lateral cervical disc herniation are better than operations for lateral lumbar disc herniation and then methods devised to further decrease that difference.

## Conclusion

Over 5500 patients were analyzed relative to long-term outcome (mean: 7 years) from operations for lateral lumbar disc herniation with radiculopathy. Patients having had standard open discectomy had 75 percent good/excellent results, microdiscectomy patients had 80 percent good/excellent results and good/excellent results were seen in 81 percent of patients who had microendoscopic discectomy. In summary, when long-term follow-up is studied, there is no statistically significant difference among the results of the three operations for lateral lumbar disc herniation.

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