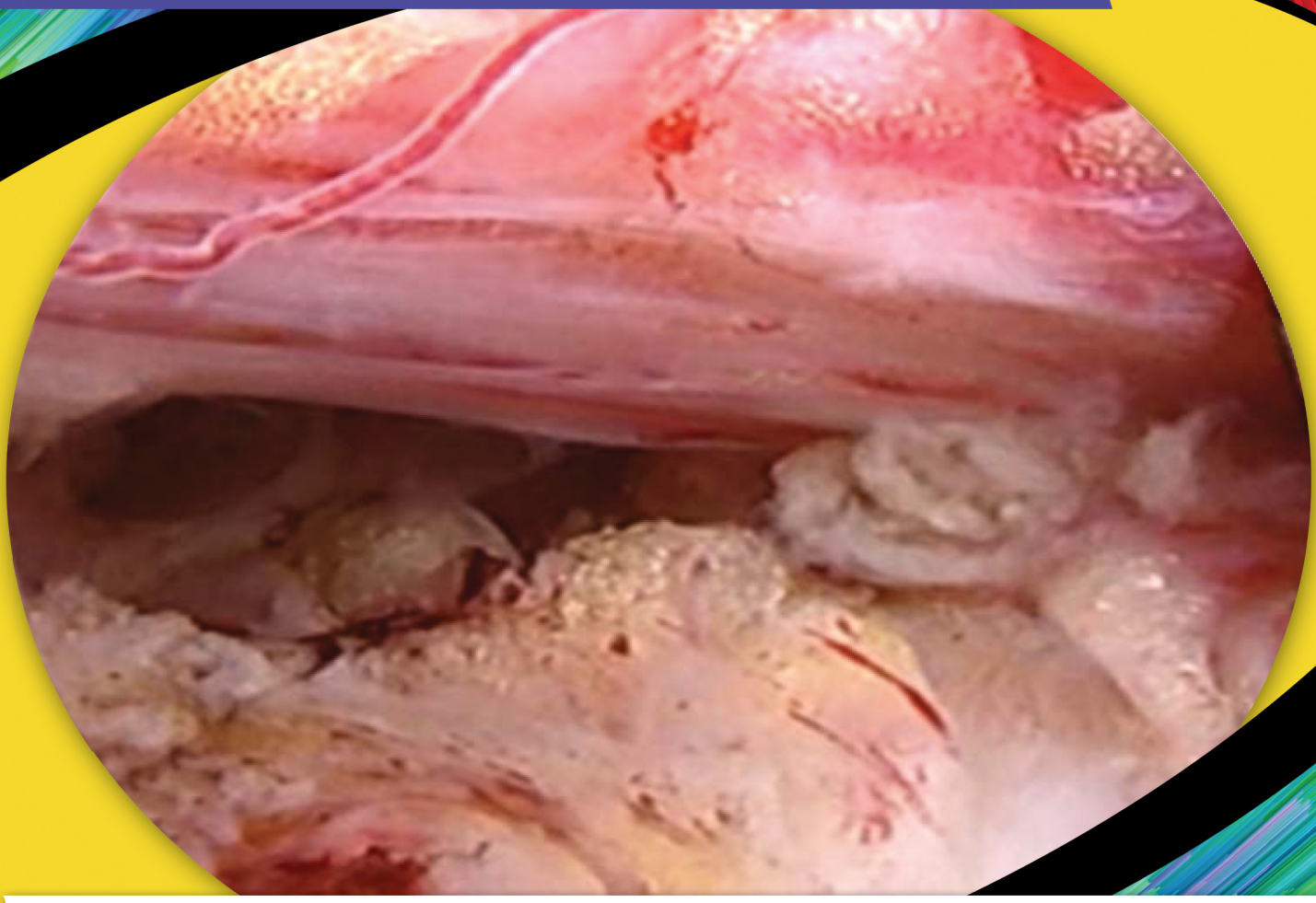
CONTEMPORARY ENDOSCOPIC SPINE SURGERY

VOLUME 2

LUMBAR SPINE



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Bentham Books

Contemporary Endoscopic Spine Surgery

(Volume 2)

Lumbar Spine

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ENDORSEMENTS

ISASS

The International Society for the Advancement of Spine Surgery (ISASS; formerly The Spine Arthroplasty Society) has its roots in motion preservation as an alternative to fusion. Since then, it has worked to achieve its mission of acting as a global, scientific and educational society with a surgeon-centered focus. ISASS was organized to provide an independent venue to discuss and address the issues involved with all aspects of basic and clinical science of motion preservation, stabilization, innovative technologies, MIS procedures, biologics, and other fundamental topics to restore and improve motion and function of the spine. ISASS has a robust international membership of orthopedic and neurosurgery spine surgeons and scientists. ISASS is dedicated to advancing evolutionary and innovative spinal techniques and procedures such as endoscopic spine surgery. Every editor of Contemporary Endoscopic Spine Surgery represents ISASS as a member, author, reviewer, or editor of its quarterly circulation – The International Journal of Spine Surgery (IJSS). The contributors of *Contemporary Endoscopic Spinal Surgery* have succeeded in compiling an exhaustive and up-to-date reference text. It is an example of our society's mission pursuit of surgeon education and scientific study. It is my pleasure to endorse this comprehensive text on behalf of ISASS.

Domagoj Coric
President
International Society for the Advancement of Spine Surgery (ISASS)
Illinois
USA

SBC

Founded on October 12, 1994, the Brazilian Spine Society (Sociedade Brasileira de Coluna - SBC) is a scientific, non-profit organization whose primary objective is the advancement of spine surgery through basic research and clinical study in orthopedics and neurosurgery. SBC is actively engaged in the accreditation and continued education of spine surgeons in Brazil. It prides itself on bringing the latest high-grade scientific evidence on novel technological advances and therapies to its professional members. SBC pursues this mission with its quarterly circulation Coluna/ Columna and its online courses, including Introduction to Endoscopy. The authors and editors of Contemporary Endoscopic Spine Surgery have put forward a comprehensive reference text essential to SBC's core curriculum of teaching spinal endoscopy to the next generation of surgeons. The presented clinical protocols for the endoscopic treatment of cervical and lumbar spine conditions are vetted and validated by peer-reviewed articles published by its contributors. It is my pleasure to endorse Contemporary Endoscopic Spine Surgery on behalf of the Brazilian Spine Society.

Cristiano Magalhães Menezes
President of the Brazilian Spine Society (Sociedade Brasileira de Coluna - SBC)
São Paulo
Brazil

MISS OF COA

The Minimally Invasive Spine Surgery (MISS) of Chinese Orthopaedic Association (COA) was founded in 2003, which is one of the most special subsidiary societies of Chinese Medical Association, aiming to promote and develop minimally invasive orthopedics especially spine surgeries in China.

The MISS society organizes global discussions and encourages our members to participate international efforts and cooperation to improve surgeon education. With this mission in mind, it is my pleasure to endorse Contemporary Endoscopic Spine Surgery on behalf of the MISS of COA. Many international editors and contributors are from China, who have made great efforts, contributions and dedications to this book. They share with and update readers all over the world about the latest endoscopic spinal surgery techniques. I am confident that *Contemporary Endoscopic Spinal Surgery* can be a textbook for spine surgeons. It should be used as medical school advanced lessons materials for continuing education courses. In sum, it is my pleasure and honor to support it on behalf of the MISS of COA.

Huilin Yang
Chairman of MISS of COA
Professor & Chairman of Orthopedic Department
The First Affiliated Hospital of Soochow University
Suzhou
China

SICCMI

SICCMI (Sociedad Interamericana De Cirugia De Columna Minimamente Invasive) was founded in 2006 with similar objectives pursued by the editors of Contemporary Endoscopic Spine Surgery: the advancement and mainstreaming of minimally invasive spine surgery (MIS). SICMII members joined to implement MIS in all countries of South America, the Caribbean, Central America, and North America. Endoscopic surgery is performed by many of its key opinion leaders at the highest level, some of which have contributed to this multi-volume text. Four of the editors are active SICCMI members in leadership positions. The book contents are exhaustive and comprehensive, encompassing topics of the cervical and lumbar spine and advanced technology applications. Contemporary Endoscopic Spine Surgery will serve as SICCMI's core curriculum and course material for endoscopic surgery of the spine. It is my pleasure to endorse it on behalf of SICCMI.

President of SICCMI
Manuel Rodriguez
President-Elect of SICCMI, Department of Neurosurgery
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SBMT

As a nonprofit organization, the Society for Brain Mapping and Therapeutics (SBMT) focuses on improving patient care by translating new technologies into life-saving diagnostic and therapeutic procedures. Contemporary Endoscopic Spine Surgery is a prime example of achieving excellence in education and scientific discovery. Authors and editors from around the globe came together to present the reader with the most up-to-date endoscopic spine surgery protocols and their supporting clinical evidence. SBMT has an active spine section led by productive innovator surgeons – some of which have demonstrated their leadership with their editorial contributions to *Contemporary Endoscopic Spinal Surgery*. The editors have embraced multidisciplinary collaborations across many cultural and geographic barriers. Their effort represents one of the core principles of SBMT's mission: to identify and bridge gaps in modern patient care with technological advances. It is my pleasure to endorse *Contemporary Endoscopic Spinal Surgery* on behalf of SBMT.

Babak Kateb
Founding Chairman of the Board of Directors
CEO and Scientific Director of SBMT
Californias
USA

SILACO

SILICO (Sociedad Ibero Latinoamericana de Columna) had its beginnings in the meetings of the Scoliosis Research Society with the first Hispano-American Congress held in 1991 in Buenos Aires Argentina. Since then, it has morphed into an organization that promotes the study of treatments and prevention of spinal conditions by bringing together spine care professionals from all subspecialties. The scientific activities of our biannual Ibero-Latin American Congress are focused on the promotion of surgeon education to the highest academic standards via international relationships between members from the Americas, Spain and Portugal.

Contemporary Endoscopic Spine Surgery resembles such a collaborative effort where authors worldwide have come together to update the reader on the latest endoscopic spinal surgery techniques.

SILACO has incorporated Contemporary Endoscopic Spine Surgery into its core curriculum and plans on using it as course material for its continuing education courses. It is my pleasure to endorse it on behalf of SILACO.

Jaime Moyano
President of SILACO
Editor Revista De Sociedad Ecuatoriana De Ortopedia y Traumatología
de la Sociedad Ecuatoriana De Ortopedia Y Traumatología
Quito, Ecuador

SOMEEC

SOMEEC- Sociedad Mexicana de Endoscopia de Columna- is Mexico's prime organization uniting spine surgeons with a diverse training background having a fundamental interest in endoscopic surgery. SOMEEC organizes annual meetings where member surgeons and international faculty update each other on their latest clinical research to promote spine care *via* endoscopic spinal surgery technique. Two of the senior lead editors of *Contemporary Endoscopic Spinal Surgery* have been active international supporters of SOMEEC. I am pleased to endorse their latest three-volume reference text, which will become an integral centerpiece of SOMEEC's continuing medical educational programs.

Cecilio Quinones
Past President of the Sociedad Mexicana de Endoscopia de Columnas

KOSESS

The Korean Research Society of Endoscopic Spine Surgery (KOSESS) was established in 2017. KOSESS was founded to bring endoscopic spine surgeons in the Republic of Korea together to advance the subspecialty of endoscopic spine surgery with high-quality clinical research. It is reflected in *Contemporary Endoscopic Spine Surgery* by the numerous contributions of Korean authors. It is *Contemporary Endoscopic Spine Surgery*. It is my pleasure to endorse it on behalf of KOSESS.

Hyeun-Sung Kim (Harrison Kim)
President of the Korean Research Society of the Endoscopic Spine Society (KOSESS)
Seoul
Republic of Korea

KOMISS

Since its establishment in 2002, the *Korean Minimally Invasive Spinal Surgery Society* (KOMISS) has had a leading role in developing new clinically applicable technologies to advance patient care with less invasive yet more effective therapies. The superiority of minimally invasive spine surgery in Korea is demonstrated by its competitiveness on the world stage at the highest academic level. It is reflected in *Contemporary Endoscopic Spine Surgery* by the numerous Korean authors who have contributed to this timely reference text with their groundbreaking clinical research on endoscopic spine surgery. I am proud of their accomplishments and want to congratulate them on acting as KOMISS ambassadors by carrying the message of Korean excellence in minimally invasive spinal surgery the world over within *Contemporary Endoscopic Spine Surgery*. It is my pleasure to endorse it on behalf of KOMISS.

Dae Hyun Kim
President of KOMISS
Seoul
Republic of Korea

NATIONAL ACADEMY OF MEDICINE OF COLOMBIA

After reviewing the table of content and some representative chapters, I am happy to inform you that the Board of Directors of the National Academy of Medicine of Colombia grants academic endorsement of your book series entitled Contemporary Endoscopy Spine Surgery. Kai-Uwe Lewandrowski, Jorge Felipe Ramírez, and Anthony Yeung produced a text of great interest and scientific impact.

On behalf of the National Academy of Medicine, I would like to express my admiration and respect for your dedication to scientific research that led to this great work's culmination. It meets the high standards required by our National Academy to support such a production spearheaded by one of our most esteemed members - Dr. Jorge Felipe Ramírez.

Gustavo Landazabal Bernal
General Secretary
National Academy of Medicine of Colombia
Bogota, Colombia

IITS

The International Intradiscal Therapy Society (IITS) was founded in 1987, initially headquartered in Belgium, Wisconsin, and led by Dr. Eugene Nordby, the first Executive Director of IITS. Members were primarily orthopaedic surgeons, anesthesiologists, radiologists, and rheumatologists dedicated to the treatment, research, and education involving The FDA-approved and validated level I studies that supported intradiscal spinal therapies.

From 2013-2017, the society began operating under International Intradiscal and Transforaminal Therapy Society (IITTSS) to reflect the advancements in endoscopic spine surgery augmenting Intradiscal therapy. The organization wanted to include and reflect the state-of-the-art evolution in intradiscal therapy with advances by intradiscal visualization of pain generators through the endoscope. However, the society reverted to IITS.

IITS now sponsors workshops on intradiscal therapy in conjunction with other International societies when it lost its original pharma support. IITS disseminates a newsletter to provide its membership, other healthcare professionals, and the general public information on the safest and cost-effective techniques to treat conditions such as herniated nucleus pulposus and other intradiscal spinal disorders.

IITS is a 501C3 non-profit organization whose focus is on intradiscal therapy aided by the endoscope as the least invasive, visually-guided treatment for discogenic pain, including extra-discal and complex foraminal decompression and stabilization procedures. The disc has been validated as the primary initial source of common back pain.

Two of the senior lead editors of Contemporary Endoscopic Spinal Surgery have been in active leadership roles in International Spine Organizations as consultants, full and associate professors, and directors. I am pleased to endorse their latest three-volume reference text, which will become integral to IITS' ongoing course programs.

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SLAOT

The Sociedad Latinoamericana de Ortopedia y Traumatologia (SLAOT)/ Latin American Society of Orthopaedics and Traumatology is a non-profit, autonomous, scientific organization of orthopaedic surgeons and orthopaedic care professionals. SLAOT has an organization structure that brings together professionals with a diverse scientific interest. It promotes continuous professional development and education at the highest level. *Contemporary Endoscopic Spine Surgery* is of interest to SLAOT because of its illustrative use of cutting-edge technology and discussion of validated clinical endoscopic spinal surgery protocols. It is my pleasure to endorse *Contemporary Endoscopic Spine Surgery* on behalf of SLAOT.

Horacio Caviglia
President of SLAOT FEDERACION
USA

CONTENTS

PREFACE

Nowadays, lumbar spinal endoscopy is well accepted. Not too long ago, its critics scrutinized it for lack of sufficient high-grade clinical evidence to endorse the implementation of endoscopic spinal surgery protocols to treat the common painful conditions of the lumbar spine. Traditionally trained spine surgeons still heavily rely on image-based medical necessity criteria for surgical intervention. These include stenosis, deformity, and instability. In essence, endoscopic spinal surgery replaces these established open lumbar spinal surgery protocols with more targeted miniaturized surgeries that largely ignore these traditional image-based criteria when establishing the indication for surgery. Instead, it focuses on treating validated pain generators, many of which escape detection by conventional advanced imaging studies such as the magnetic resonance image (MRI) scan. It is undeniable even to the untrained bystander that this amounts to a culture clash.

Contemporary Endoscopic Spine Surgery: Lumbar Spine's editors are internationally renowned key opinion leaders with decades of experience in endoscopic spinal surgery. They have come together to develop a multi-authored and clinically focused medical monograph to give the reader a most up-to-date review of modern lumbar spinal endoscopic surgeries. Moreover, they intended to disperse the myth of endoscopic lumbar spine surgery being experimental - a procedure that can only be consistently be mastered by the talented few. Therefore, the editors asked the contributing authors to illustrate their results with the endoscopic lumbar surgery in the context of the peer-reviewed literature by thoroughly discussing the available high-grade clinical evidence. The editors have authored many of these landmark articles that pushed the envelope of clinical research far beyond the initial level of personal opinion and case series reports. They went on to validate them with sophisticated statistical analysis of multi-arm clinical studies.

The publication is intended for Orthopedic Spine & Neurosurgeons interested in treating common painful conditions including herniated disc, stenosis, tumor, and infection with minimally invasive endoscopic techniques. The selection of chapters was based on contemporary trends in lumbar endoscopic spinal surgery. For this purpose, a wide array of highly timely and clinically relevant topics have been assembled based on historical and anatomical considerations. They range from the review of modern transforaminal and interlaminar decompression methods, their hybridized versions, the mobile outside-in approach for far-migrated disc herniations, the over-the-top and contralateral decompression techniques, endoscopic treatment of facet cysts, visualized rhizotomy procedures of painful facet disease, and other denervation techniques of the sinuvertebral- and basivertebral nerve, the application of endoscopic procedures in the elderly, to the illustrative discussion of challenging endoscopic indications and endoscopic and endoscopically assisted fusions. The editors identified these less costly yet safe endoscopic treatments for the lumbar spine's common painful degenerative conditions in response to patients' demand for less burdensome and less risky therapies with a shorter time to recovery and return to work. Contemporary Endoscopic Spine Surgery: Lumbar Spine was written with these goals in mind. The editors hope that the readers will find it an informative knowledge resource they will continue to revert to when implementing a lumbar endoscopic spinal surgery program in their practice setting.

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CHAPTER 1

Lumbar Endoscopy: Historical Perspectives, Present & Future

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Abstract: Endoscopy of the lumbar spine has traditionally found much broader adoption than those endoscopic procedures of other areas of the spine. Initially, a herniated disc was the target of endoscopic spine surgery techniques. Stenosis indications were later identified as technological advancements permitted. Many endoscopic spinal surgeries commenced in the domain of interventional pain management. Lasers and radiofrequency were applied to some of the procedures that nowadays are aided by direct videoendsocopic visualization of the painful pathology. In this chapter, the authors briefly reviewed the history of spinal endoscopy and its key opinion leaders. Giving credit to the most prominent pioneers of this fast-moving field sets the stage for what the reader is about to discover in this most-up-to-date publication: Contemporary Spinal Endoscopy: Lumbar Spine.

Keywords: Lumbar spine, disc herniation, stenosis, impingement, degeneration, decompression, open, minimally invasive, endoscopic, historical considerations, lasers, radiofrequency.

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Kai-Uwe Lewandrowski, Jorge Felipe Ramírez León, Anthony Yeung, Hyeun-Sung Kim, Xifeng Zhang, Gun Choi, Stefan Hellinger and Álvaro Dowling (Eds.)

INTRODUCTION

Many historical perspectives have been revisited by repurposing existing technologies in new surgical approaches within the last ten years, during which spinal endoscopy has gained significant traction among spine surgeons. Likewise, have we witnessed the resurgence of previously employed surgical techniques that have been applied in the early years of spinal endoscopy. As in the fashion industry, where specific trends reappear in a modernized form by fusing different design elements or materials to create new products and marketing strategies, spine surgeons are similarly susceptible to embracing modern trends in spinal endoscopy in their quest to overcome shortcomings of existing treatment protocols for common degenerative conditions of the spine. Industry recycles existing medical know-how and often modernizes them by technology transfer from other commercial areas, such as the aerospace or the automotive industry, by innovation mechanisms of adoption, miniaturizations, automation, and system integration to develop advanced surgical instruments-, and equipment of improved performance, reliability, and durability. Innovations widely adopted in other industries are making their way into medical applications. Examples include high-definition (HD) video technology with touch-screen displays, high-speed HD recording equipment, robotics- and navigation tools, 3D heads-up display goggles for surgeons to be worn during surgery to improve eye-hand coordination, and many others. Rapid endoscopic spine surgery product development with a myriad of instruments being pushed by an army of sales associates is another area of rapid change that has been playing itself out in the operating room — endoscopes with larger inner working channels, sturdy enough to withstand the abuse of more frequent short sterilization cycles to respond to the rising caseload, motorized shavers, drills, and large Ø rongeurs employed during rapid decompression. Endoscopes previously rated for 200 to 250 simple discectomy surgeries are now used in more complex and demanding advanced endoscopic spine procedures. These include intradiscal therapies with heat-generating lasers or radiofrequency devices for the early stages of the disease and the late stages where aggressive decompression and reconstructive procedures may be needed for spinal stenosis instability-related neural element encroachment. Endoscopic placement of spinal implants, such as interbody fusion cages and posterior supplemental fixation with pedicle screw-rod constructs, are other examples of contemporary advancements in endoscopic spinal surgery. This increasing quality and durability demand on spinal endoscopes to work in a large variety of surgical indication scenarios has widened the field of industry competitors, with some front-runners pushing clinical product portfolios, reimbursement, and coding agendas. Traditional German endoscopic equipment makers are being displaced in China, Korea, and Japan by domestic Asian manufacturers whose technological know-how has now risen to a competitive level at lower acquisition costs. In some cases, Asian spinal

endoscopy, radiofrequency, and motorized decompression equipment have even advanced beyond what European competitors can put forward, mainly because of progressive clinical agendas with broader indications for endoscopic spinal surgery.

Whether all of these innovations are genuinely impactful and leaps forward that ultimately improve patient outcomes and are not just vogue trends at an increased cost to patients and the health care system, on the whole, is not always obvious and often requires vetting them in the operating room with investigational clinical studies - all of which requires clinical testing, resources, and most of all, time. Spine surgeons have little of the latter and, by their very nature, may be innovation enthusiasts in their quest to overcome shortcomings of existing clinical protocols.

The authors of this chapter attempted to put some of these new trends in perspective within the historical context of spinal endoscopy by reviewing the contributions of some of the early key players in an attempt to help the aspiring endoscopic spine surgeon to position her-, or himself in the increasingly complex field of surgical procedures. With spinal endoscopy becoming more mainstream, many North American and European national and international spine surgeons' organizations are struggling with its adoption. They have just begun to embrace it by spelling out clinical treatment guidelines and figuring out how to establish an accredited core curriculum with validated training programs. On the contrary, if endoscopic spinal surgery training had made it into the mainstream core curriculum many years ago, informal education sources would be less and less relevant. For the time being, many novice endoscopic spine surgeons in many parts of the world – particularly in North America and Europe - have to rely on an industry-sponsored weekend cadaver- and other short instructional courses. While some of them are lucky enough to be mentored by veteran key opinion leaders (KOLs), the vast majority - by default - are autodidacts and primarily self-taught, having to go through an endoscopic learning curve that many find out is steeper than with other procedures they are routinely performing.

THE TRANSFORMATION

The final goal of spinal surgery is to decompress neural elements and stabilize unstable spinal motion segments. Traditionally, this required extensive exposure and stripping of soft tissues, which in turn may devitalize and degenerate the very structures whose integrity is paramount to maintaining a healthy spinal motion segment. Problems such as post-laminectomy instability and epidural fibrosis have long been recognized as some of the potential follow-up problems that could arise from traditional open spinal surgery [1 - 3]. Other well-recognized problems

CHAPTER 2

Endoscopic Lumbar Discectomy – Anatomy, Indications and Techniques

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Abstract: Various endoscopic spinal surgery techniques to remove herniated discs in the lumbar spine have gained popularity. The "inside-out" and "outside-in" transforaminal techniques have been employed extensively, and their clinical indications have expanded with the advances in video-imaging and endoscopic optical and surgical equipment. In this chapter, the authors review some of the relevant anatomical considerations the endoscopic spine surgeon should consider when scheduling a patient for endoscopic spinal surgery. The authors also present their most up-to-date knowledge of technological advances and new endoscopic surgery techniques to provide the reader with a snapshot of modern advancements of the established transforaminal "inside-out" and "outside-in" and interlaminar methods. This chapter sets the anatomical stage for many of the following chapters in this volume 2 of the Bentham text series on Contemporary Endoscopic Spinal Surgery.

Keywords: Endoscopic approaches & techniques, Foraminal anatomy.

INTRODUCTION

Until recently, microscopic lumbar discectomy has been a standard operation for lumbar disc surgery. Recently, percutaneous endoscopic lumbar discectomy has developed significantly [1 - 5]. Percutaneous endoscopic lumbar discectomy (PELD) can be classified into Transforaminal PELD [1, 6 - 15] and Interlaminar PELD [1, 16 - 21] according to the routes of access. And each method has its own advantages and disadvantages. In this chapter, the indications and anatomical considerations for various common clinical PELD scenario are discussed.

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ANATOMICAL CONSIDERATIONS

Considering the anatomical aspect of transforaminal PELD, disc diseases can be divided into intra- and extracanalicular categories [22 - 25]. Among many surgical approaches, the surgeon should decide which nerve should be decompressed between exiting- or traversing nerve roots. The choice of preferred approach depends on the location and type of disc herniation. For example, extraforaminal disc herniation, foraminal disc herniation, and superior migrated disc herniation may be more accessible from the transforaminal approach. It may be more associated with higher postoperative dysesthesia rates and other neurologic complications than with interlaminar decompression of the traversing root [26]. Migrated disc may be challenging to remove using a rigid percutaneous endoscope. Because of these and other pertinent considerations, the endoscopic spine surgeon should be well and accurately informed about the operative field's anatomy.

Anatomical Classification of Percutaneous Endoscopic Approach (Fig. 1) [27]

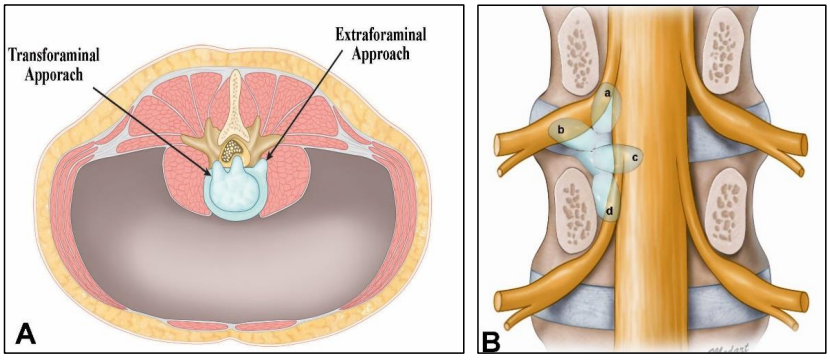

Fig. (1). Classification of percutaneous endoscopic lumbar discectomy. A. Anatomical, B. Neurological; a. superior migration, b. foraminal to far lateral, c. paracentral to central, d. inferior migration [32].

A. Extra-Foraminal Approach [2, 9, 28, 29]
   i. Far lateral Disc
B. Trans-foraminal Approach [6 - 15, 30, 31]
   i. Foraminal Disc
   ii. Superior Migration Disc
   iii. Inferior Migration Disc
   iv. Paracentral Disc
   v. Central Disc
C. Interlaminar Approach [16 - 21]
   1. Neurological Classification of Percutaneous Endoscopic Approach
      A. Exiting Root Approach

i. Far Lateral Disc
ii. Foraminal Disc
iii. Superior Migration Disc

B. Traversing Root Approach
i. Paracentral Disc
ii. Central
iii. Inferior Migrated Disc

2. Surgery Related Classification of Percutaneous Endoscopic Approach (Fig. **2**)

A. **Migration:** A migrated disc herniation was defined as a herniation, which was displaced away from the extrusion site, either above the endplate of the upper body, or below the endplate of the lower body.
i. **High grade superior migration:** Far-upward From the inferior margin of upper pedicle to 3 mm below of the inferior margin of upper pedicle
ii. **Low grade superior migration:** Near-upward From 3 mm below of the inferior margin of upper pedicle to the inferior margin of upper vertebral body
iii. **Low grade inferior migration:** Near-downward From the superior margin of lower vertebral body to the center of lower pedicle
iv. **High grade inferior migration:** Far-downward From the center to the inferior margin of lower pedicle

B. **Canal Compromise:** Herniation exceeding 50% of the canal cross sectional area
i. Mild
ii. Severe

C. **Iliac Crest:** lower part of upper vertebrae
i. Low
ii. High

D. **Foraminal Stenosis:** Lateral flexion X-ray: between posterior margin of vertebrae to ventral margin of superior articular process of lower vertebrae
i. Mild
ii. Severe

A. EQUIPMENT CONSIDERATION OF PELD

1. Equipment of endoscope
- Endoscope, working channel, suction-irrigation system, radiofrequency coagulator, video-endoscopy tower, stylet, guide needle, obturator, rongeur, forcep, punch, probe, drill, shaver [1, 13 - 15, 34 - 38].

2. Working channel

CHAPTER 3

Patient Reported Outcome Measures, Nomenclature & Classifications in Clinical Research of Endoscopic Spine Surgery

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Abstract: Uniform use of nomenclature and classification systems appears logical to anyone attempting to systematically study clinical outcomes with new emerging technology applications in spine surgery. At the introduction of spinal endoscopy into routine clinical practice, today's key opinion leaders introduced nomenclature conducive to the description of their innovations at the time. With endoscopy of the spine becoming more mainstream several authors have pushed classification systems

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for clinical outcome studies. Others have introduced terminology in hopes of them being adopted to further research and health care policy agendas. These nomenclature and classification systems' practicality in routine clinical practice may be debatable and perhaps be considered by some an academic exercise. However, the need for some common language and categorization of descriptors of painful pathology, confounding factors, and their treatments are accepted by most. This chapter summarizes the literature on nomenclature, terminology, and classification systems relevant to clinical outcome research in spinal endoscopy. It was motivated by the desire to formalize its clinical outcome research, bring it up to par with traditional translaminar spine surgery techniques, and, ultimately, incorporate it into clinical treatment and coverage guidelines formulated by spine societies and payors.

Keywords: Classification, Clinical outcome research, Nomenclature, Spinal endoscopy, Terminology.

INTRODUCTION

The pioneers of endoscopic spine surgery techniques started reporting their clinical outcomes in the late 1980s and early 1990s. At the time, there was not much interest in the procedure, and it was carried out by a few who fought an uphill battle against the proponents of traditional open spinal surgery techniques, which at the time itself were relatively new. Pedicle screws had just been introduced, and their widespread application was challenged in a class-action lawsuit in the early 1990ies. Ultimately, one of the pioneering physicians and President of the North American Spine Society at the time, Dr. Hansen Yuan, recognized the overwhelming benefit of this technology for patients and spearheaded the defense against the trial lawyers. He orchestrated the formulation of clinical treatment guidelines, which ultimately formed the basis for modern spinal surgery, based on alleviating pain by surgical freeing-up of compressed neural elements and stabilizing instability and deformity. The media attention was horrendous and spinal endoscopy appeared to be the stepchild of the public debate of indications and clinical outcomes with modern spine surgery. That debate intensified in the early 2000s, highlighting the need for more formalized outcome research to make a case for selective endoscopic treatment of validated pain generators rather than image-based treatment guidelines focusing on stenosis, instability, and deformity. The senior authors of this chapter lived through these tumultuous times and argued the case for spinal endoscopy in many debates in his local community and on a national and international level. He published the up to date most widely cited article on selective endoscopic lumbar discectomy in 2003. Some 20 years later, many of today's spinal endoscopy proponents benefit from these earlier arguments. However, the debate on whether it is appropriate to replace traditional open, translaminar, and other forms of minimally invasive spine surgeries with endoscopy continues.

WIDELY USED CLINICAL OUTCOME TOOLS

Patient-reported outcome measures (PROM) frequently used in spine outcome research include the visual analog score (VAS) [1 - 12] and the Oswestry Disability Index (ODI) [13 - 18]. Understanding the ability of these PROM scores to detect improvements in health status resulting from an intervention meaningful to the patient is critical to support conclusions in favor of one treatment over another. The VAS is a ten-digit integer score from 0 (no pain) to 10 (worst pain imaginable) [12]. The ODI is a ten-item composite instrument. It assesses pain intensity, personal care, and function, including walking, lifting, personal care, sitting, standing, sleeping, social interaction, and traveling [19 - 22]. Each ODI item is scored from 0 (no impairment) to 5 (worst impairment). Then, the scores are summed up and then multiplied by two to obtain the ODI index ranging from 0 to 100. The Macnab criteria are commonly used in spinal endoscopy outcome studies [23, 24]. Briefly, follow-up outcome results are classified as Excellent when the patient experiences little pain, and can perform desired activities with few limitations. Good Macnab outcomes are defined when the patient complains of occasional pain or dysesthesia but can perform daily activities with minor restrictions and did not need pain medication. Fair Macnab outcomes are assigned when the pain level is somewhat improved but a continued to need pain medication exists. Poor Macnab outcomes describe a patient with worse function or in need of additional surgery to address symptoms. Another way to best stratify clinical improvements in clinical research is the anchor-based approach by calculating a patient satisfaction index based on a modification of the Macnab criteria [23 - 25]. At each follow-up visit and final follow up, patients may be asked to determine whether the 1) the endoscopic surgery met their expectations, have little pain, and can perform desired activities with few limitations (Excellent), 2) the endoscopic surgery met their expectations, have occasional pain or sensory problems, but I can perform daily activities with minor restrictions and do not take pain medication (Good), 3) the endoscopic surgery met their expectations, with somewhat improved pain, but continue to need pain medication (Fair), and 4) their expectations were not met by the endoscopic surgery, and are worse off or needed additional surgery. (Poor). The patient satisfaction index can then be dichotomized considering patients with Excellent, Good, and Fair outcomes as “Improved” and with Poor outcomes as “Failed.” Then, the dichotomization results can be used in the anchor approach in a receiver operating characteristic (ROC) analysis with the area under the curve (AUC) to assess the quality of the numerical ODI and VAS PROMs to measure patient satisfaction as a result of the transforaminal endoscopic decompression procedure.

Unquestionably, these PROMs are helpful to improve patients' participation in the management of their health issues. The judgment of such improvements or the

CHAPTER 4

Transforaminal Percutaneous Endoscopic Lumbar Discectomy

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Abstract: The transforaminal spinal surgery technique is the most commonly performed way of endoscopic discectomy. Initial placement of the working cannula may determine the sequence of procedural steps. Commonly applied variations of the technique include the "inside-out" and "outside-in" techniques. In this up-to-date chapter, the authors describe the necessary procedure steps of the transforaminal endoscopic discectomy procedure, focusing on downward migrated disc herniations as these may push the endoscopic spine surgeon to the limits of his or her skill set. Therefore, the authors describe the limitations of the technique and assess adequate neural element decompression in great detail.

Keywords: Lumbar disc herniation, Transforaminal approach.

INTRODUCTION

The transforaminal technique is one of the most commonly employed endoscopic spinal surgery methods in the treatment of lumbar disc herniation [1 - 5]. Percutaneous endoscopic lumbar discectomy (PELD) can be classified into Transforaminal PELD [1, 6 - 15] and Interlaminar PELD [1, 16 - 21] by way of the primary access to the compressive pathology. In this chapter, the authors highlight the anatomical and surgical tips of the transforaminal approach.

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INDICATIONS AND APPLICATIONS

Recently, the techniques and devices used in percutaneous endoscopic lumbar discectomy have developed significantly.

Therefore, nearly all kinds of lumbar disc disease can be operated on using percutaneous endoscopic lumbar discectomy. Percutaneous endoscopic lumbar discectomy is not easy to perform due to the steep learning curve, especially in difficult and complicated cases. Some of these cases are presented in this chapter for the purpose of discussing the most modern applications of endoscopic spinal surgery technology.

1. Common Indications for Percutaneous Endoscopic Lumbar Discectomy

- Paramedian disc herniations with predominant leg pain
- Subligamentous ruptured or extruded disc with migration less than the height of the disc space
- Central disc herniation with predominant back pain
- Annular tears that cause chemical sciatica
- Lateral and extreme lateral disc herniation
- Foraminal disc herniation
- Synovial cysts of the facet joint
- Discal cyst [22]

2. Indications for Difficult Cases of Percutaneous Endoscopic Lumbar Discectomy

- Huge central protruded disc: high canal compromise
- Sequestrated disc that has migrated: superior migration, inferior migration
- Recurred Disc
    - after open lumbar discectomy
    - after percutaneous endoscopic lumbar discectomy
- Calcified disc
- Lateral recess stenosis
- Multi-level herniated disc

1. General Structural Anatomy: Posterolateral PELD Approach

According to anatomical consideration, to achieve an excellent clinical result using percutaneous endoscopic transforaminal discectomy, understanding the confines of Kambin's triangle formed by the exiting, and the traversing nerve root, and the inferior pedicle (Table **1**) [23 - 26]. The segmental artery commonly

passes under the exiting nerve root (Figs. **1 - 3**). Therefore, this segmental artery may be associated with postoperative retroperitoneal hematoma [27 - 29].

Table 1. General anatomical structures in the PELD.

1) Kambin's triangular working zone
2) Exiting nerve root
3) Traversing nerve root
4) Annulus
5) Posterior longitudinal ligament (PLL)
6) Dura
7) Sympathetic nerve and sinuvertebral nerve
8) Iliolumbar vasculature and segmental artery
9) Viscera in the retroperitoneal space

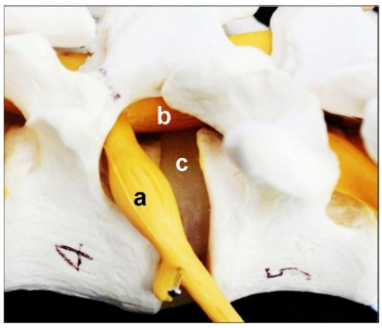

Fig. (1). Anatomical relationship of the transforaminal approach. **a.** exiting nerve root, **b.** traversing nerve root, **c.** Kambin's triangle.

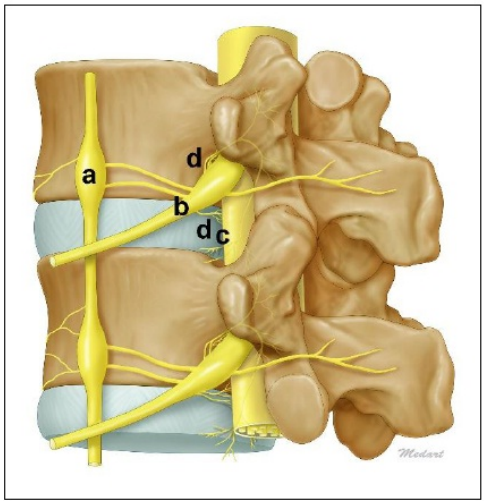

Fig. (2). Neurological relationship of the transforaminal approach. **a.** sympathetic trunk and ganglia, **b.** exiting nerve, **c.** traversing nerve, **d.** sinuvertebral nerves.

CHAPTER 5

Structural Preservation Interlaminar Endoscopic Lumbar Discectomy (IELD) For L5-S1 Herniated Disc

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Abstract: Endoscopic spine surgeries are gradually evolving and being accepted by spine surgeons globally. Transforaminal approach discectomy is one of the initial surgeries done with a fully endoscopic approach. The transforaminal approach has various advantages. Nevertheless, it has certain limitations too, and a high lying iliac crest anatomically impeding access is one of them. An Interlaminar approach for L5-S1 herniated disc exploiting a wide interlaminar window is a phenomenal endoscopic approach to this common clinical problem.

Keywords: Endoscopic approach, Interlaminar Endoscopic Lumbar Discectomy, L5-S1 Herniated Disc, Transforaminal approach.

INTRODUCTION

Initial efforts in endoscopic spine surgeries included blind percutaneous discectomy performed under fluoroscopic guidance. Later on, with the pioneering work by Kambin *et al*. a full endoscopic discectomy became a reality. Percutaneous endoscopic discectomy has been improvised by many workers in due course of time and is getting acceptance globally among spine surgeons with results equivalent or superior to conventional surgeries [1, 2]. Despite the various advantages, the endoscopic discectomy has certain limitations, and the approach to L5-S1 disc, limited by anatomy of the iliac crest, transverse process, and foramen are a few of them [1, 3]. Spine surgeons are conventionally well-versed in the interlaminar approach utilizing the interlaminar window to access thecal sac and intervertebral disc space. The same interlaminar window can be used for the

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access of the L5-S1 intervertebral disc in endoscopic surgery, bypassing the iliac crest and obviating the limitations of the transforaminal approach [2 - 7]. In this chapter, readers will be introduced to the interlaminar approach's rationale and techniques to the L5-S1 disc. The authors provide a concise description of the indications and surgical procedure, including intraoperative landmarks for skin incision, endoscope, and discectomy.

ANATOMY & RATIONALE

The interlaminar approach for endoscopic surgeries is easily possible due to a wide interlaminar window available due to the spacing of pedicles, lateral recesses, and superior and inferior laminae at the L5-S1 level [8, 9]. Knowledge of the radiographic anatomy of the L5-S1 spine is important for the interlaminar approach. The landmark for the approach are spinous process (L5 & S1), superior lamina for S1 vertebra, inferior lamina of L5 vertebra, superior articular process (SAP) of S1, inferior articular process (IAP) of L5, L5-S1 intervertebral disc, and lateral recesses [2, 6, 7, 10 - 12]. Middle sacral vessels right, and left iliac vessels are important structures lying anterior to the L5 and S1 vertebral bodies. Anatomically, they are far enough from the approach and surgical field, but care should be exerted not to injure them accidentally [10]. Recent advances in endoscopy techniques allow the transforaminal approach a great deal of flexibility, and most of the limitations of earlier techniques have been overcome. However, a high lying iliac crest, L5-S1 level, and sagittal plane deformity are still posing limitation to the transforaminal approach [1, 13, 14].

THE CONCEPT OF V-POINTS

For beginners, understanding the docking points from the start of the procedure and through intermediate steps to the conclusion is fundamental. The interlaminar approach surgery though docking points'. These docking points are typically described as 'V-Points (Fig. **1**) [5, 15, 16]. The ipsilateral V-Point is the first docking point and is defined as the junction of the most lateral points of the superior lamina of the S1 vertebra and the inferior lamina of L5 on the side skin incision is made. Midline 'V-Point' (Cranial) is the junction of the most cranial point on the ventral aspect of the L5 spinous process to the nearest point on the inferior lamina of the L5, also called cranial spinolaminar junction [5, 15, 16].

A similar midline 'V-Point' can be recognized caudally at the S1 spinous process's junction and superior S1 lamina (Fig. **1**). The contralateral 'V-point' is defined as the junction of the most lateral aspect of the superior lamina of the S1and the most caudal point of the medial part of the SAP of S1 on the opposite side. These V-points are important landmarks during surgery and guide the surgeon during the procedure. V-points are often used by the surgeon to orient

them in the endoscopic space.

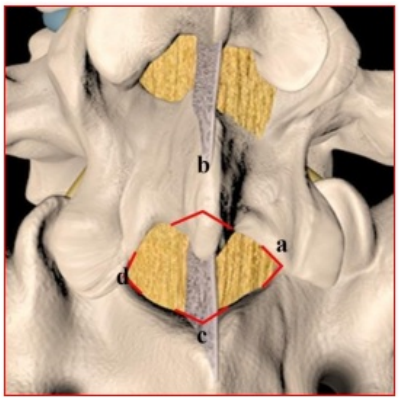

Fig. (1). "V-Points" **(a)** Ipsilateral for Right Approach **(b, c)** Cranial and Caudal Midline (Spinolaminar Junction) **(d)** Contralateral.

PRESERVATION OF THE MOTION SEGMENT

The motion segment consists of two adjacent vertebrae with the intervertebral disc and facet joints between them and their ligaments. Removal of one facet renders the motion segment unstable [17 - 19]. Interlaminar endoscopy can deal with spinal pathology with minimal resection of facets. This is also important for endoscopic discectomy at the L5-S1 level. Less facet resection translates into a decreased risk of iatrogenic instability of the motion segment [19, 20].

SURGICAL STEPS

Ipsilateral Discectomy Technique

Indications

Central, lateral, and lateral recess herniation

Anaesthesia

General anaesthesia, epidural anaesthesia

Position

Prone with hips and knees fixed. Preferably on Wilson™ (Mizuho OSI) frame.

Discography

L5-S1 discography with 0.8% Indigo Carmine (Carmine, Korea United

CHAPTER 6

Hybridized Inside-Out/Outside-In Approach for Treatment of Endstage Vacuum Degenerative Lumbar Disc Disease

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Abstract: Commonly employed transforaminal decompression techniques may use the "inside-out" and "outside-in" technique, not as a standalone technique, but as a combined technique that considers different surgical philosophies. The inside-out technique calls for an initial emphasis on visualization of the intradiscal cavity with the endoscope by advancing the working cannula inside the lumbar intervertebral disc for intradiscal examination when appropriate. In contrast, the outside-in approach places it initially into the neuroforamen and lateral recess. The authors present an illustrative case series of 411 patients in whom they employed a hybridization of these two techniques because they found it to be more reliable in cases of end-stage degenerative vacuum disc disease. The study group consisted of 192 (46.7%) females and 219 (53.3%) males with an average age of 54.84 ± 16.32. The average follow-up of 43.2 ± 26.53 months. Patients underwent surgery for herniated disc (135/411;32.8%), foraminal spinal stenosis (101/411;24.6%), a combination of the latter two conditions (162/411;39.4%), or low-grade spondylolisthesis (13/411;3.2%).

Results of our clinical series showed a significant reduction of preoperative ODI and VAS for leg pain of 49.8 ± 17.65, and 7.9 ± 1.55 to postoperatively 12.2 ± 9.34, and 2.41 ±5 1.55 at final follow-up (p 0.0001), respectively. Macnab outcomes were Excellent in 134 (32.6%), Good in 228 (55.5%), Fair in 40 (9.7%), and Poor in 9 (2.2%) patients, respectively. There was end-stage degenerative vacuum disc disease in 304 (74%) of the 411 patients; 37.5% had Excellent and 50% Good Macnab outcomes.

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Patients without vacuum discs had Excellent and Good 18.7% and 71.% of the time. With our hybridized technique, patients with end-stage degenerative vacuum disc disease did very well with the endoscopic decompression procedure. Improved clinical outcomes may be obtained with the direct visualization of pain generators in the epidural- and intradiscal space. It is the authors' preferred transforaminal decompression technique.

Keywords: Clinical outcomes, Inside-out, Outside-In, Transforaminal endoscopy.

INTRODUCTION

Spinal stenosis related operations are on the rise creating the demand for less costly, and less complicated surgical treatments that allow patients to stay out of hospitals and return to their demanding lives sooner with fewer disruptions in the postoperative recovery [1, 2]. The increased demand for these simplified spinal decompression of procedures will become more relevant to all stakeholders of the healthcare delivery equation as older patients seek medical attention for stenosis related problems. Simplified solutions are need to treat this increasing number of patients as many public health care systems are already stressed due to lack of resources. Better value-based solutions are needed to avoid rationing of traditional open spine surgery [3, 4]. The traditional image-based clinical decision-making now seems outdated and does not work well with the personalized spine care approach required to make endoscopic spine care focused on treating validated pain generators work [5 - 9]. Instead, the authors' endoscopic interventional spine surgery approach has focused limiting treatment to the lumbar level to which the patients' subjective weakness, and intermittent claudication limiting walking endurance and other physical activities can be traced back to [10]. These diagnostic and pain management strategies often lead to a unilateral or single-level foraminal stenotic process as a frequent source of pain [11, 12].

The "inside-out" technique was the first transforaminal technique proposed for lumbar endoscopy. It was based on the available technology at the time [13, 14]. Kambin supported this treatment of lumbar decompression as "arthroscopic microdiscectomy" or abbreviated as "AMD." Kambin initially believed that avoiding going into the epidural space avoided the surgical scarring inherent from the translaminar approach for herniated lumbar discs. He later tried to develop an operating endoscope, and not very functional, even by including an "oval" cannula. The operating endoscope was too delicate and did not allow levering around bony anatomy. Yeung quickly modified Kambin's technique and used Kambin's arthroscopic micro-discectomy concept of visualizing intradiscal patho-anatomy such as annular tears, intradiscal visualization of annular defects, inflammatory conditions inside the disc correlating intradiscal with extradiscal and foraminal patho-anatomy. In 1998, Yeung *et al*. was the key opinion leader in

the United States who first proposed the wide-spread use of spinal endoscopy based on his "inside-out" technique. The Yeung Endoscopic Spine System YESS™ was commercialized and accompanied by a wide array of specialized endoscopic decompression tools [15 - 22]. In the late 1990ies, the "outside-in" technique came about because other surgeons, including Thomas Hoogland's [23 - 25], became interested in addressing pathology in the epidural space outside the intervertebral disc as previously shown by Leu and Hauser [26 - 28]. These surgeons recognized that stenosis in the lateral canal and foramen needed to be addressed in conjunction with endoscopic herniated disc surgery as many patients suffered from both conditions [29 - 31]. The first author began with the "outside-in" transforaminal endoscopic decompression technique [29 - 31]. As endoscopic visualization of painful pathology improved with advances in endoscopic design and illumination technology, combining treatment of intradiscal pathology with the "outside-in" technique complementing the "inside out" technique allowed a gradual evolution of surgical protocols into a hybrid procedure for transforaminal lumbar decompression targeting the pain generator. Gradually highly skilled MIS surgeons included open and endoscopic decompression of the cervical, thoracic, and lumbar spine. Yeung also studied and stratified his indication every five years, taking more technically tricky cases at the request of his growing patient population requesting individualized options. Yeung accepted more endoscopically difficult cases based on his surgical successes that did not "burn any bridges" for a subsequent procedure if the endoscopic procedure failed.

In time and as a result of detailed statistical analysis of their respective clinical outcomes, both authors of this chapter merged their "outside-in" [32] approach with the "inside-out" [33] technique and vice versa, effectively hybridizing the two methods. In a joint analysis of their clinical outcome data, they realized that direct visualization of pain generators might be located in the posterior annulus directly underneath the dural sac. Their endoscopic treatment is just as important as treating such conditions in the epidural space [33 - 35]. Neither one of the two techniques alone afford the surgeon the ability to endoscopically treat all relevant pain generators in a symptomatic lumbar spinal motion segment. The "outside-in" has limitations since the working cannula is placed posterolaterally to the dural sac and above the intervertebral disc. The inside-out technique is limited because the working cannula sits underneath the dural sac, and painful pathology outside the intervertebral disc is not visualized and, hence, not treated. To overcome these shortcomings, the authors decided to hybridize these two approaches. In this chapter, the authors present an illustrative case series of 411 patients of the more advanced spinal conditions where many if most fellowship-trained spine surgeons prefer to depend on what they learned in their training. By employing a hybridization of these two transforaminal techniques, they found it to be more efficacious and cost-effective in cases of end-stage degenerative vacuum disc

CHAPTER 7

Full Endoscopic Interlaminar Contra-Lateral Lumbar Foraminotomy

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Abstract: Foraminal stenosis is often underestimated due to difficulties in approaching the region surgically. The evolution of the transforaminal approach allowed safe surgical exploration of foraminal pathology under direct vision. Postoperative Dysesthesia (POD) due to irritation of the dorsal root ganglion (DRG) of lumbar nerve roots at the surgical level is a common sequela associated with the transforaminal approach. Minimal dorsal root ganglion (DRG) retraction is critical to prevent POD. Full endoscopic interlaminar contra-lateral lumbar foraminotomy consists of a sublaminar approach or translaminar approach. It is followed by contralateral foraminotomy and extraforaminal decompression. The contralateral approach's principle is to create a safe path to the contralateral foramen, preserving the ipsilateral anatomy. It allows simultaneous lateral recess, contra-lateral foramen, and extraforaminal decompression along the nerve root with minimal nerve root manipulation in the foramen. However, the learning curve for the technique is steep compared to the transforaminal technique.

Keywords: Dorsal root ganglion, Foraminal stenosis, Postoperative dysesthesia, Transforaminal approach.

INTRODUCTION

Lumbar foraminal stenosis (LFS) is defined as a spinal nerve root's entrapment into the narrowed intervertebral foramen caused by degenerative disease. The incidence of LFS has proportionally risen, accounting for approximately 8-11% of degenerative lumbar diseases requiring surgical treatment [1]. However, it's often underestimated due to difficulties to surgically approach the region. Conventionally, there are two types of surgeries defined for foraminal stenosis. The first is total facetectomy with lumbar interbody fusion, and the second is open micro-foraminotomy as defined by Wiltse and Spencer [2]. However, lumbar

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interbody fusion has its own drawbacks such as pseudoarthrosis, implant failure, and adjacent segment disease.

Though micro-foraminotomy is considered the gold standard procedure, it was associated with poor visualization and incomplete decompression. The success rate has been reported between 58-80% [3, 4].

Endoscopic spine surgery has evolved in the last few decades [5]. The introduction of the transforaminal approach by Young *et al*. [6] allowed safe surgical removal of disc material and exploration of foraminal anatomy under direct vision. It helped us understand that causes for the foraminal stenosis are extrinsic compressive pathology and intrinsic pathologies. We have described the technique of full endoscopic interlaminar contra-lateral lumbar foraminotomy for the foraminal decompression. Simultaneous lateral recess, contra-lateral foramen, and extraforaminal decompression along the course of the nerve root can be carried out through a single approach [7].

SURGICAL ANATOMY

Lee *et al*. [8] defined the intervertebral foramen into 3 zones: Subarticular (entry zone), Foraminal (mid zone) and Extraforaminal (exit zone). The intervertebral foramen is an inverted teardrop-shaped structure bounded anteriorly by the posterior wall of the segmental vertebra body and intervertebral disc, superiorly and inferiorly by the pedicles of cephalad and corresponding caudal vertebra, and posteriorly by the facet joint. The neuroforaminal content consists of the spinal nerve roots, dorsal root ganglion of the exiting nerve root, the radicular artery and vein, lymphatics, and the intervertebral- and foraminal ligaments [9]. The foraminal ligaments are comprised of the transforaminal ligaments – namely the superior, middle and inferior transforaminal ligaments, and the radial ligaments – and the extraforaminal ligaments – the superior- and inferior corpotranverse ligaments, and intertransverse ligaments. Hence causes of foraminal stenosis are not only compressive pathologies from outside but also intrinsic inflammatory pathologies.

SURGICAL INDICATIONS

Depending on the pathology, causes of foraminal stenosis can be divided into:

a. Extrinsic pathology
   - Foraminal disc herniation
   - Extra-foraminal disc herniation
   - Double crush syndrome

- Degenerative disc disease with lateral wedging
- Ligamentum flavum hypertrophy
- Superior articular process overriding
- Decreased foraminal height
- Osteophytes/Syndesmophytes
- Facet arthropathy/hypertrophy
- Facet cyst
- Post-traumatic
- Post-surgical (failed back syndrome)

b. Intrinsic pathology
- Foraminal adhesion or fibrosis either due to inflammatory, infective or post-surgical scar tissue formation
- Transforaminal ligament due to hypertrophy, fibrosis or calcification

CONTRAINDICATIONS

There are a few contraindications to the full endoscopic interlaminar contra-lateral lumbar foraminotomy worth mentioning:

- Gross segmental instability evident on dynamic radiographs (> 4mm of translation or > 10^0 angular opening)
- Grade 2 or more spondylolisthesis according to Meyerding's criteria
- Bilateral foraminal stenosis (more suitable for fusion)
- Severe degenerative scoliosis
- Infection
- Malignancy

SURGICAL TECHNIQUE

Preoperative Planning

We routinely perform plain radiograph AP, lateral, oblique, and dynamic views of the lumbar spine. The plain radiographs are evaluated for the alignment of the spine for the presence of degenerative scoliosis. Dynamic views are assessed for segmental instability. For surgical planning, the AP view is evaluated for the width of cranial, caudal laminae, and the extent of the interlaminar window, which is reduced in most spinal canal stenosis cases. The height and width of the foramen are evaluated for safe bony decompression.

Ligamentum flavum's sublaminar and subarticular extent, along with thickness, is evaluated in MRI. CT scan assessed in axial cut for the size, shape, and

CHAPTER 8

Mobile Outside In, SCOT (Suprapedicular Circumferential Opening Technique) Approach for Highly Inferior Migrated HNP

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Abstract: Downward migrated lumbar disc herniation can present a challenge to any spine surgeon. Open spine surgery requires an aggressive decompression of the posterior bony elements, which ultimately may lead to postlaminectomy syndrome and instability – both of which have been associated with higher reoperation rates. The interlaminar endoscopic approach is a reasonable alternative to open translaminar surgery but still carries the risk of dural tear and does not afford the ability for an intradiscal discectomy. The authors offer a modification of the outside-in transforaminal approach - the suprapedicular circumferential opening technique (SCOT) to gain better access to downward- and far-migrated extruded lumbar disc herniations.

Keywords: Downward migrated lumbar herniated disc, Suprapedicular decompression, Transforaminal approach.

INTRODUCTION

Lumbar disc herniations (LDH) are increasingly treated with the transforaminal endoscopic lumbar discectomy (TELD) procedure. Besides minor tissue damage, fewer problems with iatrogenic instability, epidural scarring, and retraction of the neural tissue are also notable advantages [1 - 6]. One of the more challenging clinical scenarios are downward migrated disc herniations alongside and below the traversing nerve root. Access to these high-grade interiorly migrated disc herniations may be obstructed by the pedicle and osteophytes of the ring apophysis [1 - 6]. Unless all fragments are removed in their entirety, the operation may fail [1, 4, 5]. Technological advances have made it possible for the experienced spinal endoscopist to go after these downward-migrated extruded

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disc herniations, which many perhaps earlier would have considered an indication for open surgery [6 - 8]. In this chapter, the authors describe their transforaminal suprapedicular circumferential opening technique (SCOT) intended to master the challenges of endoscopically removing high-grade inferiorly migrated lumbar disc herniations.

RATIONALE FOR SCOT

One might ask why the transforaminal and not the interlaminar approach is used for these inferior migrated disc herniations, causing painful compression syndromes of the traversing nerve root? However, the transforaminal approach has several advantages that the authors of this chapter ask the reader to consider [9, 10]. These obvious advantages include a much lower risk of a dural tear. Typically, the dural sac is displaced posteriorly by these bulky disc herniations creating a surgical compartment where the surgeon can work safely *via* the transforaminal approach without much nerve root retraction. The contrary is the case with the interlaminar approach. The endoscopic spine surgeon will encounter the posterior displaced compressed dural sac if the interlaminar approach is chosen.

Another advantage of the transforaminal approach lies in its minimal disruption of the lumbar motion segment and the preservation of its anatomical structures. There is no need to remove bone from the overhanging rostral lamina, such as during the interlaminar approach. Conceivably, this could destabilize the motion segment and prompt more surgery later on. Another consideration is that such laminotomy to establish the interlaminar access to the disc herniation is time-consuming, making this technique less suitable for an outpatient surgery center where rapid turn-overs and early discharge are crucial to making such a clinical decision operation work. Besides, the transforaminal approach can easily be carried out at all lumbar levels, where the interlaminar approach may have some limitations above the L5/S1 level since the interlaminar windows are much smaller or may not exist because of anatomical variations or vertical collapse due to progressive degenerative disease in the aging spine.

Another shortcoming of the interlaminar approach is that the endoscopic visualization is limited to the epidural space. An intradiscal exploration is challenging, if not impossible, from the intradiscal approach. On the other hand, the transforaminal approach allows the surgeon to work in the epidural space and the intradiscal compartment by advancing the working cannula into the interspace. Any unstable intradiscal tissue that could lead to recurrent postoperative disc extrusions could be preemptively removed during the intradiscal portion of the transforaminal decompression procedure. The transforaminal approach is also

more conducive to performing decompression surgery under local anesthesia than the interlaminar approach, which patients do not tolerate unless it is done under general anesthesia.

SURGICAL STEPS

As described in many other chapters in this Bentham series on spinal endoscopy, the patient should undergo the transforaminal SCOT procedure in the prone position on a radiolucent Wilson frame. Under local anesthesia, the authors establish a transforaminal endoscopic access portal under fluoroscopic control. The authors' preference is to inject the skin entry point with 1% lidocaine followed by injection of another 7–10 cc 1% lidocaine into the neuroforaminal area and 2-3 cc of 1.6% lidocaine with epinephrine 3–5 minutes after the first injection [5, 10 - 12]. The planning and placement of the skin entry point and the access trajectory to the surgical neuroforamen have also been described by many able authors in this Bentham series. The spinal access needle should be aimed at the most distal and caudal portion of the disc space. The authors recommend performing a discogram in the center-section of the surgical disc space to visualize any extruded disc fragments and their relationship to the disc tissue within the interspace using 6 ml of iohexol dye mixed with 1 ml indigo carmine. Neither of these substances is neurotoxic. The insertion of sequential dilators over a guidewire follows the THESYS technique popularized by Hoogland *et al*., which culminates in the docking of a beveled working cannula into the neuroforamen. The authors use the endoscopic spine surgery system provided by JoimaxGmbH, Raumfabrik 33A, Amalienbadstraße, Karlsruhe, Germany.

Initially, the authors employ the inside-out technique to complete the intradiscal decompression. Then, the working cannula is retracted and directed caudally within the epidural space at the suprapedicular notch employing outside-in maneuvers [8]. A radiofrequency probe (Elliquence, New York, USA) and pituitary forceps are used to clear the pedicle of any soft tissue. The core steps of the SCOT procedure are executed by first drilling the central part of the superior articular process using a power drill (Primado 2, NSK, Tochigi, Japan). Then, the suprapedicular notch is further drilled out. Finally, the ring apophysis of the caudal vertebral body is drilled down directly underneath the traversing nerve root to increase the neuroforaminal volume to pursue the inferiorly migrated disc herniation further. The indigo carmine-stained extruded disc tissue is typically easily discernable during the video-endoscopic examination of the epidural space below the traversing nerve root (Figs. **1** and **2**). A semirigid flexible probe that can be curved by squeezing its handle can be used as an alternative to rigid probe and forceps should it be challenging to extirpate the extruded disc in its entirety. After all, extruded disc herniations are highly inflammatory. Bleeding may occur

CHAPTER 9

Over-The-Top *versus* Transforaminal Lumbar Endoscopic Techniques

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Abstract: A systematic review of contemporary lumbar endoscopic decompression techniques shows that the lion's share of lumbar endoscopic decompressions is done *via* the transforaminal and interlaminar approach. Many modifications and diverse applications for the more complex clinical applications have been described. Clinical outcomes in well-trained, experienced hands suggest that these modified endoscopic procedures are genuine advances. However, from the point of view of the community-based or academic traditionally trained spine surgeon adoption of these complex endoscopic procedures may still seem either impractical or out of reach when these endoscopic procedures are considered for each individual patient. The surgeon will have to figure out how to implement these procedures into their routine clinical operations by replacing the well-tried, time-proven and reliable open or other forms of minimally invasive spine surgeries. Recognizing a surgical technique's clinical advantages over another is one thing, but transforming one's practice is much more complex and depends not only on one's training or comfort level, but in most cases, the actual experience for each surgeon that will evolve due to the feedback from their patients. In patients who have experienced both the transforaminal and translaminar endoscopic approach, each surgeon will likely use the approach that gives the safest, most cost-effective, as well as the approach chosen by the surgeon for each anatomically based and guided approach. Many additional factors could potentially impede endoscopic spine surgery implementation, most of which will evolve, as the surgeon circle around the anatomic limitations of each approach. The availability or lack of equipment, trained staff, and support system also plays a role.

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The institutionalized spine surgeons may encounter additional hurdles since endoscopic spine surgery's disparate nature may disrupt well-established revenue cycles, making its implementation difficult. The surgeon's institutions may have to shoulder the burden of capital equipment purchases while facing lower reimbursement. To aid the prospective endoscopic spine surgeons in overcoming these implementation hurdles, the authors aimed to provide a systematic step-by-step comparison of the lumbar endoscopic over-the-top *versus* the transforaminal decompression techniques to illustrate their various technical aspects and clinical indications to aid the reader in selecting a "preferred" endoscopic technique.

Keywords: Endoscopy, Lumbar endoscopic surgery, Over the top technique, Transforaminal approach.

INTRODUCTION

Endoscopic procedures demonstrate equivalent clinical outcomes compared to the traditional open microsurgery with minor tissue trauma. Additionally, shorter hospital stays, lower costs of post-operative care may result in lower direct and indirect costs and earlier return to work due to rapid rehabilitation. The increase in the number of elderly patients and the need for an early return to work has increased the demand for developing the percutaneous endoscopic decompression and fusion techniques in the lumbar spine. In the last two decades, the technical evolution has been outstanding because of better optics design, improvements in surgical instruments and surgical approaches. The paradigm of percutaneous endoscopic spine surgery is shifting. Many original research articles and reviews relevant to this special issue confirm optimal endoscopic spinal surgery results.

The history of endoscopic lumbar spine surgery shows that its protagonists reached significant millstones by employing disruptive techniques and protocols that were disparaging to traditional and translaminar minimally invasive surgical technology. These newer endoscopic protocols came to prominence due to the need for safe, and more cost-effective minimally invasive techniques that are also associated with fewer dural leaks and iatrogenic instability or disabling back pain due to failed back surgery. In 1939, JG Love was the first to publish a description of the interlaminar approach. His original report indicated high patient satisfaction and nerve root compression signs had a significant improvement. The reduction of collateral damage was the driving force for the pioneers of microsurgery [1].

In 1977, Caspar [2] and Yasargil [3] independently described a microsurgical interlaminar approach. Microsurgery was shown to improve the short-term clinical outcome of lumbar discectomy significantly, mainly by reducing iatrogenic collateral damage. Postoperative pain was much better controlled with this surgical approach techniques. The intraoperative blood loss and infection risk

were recognized to be lower, and hospital stays were shorter. Various factors than short-term results predict long-term clinical outcomes due to the nature of the progressive underlying degenerative lumbar spine disease [4]. Historically, current modern endoscopic techniques are centered around Yeung and Hoogland. Both endoscopic surgeon's operative techniques only differed on their approaches to the same patho-anatomy. Others have since contributed in the past few years. In the authors' opinion, recent modern concepts contributed to the current adoption of minimally invasive and endoscopic spinal surgery techniques by traditionally trained open and endoscopic spine surgeons.

In a more comprehensive historical review, in 1964, Lyman Smith published a paper about the enzymatic dissolution of the lumbar nucleus pulposus [5, 6]. The long-term outcomes were good and complications were rare and chemonucleolysis seemed to become a viable alternative to surgical discectomy [7, 8]. Parviz Kambin, a Philadelphian surgeon, further developed the posterolateral approach in 1980 [9 - 12]. He described a safe corridor to the lumbar disc between the exiting nerve root and the superior facet in his pioneering works. This safe zone was later universally accepted as Kambin's Triangle. Later, Suezawa, Schreiber, and Leu improved upon Kambin's percutaneous technique by visualizing the procedure with an endoscope. They called this modification of Kambin's original technique discoscopy [13 - 15]. In the 90s, Anthony Yeung [16, 17] and Hal Matthews [18, 19] described a more lateral access route. Their transforaminal approach aimed at far lateral disc herniations and more medially located pathologies. These surgical procedures were now possible because the surgical access corridor was aimed more parallel at the annulus's posterior rim. Anthony Yeung advanced the intradiscal therapies concepts *via* the transforaminal approach by describing visualized endoscopic treatments of validated pain generators. Based on these advances, he developed the YESS™ endoscopic spine system, which turned out to be versatile for both the transforaminal and interlaminar approach techniques [17, 20]. Sebastian Ruetten chiefly popularized the latter [21 - 25]. While several chapters in this Bentham book series recognize these individual contributing surgeons, in this chapter, the authors describe the most commonly employed contemporary lumbar endoscopic approaches and their associated techniques.

TRANSFORAMINAL APPROCHES

The transforaminal approach has significantly evolved in the last few decades. From the first attempts in 1963 with Smith injecting chymopapain into the disk to the very early origins with Hijikata [13] in 1975 with percutaneous nucleotomy and nonspecific disc depressurization in the 80s [9, 10, 26 - 28]. The "previsualization era," as defined by Kim *et al*. [29], reached its peak with the

CHAPTER 10

Endoscopic Treatment of Lumbar Facet Cysts

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Abstract: Cysts associated with degeneration of the lumbar facet joints are commonly encountered during routine lumbar endoscopy. They can be difficult to dissect and may heighten the risk of nerve root injury when they are fibrotically attached. Many of these cysts are extradural. Because of their highly inflammatory nature, they may be associated with radicular symptoms even without associated mechanical compression of the traversing or exiting nerve root of the symptomatic surgical level. These synovial cysts may be acutely painful. Their related symptoms may be difficult to distinguish from those caused by lumbar disc herniation or stenosis in the lateral spinal canal on clinical examination. The endoscopic spine surgeon is often forced to deal with them to complete the neural element decompression. What is less clear is what to do with patients with sizeable isolated facet joint based cysts without much other clinical pathology. The surgical indications and prognosticators of favorable clinical outcomes with endoscopic surgery are less well understood. Therefore, the authors performed a systematic analysis of their clinical series of patients they identified to have had synovial cysts either on preoperative advanced imaging studies or on those they found serendipitously during routine lumbar endoscopy. In total, 48 were identified in whom removal of the extradural cyst was performed during routine transforaminal and interlaminar endoscopy. The primary indication for surgery in these patients was painful foraminal and lateral recess stenosis. The patients were divided into 26 females and 22 males. The L4/5 level was the most frequent site of facet based cysts. It was found in 26 patients (72.2%). The second most common site was the L5/S1 level in 8 patients (22.2%), followed by two patients (5.6%) at the L3/4 level. A single patient had endoscopic decompression at the T9/10 level. Outcome analysis showed clinical improvements in all patients. According to the modified Macnab criteria, 19/48 (39.6%) patients had excellent outcomes. Good and fair results were achieved in 18/48 (37.5%) and 11/48 (22.9%) patients, respectively. The observed VAS leg pain score reductions were substantial and statistically significant ($p < 0.000$) from preoperative 8.06 ± 1.57 to postoperative 1.92 ± 1.49, and 1.77 ± 1.32 at final follow-up. One patient had a recurrent disc herniation, and another patient did not improve. Two patients

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underwent fusion during the follow-up period. Patients with Fair outcomes had a statistically significant association ($p < 0.001$) with facet instability as suggested by axial T2-weighted MRI imaging findings of thickened ligamentum flavum, facet joint hypertrophy, and a bright white fluid-filled joint gap of > 2 mm. Endoscopic resection of extradural spinal cysts that nearly exclusively stem from degenerated lumbar facet joints in skilled hands is feasible. Instability was one of the prognosticators of Fair Macnab outcomes.

Keywords: Endoscopic decompression, Extradural cysts, Lumbar foraminal stenosis.

INTRODUCTION

Facet cysts are often encountered during routine lumbar endoscopy. These extradural cysts may cause raging sciatica-type back and leg pain since they are often highly inflammatory. Although they are less commonly problematic than a herniated disc or a stenotic process in the foramen or the lateral recess, the radiculopathy is often a result of inflammation of the dorsal root ganglion, tethering or scarring of the traversing or exiting nerve root. Therefore, symptoms may be seemingly out of proportion with the mechanical compression seen on the preoperative MRI scan [1 - 3]. One should consider synovial extradural cyst in the differential diagnosis, mainly if the patient's symptoms cannot be explained due to the absence of corresponding compressive pathology on the preoperative MRI scan. It is not uncommon to encounter a pain syndrome in the patient's presentation that on physical examination may be impossible to differentiate from those caused by lumbar disc herniation or stenosis in the lateral spinal canal. One of the patient's history elements that should elevate the surgeon's suspicion for the presence of a facet cyst is very painful radiculopathy without neurogenic claudication [4 - 9]. Therefore, a painful facet cyst diagnosis is based on a thorough history and physical examination and corroborating advanced magnetic resonance imaging (MRI), whose sensitivity has been reported as high as 90% compared to 70% of computed tomography (CT) scan [10 - 13].

ETIOLOGY

The etiology and natural history of cysts are unclear [13 - 15]. Acute trauma and repetitive micro-trauma are thought to have causative roles in the formation of cysts. Juxtafacet cysts occur most frequently at the L4-5, which is the most mobile lumbar segment. Cysts are positively associated with facet osteoarthritis, disc degeneration, and degenerative spondylolisthesis. Most cysts probably occur due to interaction between abnormal motion and progressive degenerative process at the facet joint. Lumbar juxtafacet cysts originate from degenerated facet joints or ligamentum flavum as part of a generalized segmental degenerative process.

Radicular symptoms can occur due to the exiting or traversing spinal nerve's irritation by the juxtafacet cyst, often in association with a protruding disc. When synovial cysts are seen, the presence of facet arthrosis may or may not be evident on X-ray or MRI but maybe visualized endoscopically. Some synovial cysts are located at the lateral recess and incidentally visualized by the spine endoscope. Lumbar juxtafacet cysts are extradural cysts of the spine originating from the degenerated facet joint (synovial cyst) or myxomatous degeneration of ligamentum flavum (ganglion cyst). Juxtafacet cysts with features of both synovial and ganglion cysts have been described. Calcification of cyst lining and hemosiderin deposits within the cyst has been seen histologically.

CLINICAL COURSE

Clinically, juxtafacet cysts can contribute to radicular as well as low back pain. Radicular pain occurs when the spinal nerve becomes inflamed due to chronic compression by the cyst. Although the cyst may be the significant compressive structure upon the nerve, significant contributions can come from co-existing annular tears, herniated disc, vertebral osteophyte, and foraminal stenosis. Radicular pain, radiculopathy (reflex, motor, and sensory changes), and neurogenic claudication patterns are dependent upon the size, shape, and location of the cyst to the spinal nerve. These findings are influenced by the fixed shape and size of the spinal canal within which the cyst and the nerve reside. Cysts can change in size, and this may explain clinical fluctuations. The juxtafacet cyst itself is generally not the cause of chronic low back pain. However, the cyst is usually associated with degenerated and hypermobile facets and disc, which can be the source(s) of pain. Excessive repetitive loading upon the facet/disc exceeding their mechanical strength and reparative ability result in capsular and annular strain/tears. Microscopic injury activates mediators of the inflammatory process and pain. The cyst is a marker of progressive motion segment deterioration involving the corresponding facet and the disc.

DIFFERENTIAL DIAGNOSIS

The differential diagnosis of facet cysts - which are also commonly called synovial or ganglion cysts [13] - consists of extradural arachnoid cysts [14, 15], perineural (Tarlov) cysts [16, 17], dermoid cysts [18, 19], neurofibroma with cystic degeneration [20]. Juxtafacet cysts are quite uncommon causes of radiculopathy, low back pain, and neurogenic claudication and are often associated with advanced spinal degenerative disease. Facet-based synovial cysts are by far the most common intraspinal cysts that are histologically distinct from the other types of cysts and have been deemed to be associated with instability of the degenerated lumbar spinal motion segment (Table **1**).

CHAPTER 11

Transforaminal Endoscopic Lumbar Foraminotomy TELF for Lumbar Stenosis in Patients Aged Over 80 Years

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Abstract: Neurogenic claudication due to a herniated disc, spinal stenosis, instability, or deformity is typical in the elderly. When conservative management fails, and the patient's disability prevents a healthy lifestyle, surgery is often recommended. There are multiple concerns with open spine surgery in the geriatric patient population, including medical comorbidities and fewer overall reserves to tolerate aggressive operations with high blood loss and long operating times. Endoscopic foraminal decompression has gained popularity and is now openly competing with open decompression and fusion operations by focusing the treatment on validated pain generators. Such simplified treatments often consist of targeted single-level and unilateral neuroforaminal decompressions. It is evident that appropriate patient selection and a diagnostic workup employing validated prognosticators of a favorable outcome are necessary to make such an endoscopic spinal surgery program work in the elderly. In this chapter, the authors describe their patient selection algorithms and preferred surgical techniques. In their experience, high patient satisfaction may be achieved when employing their clinical protocols.

Keywords: Geriatric patients, Neurogenic claudication, Spinal stenosis.

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INTRODUCTION

Advances in medicine have dramatically increased average life expectancy. Some recent demographic studies expect that the 65 years of age and older population in the US will reach 20% by 2030 [1]. Similar data is expected in the UK (22%). In the rest of Europe and over the world, the number of persons aged 80 years will be 426 million in 2050, three times the 2019 data (143 million), this growing geriatric population create new challenges for the medical fields, including all the degenerative pain-related diseases that also have raised and now are quite prevalent in developing countries [2 - 5]. For instance, musculoskeletal pain's global prevalence in the elderly ranges from 65 to 85% [1] and is positively associated with reduced quality of life, depression, and adverse health effects [5]. Specifically, for low back pain LBP the prevalence is between 24 and 36%, being osteoarthrosis and lumbar stenosis, the most common pathologies (1). Studies found that chronic and severe LBP prevalence and incidence could increase up to three times in patients in their 80ies *versus* their 50ies [6 - 8].

LBP intensity and disability are more severe and is the primary cause for visiting a health care provider. Treating the older population can be challenging due to associated comorbidities, high risk of complications, elevated cost, poor outcomes, and functional disability. Therefore, many older patients are undertreated or receive no treatment for spinal stenosis at all. Although the first treatment option must be non-operative management, in some instances, the surgical treatment has proven to be a good option for relieving pain in older patients [4]. Recently, with the development of new technologies, endoscopic spine surgery has been an excellent and safe option to treat LBP and radiculopathy in older patients. Still, there are few reports of its use on the geriatric population (over 80 years of age) using a full-endoscopic foraminal decompression. Endoscopic Spine Surgery offers new treatment alternatives to even more complex pathologies, looking for the maximal reduction of injury to adjacent tissues and preserving the natural structure and function of the lumbar motion segment [9 - 12]. This chapter will cover the use of the minimally invasive Transforaminal Endoscopic Lumbar Foraminotomy for lumbar spinal stenosis in patients aged over 80 years.

RADICULOPATHY

One of the most common spine pain pathologies in geriatric patients is nerve root compression [6]. Many degenerated spine structures may lead to lumbar spinal stenosis (LSS) and the subsequent radiculopathy with radiating pain [1]. LSS is defined as the syndrome associated with narrowing the lumbar spinal canal and neural compression; it may have two origins: degenerative changes and

developmental or congenital phenomena [13]. The degenerative type occurs mainly in older people starting around the fifth or sixth decade [1, 9, 12], and it is generally associated with arthritic changes in bony structures such as the intervertebral disc (loss of height), articular facets (hypertrophy), vertebral channel adjacent ligaments, or the presence of spondylolisthesis.

Previous to implementing any surgical alternative, all the medical options must have been tried, including weight loss. Once the surgical decision has been made to treat this pathology, it is advisable to start with procedures that preserve as much as possible the normal anatomy and function of adjacent tissues, *i.e.*, minimally invasive techniques including full endoscopic procedures [12, 14 - 16]. Although many conventional surgical alternatives have proven safe and effective [4, 17], open decompression implies disadvantages like severe damage in surrounding tissues, prolonged hospitalization, the need for general anesthesia, and slower recovery [9]. Nowadays, the less aggressive and safest option for foraminal stenosis treatment in geriatric patients is Transforaminal Endoscopic Lumbar Foraminotomy TELF, formerly called Endoscopic Lumbar Foraminoplasty (ELF) [18].

TRANSFORAMINAL ENDOSCOPIC LUMBAR FORAMINOTOMY

Transforaminal endoscopic lumbar foraminotomy (TELF) is defined as “the process of widening the foramen through endoscopic instruments” [18]. This full-endoscopic procedure allows to perform foraminal decompression with minimal invasion, nerve root mobilization and neurolysis, osteophyte ablation, disc collagen fiber tension, epidural scarring tissue liberation, and sequestered and extruded disc protrusion removal with a good exploration of the foramen, extraforaminal area, epidural and intradiscal space [19]. Because of its inherent benefits, TELF is an excellent alternative for the treatment of lumbar stenosis. Nevertheless, there are few reports of its use in the geriatric population. It is necessary to understand better the fundamental aspects of evolution, indications, advantages, surgical techniques, and, of course, to report the authors' results and compare them with other reports.

TELF EVOLUTION

Spinal endoscopic techniques underwent a remarkable development in the last 30 years, which has permitted to increase its range of indications. As far as its beginnings, we must highlight Kambin, who described the safe triangle in 1991 [20]. Later, in 1994, Knight in England [21], Siebert [22] and Hoogland [23] in Germany, and Yeung [24, 25] in the United States performed the first percutaneous endoscopic lumbar discectomies (PELD) with a transforaminal approach [26]. Martin Knight in 1994 [27] described the Endoscopic Laser

CHAPTER 12

Safety and Effectiveness of the Endoscopic Rhizotomy for the Treatment of Facet-Related Chronic Low Back Pain

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Abstract: Lumbar spinal facet joints may be a significant source of chronic low back pain, with a reported prevalence of 7.7 to 75%. The clinical entity has been called facet joint syndrome. However, this syndrome and its therapies remain controversial as the clinical evidence for its treatment has been graded as weak. Intra- or periarticular injections have found acceptance as a diagnostic tool. Its etiology may be multifactorial, with degeneration of the joints' cartilage being the likely leading cause. This process incites an inflammatory response involving the synthesis of proinflammatory cytokines and metalloproteinases. Hence, local injections of glucocorticoids into the affected joint has become an accepted short-term treatment option but with weak long-term benefit. In this chapter, the authors review their clinical experience with the endoscopic rhizotomy when treating chronic low back pain due to facet syndrome. Its safety and effectiveness were evaluated in 84 patients, including 48 females and 36 males with a mean age of 65, ranging from 52 to 82. Patients were included in the study if they reported greater than 80% pain relief with lumbar medial branch blocks using ropivacaine on two separate occasions. Primary clinical outcome measures were the VAS BACK score and the Oswestry Disability Index (ODI). There were no adverse events and complications except one patient with a postoperative hematoma, which resolved with conservative care. At the final six months follow-up, the VAS scores were significantly lower (postop VAS 2.3; range 0 - 4) than before endoscopic rhizotomy (preop VAS mean 6.4; range 4-7; $p < 0.05$). The postoperative

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ODI of 24 (range 12 - 48) was significantly lower than its preoperative value 52 (range 42-67). The authors conclude that dorsal endoscopic rhizotomy is safe and effective for facet-related low back pain.

Keywords: Low back pain, Lumbar facet pain, Neurectomy, Rhizotomy.

INTRODUCION

The societal burden of chronic low-back pain (CLBP) is on the rise due to aging populations. The annualized prevalence is estimated to be between 3% to 10%. In the elderly, CLBP causes health care expenditures in other seemingly unrelated areas due to treatments of depression and poorly managed medical comorbidities due to immobilization [1]. The additional indirect cost of poorly managed CLBP due to lost wages is relevant to businesses and their employees. CLBP due to degenerative facet disease is often overlooked, notably when advanced imaging studies do not support standard treatments for compression of neural elements from a herniated disc or spinal stenosis in the central or lateral canal [2].

The etiology of CLBP from degeneration of the lumbar facet joints is believed to be related to the abundant innervation of the lumbar joint synovial membrane and joint capsule by nerve endings emanating from the medial branch of the dorsal ramus of the spinal nerve [3]. As the spinal nerve exits the lumbar neuroforamen, the posterior medial branch runs on the upper edge of the transverse process of the lower vertebral body and the lateral aspect of the superior articular process where it enters a fibro-osseous canal between the mammillary and the accessory processes. From there, it gives rise to fibers to facet joints, the muscles that attach to it [4]. It has been stipulated that facet degeneration produces increased stresses across the zygapophysial joint spaces. In turn, impingement of the synovial membrane folds reportedly stimulates the joint capsule's sensory receptors, causing inflammation [5] and pain *via* the medial branch [4]. The patient may complain of radiating pain not following a specific dermatome or localized mechanical low back pain [2].

The posterior branch of the spinal nerve exit from each lumbar neuroforamen also gives rise to the lateral branch, which may innervate the facet joint complex below, thus, creating abundant cross innervation [4, 6]. Therefore, ablation of the posterior medial branch as it runs on the upper edge of the lower vertebral body's transverse process and the lateral aspect of the superior articular process may result in incomplete pain relief [7]. Consequently, medial branch blocks have been employed to diagnostically determine whether the suspected facet joint complex is the pain generator relevant to the patient [8]. Unfortunately, these diagnostic blocks are not very accurate, with a false positive rate of 22% to 32% having been

reported [9]. Therefore, many clinical investigators have proposed to perform at minimum two diagnostic injections with short- and long-acting local anesthetics to confirm the diagnosis and reduce the chance of a false positive response, which could prompt an unwarranted intervention. Some authors even go as far as only considering patients as true positive responders to diagnostic injections if their pain relief following the injections lasts as long as the expected half-life of a short- *Versus* long-acting local anesthetic [10]. If the response is consistent and the diagnosis is confirmed, additional treatments beyond the scope of non-steroidal anti-inflammatories, activity modifications, physical therapy, and other modalities can be considered. Repeated medial branch blocks may provide short-term pain without long-term benefit [11]. Typically, interventional pain management physicians perform needle-based percutaneous radiofrequency ablations with the reported longevity of the therapeutic benefit averaging three months because of the medial branch's regeneration and reinnervation of the painful facet joint complex [12]. In this chapter, the authors present their clinical experience with the endoscopically assisted rhizotomy, a surgically directly visualized facet joint denervation carried out with mechanical and radiofrequency ablation of the symptomatic facet joint.

ANATOMICAL BASIS FOR ANTERIOR & POSTERIOR COLUMN DENERVATION

Chronic low back pain related to anterior column degeneration is associated with Modic changes in the endplates and vertebral bodies [13]. Type I Modic changes appear more frequently associated with clinical symptoms [14 - 16] and have been successfully treated by denervation of the vertebral body's nerve supply. The innervation of the vertebral body was studied by Sherman *et al*. in 1963, who reported on a 'large solitary nerve trunk' tunneling into the posterior cortex that was communicating with the sinuvertebral nerve, which emanates from the ventral rami of the spinal nerves or nerves derived from the gray rami communicantes [17]. In 1997, Antonacci *et al*. corroborated this observation in a larger sample of the human vertebra by proving neurovascular bundles within the basivertebral foramen (BFV), and first using the term 'basivertebral nerves [18]. Later, they were associated with the vertebral osseous structures' microdamage, and their presence was confirmed with histopathological markers [19]. The innervation pathways linking endplate nociceptors to the basivertebral nerve trunk has been studied by Bailey *et al* [20]. They concluded that the vertebra courses' rich innervation along the intervertebral blood vessels toward the center of the vertebra from the branch out towards the endplates. These intimate structural interactions between the vertebral endplates and the intervertebral discs that axial back pain from multiple pain generators within the lumbar motion segment may be transmitted by the basivertebral nerve (BVN) [20 - 22]. The BVN accompanied

CHAPTER 13

Visualized Endoscopic Radiofrequency Ablation of Sinuvertebral Nerve and Basivertebral Nerve for Chronic Discogenic Back Pain

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Abstract: Chronic discogenic back pain is a leading cause of disability in man. Degenerative disc disease and its associated pathological neurotization of the sinuvertebral and basivertebral nerve are some of the mechanisms that lead to lower back pain. The use of radiofrequency ablation to denervate pathological sensitized sinuvertebral and basivertebral nerve has been described to decrease pain in patients with degenerative disc disease. Radiofrequency energy system can be introduced into the region of sinuvertebral and basivertebral nerve *via* inside out and outside in technique through fluoroscopic and/or endoscopic guidance. This chapter discusses the methods of outside-in-endoscopic guided radiofrequency ablation of sinuvertebral and basivertebral nerves.

Keywords: Basivertebral nerve, Chronic discogenic back pain, Degenerative disc disease, Neurotization, Radiofrequency energy system, Sinuvertebral nerve.

INTRODUCTION

Lower back pain affects 70-85% of people during their lifetime, and recurred back pain episodes are as high as 85% [1]. Multiple factors can contribute to lower back pain, including degenerative disc disease, facet arthritis, lumbar prolapsed intervertebral disc, lumbar spondylolysis, and spondylolisthesis. Most of the time, more than one concurrent factor may lead to lower back pain. Management of degenerative disc disease ranges from conservative management, restorative therapy, reconstructive therapy, and surgery [2]. A normal intervertebral disc is avascular, aneural, and mechanically stable.

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Disruption of the intervertebral disc's mechanical and anatomical structure leads to an inflammatory response with the generation with its secreted cytokines and vascular factors, which leads to neurotization of the diseased disc [3]. This pathological neurotization leads to the sensitization of native sinuvertebral and basivertebral nerves around the disc. These nerves send pain signals to the central nervous system. They are leading to hyperalgesia and allodynia of normal and increased load to the affected disc [4]. Radiofrequency ablation of these pathological nerves can provide sustained relief for patients who suffer from lower back pain [5].

RATIONALE

Pathoanatomical and Pathophysiological Considerations of Degenerated Lumbar Intervertebral Disc Structural Degeneration

Necrosis of chondrocyte-like cells in the nucleus is a natural process with an accelerating rate (with age 2% at birth to 50% in adulthood). This degeneration and necrosis accelerate during pathological processes such as prolapsed intervertebral disc (PID). Structural changes in the spinal column include syndesmophyte formation, osteophyte at the facet joint, decreased disc height, and stiffening of the intervertebral disc (IVD) [5]. Degenerative disc disease results from complex multifactorial etiology interplay of structural changes, genetics, trauma, environmental factors, and aging.

Triggers for accelerated degeneration: In the literature, several trigger events are attributed to DDD progression. They are: 1) alteration of coronal and sagittal parameters, 2) ligamentous laxity and muscle imbalance, 3) excessive mechanical load or repetitive and chronic exposure to high mechanical load, 4) predisposing genetics vulnerability, 5) smoking, obesity, and diabetes mellitus 6) Nutritional deficiency [5].

Inflammatory Cascade, Neuronal Sensitization and Pathologic Neuronization of the Disc

Inflammatory response plays a crucial role in the induction of hyperalgesia of the disc. Animals experiments showed that exposure of the ruptured nucleus could lead to increase inflammation around the ruptured area [4]. We found significant neovascularization and adhesive tissue around the region of disc degeneration, sinuvertebral, and basivertebral nerve region.

Anatomy of Sinuvertebral Nerve and Basiverebral Nerve (BVN)

Dr. Hubert von Luschka described the sinuvertebral nerve (SVN) in 1850 as a

sympathetic nerve derived from the spinal nerve. There are extensive intersegmental anastomoses with extension to posterior annulus fibrosus. The sinuvertebral nerve is derived by combining the somatic root from the ventral ramus and autonomic root by grey ramus. It supplies both proprioceptive and pain fibers to join at grey ramus communicans. After joining grey ramus communicans, it has a recurrent course to the spinal canal through intervertebral foramen along the upper portion of the pedicle cephalad to the corresponding disc. It gives rise to an ascending branch, which goes intraosseous to provide an increase to Basivertebral Nerve. Basivertebral nerve (BVN) is a nerve in pairs as branches from SVN, which provides nociceptive transmission for endplates, which enters the vertebral body from the central vascular foramen around the endplates. It arises from the ascending branch of sinuvertebral nerves, which goes intraosseous and give rise to Basivertebral Nerves near the upper medial pedicle [5, 6]. Sinuvertebral nerve also gives out a descending branch that supplies adjacent to the posterior longitudinal ligament and disc. This is the region which we target for sinuvertebral nerve radiofrequency ablation (Fig. **1**) [7].

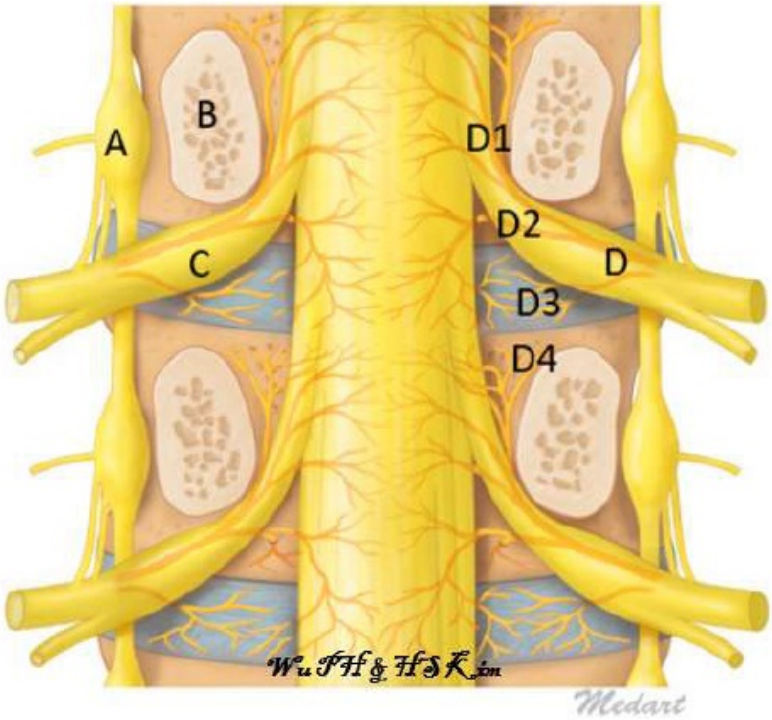

Fig. (1). The figure of Coronal Mid Pedicle Cut of Lumbar Spine. A: Sympathetic ganglion, B: Pedicle, C: Dorsal Root Ganglion, D: Sinuvertebral Nerve giving rise to branches D1: Ascending branch, which goes intraosseous and gives rise to Basivertebral Nerve near the pedicle D4, D2: Descending Branch supplying adjacent to Posterior longitudinal ligament and disc, D3: Direct branches to intervertebral disc.

CHAPTER 14

Endoscopic Resection of Schwannoma in the Psoas Major Muscle

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Abstract: Surgical treatment of benign tumors of the spine when required is still aggressive compared to the lack of malignancy of the underlying disease process. While such lesions rarely cause systemic problems, grow slowly, and rarely degenerate into the malignant lesions or metastasize, their open surgical treatment rivals that done for malignant lesions causing tremendous exposure-related collateral damage from tissue dissections, blood loss, and scarring of the surgical corridor. Endoscopic spinal surgery techniques offer an attractive alternative to gain access and visualize areas deep to the spine that ordinarily would require complicated anterior, posterior, or even combined approaches to decompress and stabilize iatrogenic instability. In this chapter, the authors present an exemplary case of applying endoscopy to treating benign nerve sheath tumors of the lumbar spine – a schwannoma.

Keywords: Benign tumor, Endoscopic decompression, Lumbar nerve compression.

INTRODUCTION

Degenerative conditions of the spine are the most common reason patients seek spine surgeons' attention to alleviate pain and improve function. At the heart of every spinal surgery is neural element decompression and, in some cases, stabilization of the spine when dictated by the underlying disease or when the decompression induces instability [1]. It is only understandable that endoscopic spine surgery is venturing out of the degenerative arena [2 - 13] into other spine surgery areas where infections and tumors may be the underlying cause of pain and disability. In this chapter, the authors present such an example where a tumorous paraspinal lesion was treated with full endoscopic techniques.

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EXEMPLARY CASE

The patient is a 76-year-old female with a chief complaint of pain and numbness radiating into the left lower extremity for three years, which was recently aggravated for the last three months before presenting to our hospital. Most recently, the patient's complaint included pain and numbness in the buttock, now radiating to the left heel. She had tried several traditional Chinese Medicine modalities, including acupuncture, massage, and physiotherapy, none of which were effective. At its worst, the patient had symptoms at rest, which were slightly relieved by standing up and ambulation. The physical examination did not reveal any apparent abnormalities. There were negative upper motor neuron signs. The lumbar MRI scan produced at admission to our hospital did not show any obvious abnormalities within the spinal canal or the foramina. However, there were circular patterns with a mixed-signal in the left psoas major muscle at the L3-4 level, which seemed to be emanating from the left spinal canal (Figs. **1** and **2**). Because of failed non-operative care and the worrisome lesion in the left psoas major muscle, the indication for an excisional biopsy was determined. To minimize the collateral damage to reaching the psoas muscle, an endoscopic approach under local anesthesia under videoendoscopic and fluoroscopic control was planned.

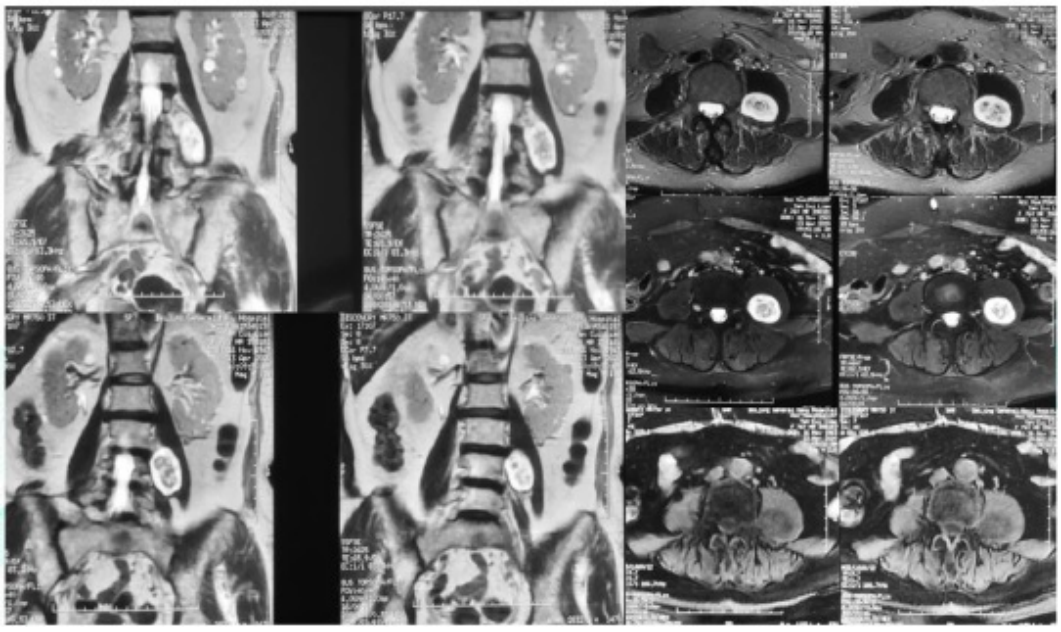

Fig. (1). Coronal and axial T1- and T2-weighted MRI scans of the patient diagnosed with a Schwannoma in the left psoas major likely emanating from the L3/4 level.

Fig. (2). CT examination of lumbar spine shows a space occupying lesion in the psoas major muscle on the left side at the lumbar 3-4 level.

SURGICAL PROCEDURE

The patient was placed on a Wilson frame in the prone position and prepped and draped in standard surgical fashion. The L4 vertebral body was marked employing intraoperative fluoroscopy. The lesion was approached approximately 5 – 6 cm from the midline on the left side The needle entry point was infiltrated with local anesthesia using 20 ml of 2% lidocaine mixed with 40 ml 0.9% sodium chloride. Under fluoroscopic confirmation, a spinal needle was vertically inserted about 6 cms to the left of the L4 transverse process. A guidewire was inserted through the spinal needle, which was then removed. After serial dilation, the working cannula was placed onto the L4 transverse process. The endoscope was inserted to directly visualize the space-occupying lesion within the left psoas major muscle.

After initial exploration and dissection, a 2.5 x 3 cm mass could clearly be demarcated from the surrounding area. A soft and light yellow mass was seen. The surrounding muscle tissue was dissected of the mass using a disposable radiofrequency probe under direct endoscopic visualization. Pituitary rongeurs were also used during the dissection. After excisional biopsy of the lesion was completed, the wound was thoroughly irrigated and the endoscopic instruments were withdrawn after wich the wound was closed with a single stitch. Some representative intraoperative images are shown in Figs. (**3 - 5**).

CHAPTER 15

Endoscopic Uninstrumented Transforaminal Lumbar Interbody Fusion with Allograft for Surgical Management of Endstage Degenerative Vacuum Disc Disease

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Abstract: Not every patient with painful end-stage degenerative disc disease is a candidate for instrumented fusion surgery or wants it regardless of whether it is carried out through open, mini-open, or minimally invasive incisions. The authors were intrigued by their anecdotal observation that elderly patients with painful vacuum discs serendipitously found during endoscopic decompression went on to successful fusion and enjoyed substantial long-term pain relief. Therefore, we investigated the feasibility of a transforaminal endoscopic decompression and un-instrumented lumbar interbody fusion procedures with cancellous bone allograft. A total of 29 patients had their vacuum discs directly visualized with a modified hybrid transforaminal technique employing procedural components of both the outside-in and the inside-out technique. Intraoperative endoscopic visualization of a painful, hollow collapsed, rigid intervertebral disc space allowed grafting it with cancellous allograft chips. In addition to the two-year radiographic assessment of fusion, patients were evaluated with VAS, ODI, and modified MacNab criteria. At the final follow-up, mean VAS and ODI scores reduced from 7.34 ± 1.63 and 50.03 ± 10.64 preoperatively to 1.62 ± 1.741 and 6.69 ± 4.294 postoperatively ($p < 0.0001$). According to Macnab criteria, excellent and good clinical outcomes were obtained in 34.5% and 62.1% of patients, respectively. Only one patient had minimal improvement from "Poor" preoperatively to "Fair" postoperatively. Computed tomography assessment of interbody fusion at the last

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follow-up showed successful fusion in 91.4% of patients. Based on these study observations, the authors concluded that an un-instrumented interbody fusion by packing a hollow interspace with cancellous bone allograft chips could be an adjunct to endoscopic foraminal lateral recess decompression select patients with validated painful, collapsed, and rigid motion segments.

Keywords: Allograft, Endoscopic lumbar decompression, Interbody fusion.

INTRODUCTION

A vacuum phenomenon is often seen on plain radiographs in patients with painful end-stage lumbar degenerative disc disease [1 - 20]. Recently, this radiographic finding has been correlated with directly visualized pathology often seen during routine lumbar endoscopy [10]. Patients often complain of a combination of mechanical back pain and neurogenic claudication [11, 13, 17, 18]. Naturally, this condition usually occurs in the elderly, often lacking general health status. Medical comorbidities often prohibit extensive spinal decompression and reconstructive fusion procedures. However, longer life expectancies and cumulative disability from spinal stenosis bring these types of patients routinely back into the office for evaluation and re-evaluation in search of less aggressive yet effective ways to treat their spinal stenosis-related walking endurance problems with less burdensome treatment [21 - 24]. While these visits can be frustrating for both the surgeon and the patient as seemingly nothing is getting done, the debate about what to do with these geriatric patients in their 80ies and 90ies remains [25].

In the elderly, the lumbar spine is often vertically collapsed, deformed, and may show radiographic signs of instability [11, 26 - 28]. Mechanical back pain is often combined with claudication symptoms making it increasingly difficult to get around. Many of these patients become increasingly dependent on assistive devices and, in the worst cases, on others' help. In many patients, painful collapsed lumbar motion segments may be associated with or vertical and anterolateral instability. Facet joints disease may also be involved [26]. This process can lead to the motion segment's complete structural failure and the loss of its biological function. Pfirrmann *et al*. published on the MRI appearance of advanced disc degeneration [27]. The vacuum phenomenon is often seen on plain radiographs, or CT scan images represent progressive intervertebral disc degeneration [14, 28]. This vacuum sign suggests complete disintegration of the nucleus pulposus tissue. Its underlying cause is unknown [18]. Patients' symptoms are often attributable to this type of severe disc degeneration because of associated stenosis in the central and lateral spinal canal, instability, and deformity [12]. Ongoing vertical collapse with spontaneous fusion may stabilize the spine but could also add to mechanical axial low back pain [29 - 33].

In the elderly, instrumented fusion surgeries are often not wanted by patients or prevented by the complexity of their poorly managed medical comorbidities. While the stenosis-related symptoms can easily be addressed with the various endoscopic decompression techniques, the empty vacuum disc is often left untreated. Hence, patients may continue to suffer from back pain since pain generators residing inside the intervertebral disc space remain untreated. This shortcoming of the endoscopic foraminal or lateral recess decompression provided the rationale for the authors' feasibility investigation of achieving more sustainable and reliable relief of low back pain by performing a concomitant interbody fusion with allograft bone chips. The authors expected that the addition of this simplified interbody fusion procedure by decorticating the endplates under direct endoscopic visualization and placing bone graft into the hollow vacuum disc interspace would provide patients with more reliable and longer-lasting pain relief.

The "insight-out" transforaminal endoscopic decompression technique is one of the initial techniques developed by many of the earlier key opinion leader spine surgeons – two of them are co-editor of this Bentham text on spinal endoscopy. While many surgeons have advocated other endoscopic techniques, the time-proven "insight-out" technique has afforded the authors of this chapter the ability to visualize the interior of an empty intervertebral disc space that they often encountered serendipitously during routine transforaminal endoscopic surgery. The video-endoscopic examination of an end-stage degenerative vacuum disc and direct visualization of pain generators within it has provided the conceptual basis for the authors' study on the clinical benefit of placing bone graft inside such a painful vacuum disc that can be easily validated with diagnostic provocative- and analgesia injections [34 - 38] either preoperatively or intraoperatively in the sedated yet awake patient [39 - 45]. The placement of bone graft into a vacuum disc space does not add much complexity to the endoscopic decompression surgery. In this chapter, the authors report clinical outcomes with the percutaneous transforaminal endoscopic decompression with the report on the feasibility of an un-instrumented interbody fusion with impaction of bone allograft into the lumbar interspace through the endoscopic working cannula as an alternative to more complex spinal procedures for those patients who are either unsuitable for or unwilling to undergo these more burdensome surgeries.

POSITION, ANESTHESIA & ACCESS PLANING

As with routine lumbar endoscopy, the patients are placed in a prone position on a lordotic frame under local anesthesia and sedation in all patients. The access trajectories for the transforaminal approach are also described in great detail in the peer-reviewed literature and several chapters of this Bentham book series on

CHAPTER 16

Full Endoscopic Endplate Decortication and Vertebral Mobilization Technique of Transforaminal Lumbar Interbody Fusion for Degenerative Spondylolisthesis

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Abstract: There are two kinds of endoscopic lumbar interbody fusion. One approach is a transforaminal approach using uniportal endoscopic surgery [6-8], and the other is a posterolateral approach like MIS TLIF using uniportal or biportal endoscopic surgery. The transkambin approach is similar to transforaminal uniportal endoscopic lumbar discectomy through the Kambin triangle through which also the endplate preparation and cage insertion are done. The posterolateral endoscopic TLIF techniques are similar to MIS TLIF using a tubular retractor system and mainly used by the surgeons who practice biportal endoscopic surgery. Because of the paucity of literature describing the uniportal endoscopic posterolateral approach for transforaminal interbody fusion (Endo-TLIF), we describe in this chapter the technique of full endoscopic endplate denudation and adhesion releasing technique of endoscopic transforaminal lumbar interbody fusion for degenerative spondylolisthesis and degenerative scoliosis.

Keywords: Endoscopic, Endplate Preparation, Fusion, Transforaminal Interbody Fusion.

INTRODUCTION

The aging population has increased the incidence of symptomatic degenerative spinal diseases such as degenerative spinal stenosis, spondylolisthesis, and degenerative disc disease [1]. Minimal invasive (MIS) spine surgery has the advantages of early recovery and normal structure preservations. The technical advancements in endoscopic spine surgery have led to more minimally invasive options for lumbar spine surgery [2]. Endoscopic lumbar interbody fusion has been attempted [3 - 5]. There are two kinds of endoscopic lumbar interbody fusion. According to the approaching route or corridors, one approach is a

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transforaminal approach using uniportal endoscopic surgery [6 - 8], and the other is a posterolateral approach like MIS TLIF using uniportal or biportal endoscopic surgery [3, 9, 10] (Figs. **1A** and **1B**). The transkambin approach is similar to transforaminal uniportal endoscopic lumbar discectomy through the Kambin triangle. Endplate preparation and cage insertion were performed *via* Kambin's triangle [6]. The posterolateral endoscopic TLIF techniques are similar to MIS TLIF using a tubular retractor system and mainly used by the surgeons who practice biportal endoscopic surgery. A paucity of literature describes the uniportal endoscopic posterolateral approach for transforaminal interbody fusion (Endo-TLIF). Kim and Wu *et al*. reported the clinical and computer tomographic study with technical note using the uniportal full endoscopic posterolateral transforaminal lumbar interbody fusion with endoscopic disc drilling preparation technique for symptomatic foraminal stenosis [3]. As the methods of the Endo-TLIF have developed, surgical indications have extended to most lumbar degenerative conditions, including spondylolisthesis and scoliosis.

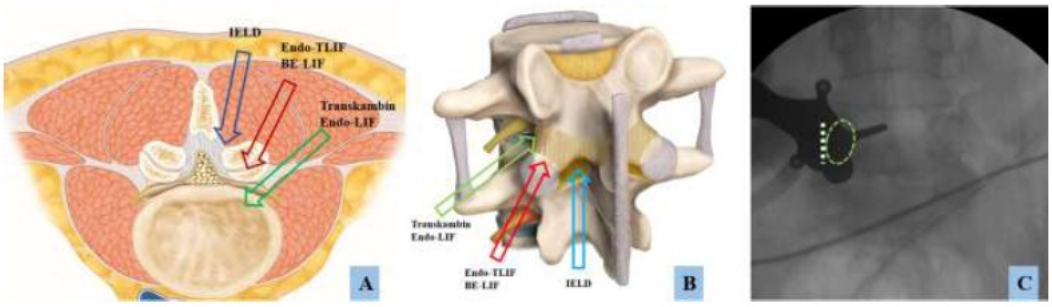

Fig. (1). Three routes of Endoscopy were illustrated on the axial plane **(A)** and the 3D vertebral model **(B).** IELD is an interlaminar endoscopic lumbar discectomy, Endo-TLIF is uniportal full endoscopic posterolateral transforaminal lumbar interbody fusion, BE-LIF is biportal endoscopic lumbar interbody fusion, Transkambin EndoLIF is uniporal transforaminal transkambin approach endoscopic lumbar interbody fusion. Docking position of left L5-S1 Endo-TLIF **(C).** The incision (dotted white line) was made over the left L5 pedicle (dotted green circle), and the working cannula was docked on the pars interarticularlis of right L5-S1.

In this chapter, we elaborate on the technique of full endoscopic endplate denudation and adhesion releasing technique of endoscopic transforaminal lumbar interbody fusion for degenerative spondylolisthesis and degenerative scoliosis, which decreases the endplate injury during endplate preparation by denudation technique and increase the mobility of the index segment for deformity correction by releasing the adhesions in the intravertebral disc space.

RATIONALE

Anatomical Considerations During Endo-TLIF Surgery

Uniportal transforaminal endoscopic fusion surgery is performed within a small safe corridor of Kambin's triangle [11]. It has to use a narrow-width cage to fit through the narrow safety corridor not to injure the exiting nerve root. In the uniportal full endoscopic posterolateral route transforaminal interbody fusion, the complete resection of the ipsilateral facet joint created enough space for the sizable interbody cage used in microscopic tubular transforaminal lumbar interbody fusion [1] (Figs. **1A** and **1B**).

Direct Bilateral and Contralateral Decompression of Central Spinal Canal and Nerve Roots with Endo-TLIF

Endo-TLIF has the advantages of both MIS fusion and endoscopic surgery. This technique is based on conventional MIS TLIF procedures [12] so that Endo-TLIF can perform direct decompression of neural structure [1 - 3]. Unilateral laminotomy for bilateral decompression is one of the advantages of the uniportal full endoscopic approach [13]. The contralateral nerve root could be fully decompressed through the inside-out and outside-in techniques [4, 5, 14]. The outside-in technique is defined as bony de¬compression of cephalad lamina, caudal lamina, inferior articu¬lar process, and superior articular process ("outside") to the ex¬tent that is sufficient for complete release of ligamentum flavum before removal of ligamentum en-bloc with a blunt instrument in the last part of the procedure to expose the spinal canal ("in"). This technique is commonly known as over the top decompression technique. [1, 4.15] The inside-out technique, on the other hand, involved bony decompression of the lamina, inferior articular process, and superior articular process with the early splitting of ligamentum flavum to get into the spinal canal ("inside") before releasing ligamentum flavum from within the spinal canal with concurrent bony decompression ("out") [5, 6]. Also, indirect decompression of the contralateral foramen can be achieved by reducing spondylolisthesis and restoration of the collapsed disc space by inserting a large-sized cage [7]. In the case that indirect decompression is insufficient, contralateral direct foraminotomy could be done by Endo-TLIF [16].

Concepts of Full Endoscopic Adhesion Releasing Technique with Endoscopic Drill

In a severe collapsed disc space, large syndesmophytes or a calcified disc may obstruct the disc space's entry due to extreme disc adhesion in the annulus portion of the intravertebral disc space. In these cases, it is difficult to open up the annulus

CHAPTER 17

Technical Pearls for Difficult Cases, Controversies and Complications of Lumbar Endoscopy

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Abstract: Spinal endoscopy has the stigma of being reserved for only a few that figure out how to master the steep learning curve and develop clinical practice settings where an endoscopic spine surgery can thrive. In essence, endoscopic treatment of herniated discs specifically and nerve root compression in the lumbar spine in general amounts to replacing traditional open spine surgery protocols with spinal endoscopic surgery techniques. In doing so, the endoscopic spine surgeon must be confident that the degenerative spine's common painful problems can be handled with the endoscopic spinal surgery techniques with at least comparable clinical results and complication rates. This chapter illustrates several complex clinical examples and proposes treatment algorithms with pertinent pearls and tips for revision and complication cases.

Keywords: Complications, Controversies, Endoscopic techniques, Herniated disc.

INTRODUCTION

The increasing utilization of percutaneous endoscopic lumbar discectomy has also brought to light its advantages and clinical outcomes [1 - 5]. As with any new technology, there is a surge of utilization followed by a rise in less favorable results and complications highlighting the procedure's limitations. Percutaneous endoscopic lumbar discectomy (PELD) – whether in its transforaminal [1, 6 - 15] or interlaminar form [1, 16 - 21] – has procedure-specific shortcomings and additional limitations dictated by the underlying degenerative disc disease that is

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worth discussing. In this chapter, the authors list the common problems responsible for inferior clinical outcomes, complications, controversies, and technical tips and pearls on how to resolve them.

1. Early Recurrence

To achieve successful long-term outcomes with the PELD, avoiding complications is essential. Early relapse after PELD is one of the problems though that may occur after PELD (Fig. **1**). While there may be patient-related factors, procedural details include incomplete decompression that may be responsible for an early recurrence.

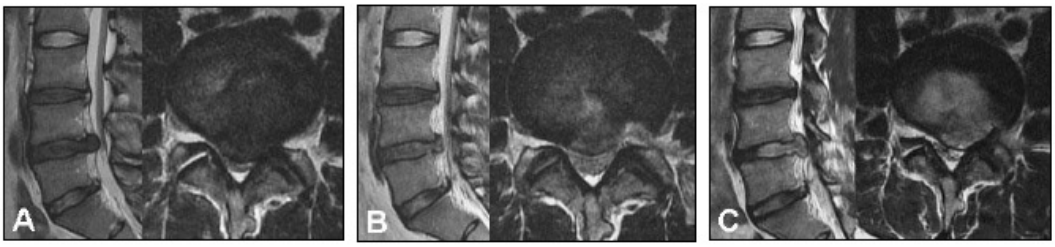

Fig. (1). Recurrence after PELD. Recurrence after PELD may be related to the early segmental loading to the operation segment after percutaneous endoscopic lumbar discectomy. (A) Preoperative MRI, (B) Immediate postoperative MRI, (C) Recurrence 3 months after PELD.

Giving patients clear postoperative instructions, including short-term bed rest, lifting limitations, choreographed walking schedules, is crucially important in avoiding problems induced by poor patient compliance during the early postoperative recovery. Physical therapy should be cautiously started 6 - 12 weeks after surgery, if at all, as many patients recover without such active exercise programs. The most controversial aspect of the endoscopic discectomy operation is to decide when to end it. In other words, when having sufficient amounts of disc tissue been removed to complete the procedure. The answer to this seemingly trivial question is not apparent. This team of authors recommends removing all unstable, delaminated, fissured, and devitalized tissue from the intervertebral disc spaces. It is during this portion where the intradiscal “inside-out” technique is most advantageous. While this subject is complex and no straightforward answer exists to the question of whether there are any prognosticators that the endoscopic spine surgeon could discern during the operation to help decide the extent of the discectomy, it is just as reasonable to assume that the underlying disease and the ability of the operated diseased remaining intervertebral disc is capable of withstanding the repetitive compressive loads of daily activities and of preventing vertical collapse is as much responsible for early recurrence. The latter question is clearly out of the surgeons' hands. Therefore, each patient should be monitored

closely during the early recovery period for signs and symptoms of recurrent disc herniation.

2. VASCULAR INJURY

One of the dreaded complications of PELD is an injury to the vascular structures anterior and lateral to the spine. Especially, injuries to the segmental artery and major vessels are of concern. Segmental artery injury mainly occurs during transforaminal work, especially when using the exiting nerve root approach, because the segmental artery passes under the exiting nerve root (Fig. **2**). This segmental artery injury may induce serious retroperitoneal hematoma after PELD. The authors recommend that the endoscopic spine surgeon control bleeding from the segmental artery with radiofrequency coagulation. In the authors' experience, conversion to open surgery has not been necessary. If a symptomatic retroperitoneal hematoma should form, it can be treated with open or interventional radiology hematoma evacuation. Observation and supportive care measures are usually sufficient to manage such a retroperitoneal hematoma [22 - 24]. The authors are unaware of any publication detailing the application of embolization procedures to manage this unpleasant problem.

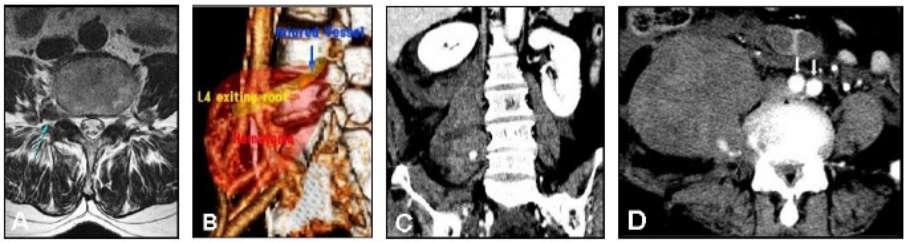

Fig. (2). Retroperitoneal hematoma (C,D) after percutaneous endoscopic lumbar discectomy for far lateral disc (A) due to segmental artery injury (B) [22].

3. NEURAL INJURY

Neural injury after PELD, although uncommon, will likely occur at one point or another during the carrier of an endoscopic spine surgeon. These are characterized by motor weakness and sensory loss. These injuries are commonly related to retraction-related neuropraxia. True surgical transection of traversing or exiting nerve root during routine lumbar endoscopy is very uncommon, and this team of authors is unaware of any such reports. Therefore, neuropraxia related problems will likely resolve spontaneously with supportive care measures, and patients should be reassured. Neuropraxia should be distinguished from dysesthesia, which frequently occurs after PELD [3, 18]. The burning sensation with decreased sensation and proprioception – although irritating to the patient – typically resolves with transforaminal epidural steroid injections and medical management

CHAPTER 18

Treatment of Degenerative Lumbar Spondylolisthesis with Endoscopic Decompression of the Lumbar Spinal Canal

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Abstract: Degenerative spondylolisthesis is a common problem in the elderly. The associated spinal stenosis in the central canal and the foramina may cause sciatica-type claudication symptoms affecting the lower back and extremities. Walking endurance is typically reduced. Eventually, patients may decide on surgical decompression if conservative care measures, including spinal injections, physical therapy, activity modifications, and pain medication, no longer provide relief. In the elderly, extensive spine surgery is always of concern regarding operation length, blood loss, postoperative pain management, and medical comorbidities whose management may easily spin out of control following major spine surgery. In a small subset of spondylolisthesis patients, decompression alone may suffice, particularly in those where the spinal motion segment has become rigid due to endstage degenerative disc disease, vertical collapse, and auto fusion. On the other hand, stenosis is often severe in these types of patients, for which reason extensive decompression may be necessary, and postoperative iatrogenic instability may ensue. In this article, the authors present the technique of endoscopic canal and foraminal decompression in patients with such advanced spondylolisthesis. They discuss the technical caveats and limitations of the procedure.

Keywords: Degenerative spondylolisthesis, Endoscopic decompression, Spinal stenosis.

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INTRODUCTION

Spondylolisthesis may cause severe stenosis in the central spinal canal, the bilateral lateral recesses, and neuroforamina [1, 2]. Decompression without instrumentation may be tried but may fail if the patient develops postoperative instability [3]. This topic has been subject to extensive clinical investigation in the Spine Patient Outcome Research Trials (SPORT) and other studies [4 - 9]. Limited decompression with laminotomy or laminoforaminotomy has been tried [10]. With the recent advent of minimally invasive spinal surgeries, including endoscopic decompression techniques, this somewhat controversial subject has been revisited as the collateral exposure-related damage may not be as extensive. Endoscopic decompression strategies may be useful in patients with rigid end-stage degenerative disc disease and the complete vertical collapse of the intervertebral disc space. In those cases, a spontaneous fusion of the anterior column may be present *via* bridging sentinel osteophytes or even through the interbody space itself. In these types of patients, endoscopic decompression for claudication-related spinal stenosis symptoms may be an alternative to traditional open decompression without the associated blood loss, postoperative pain, and recovery associated with laminectomy with and without fusion. In this chapter, the authors present two illustrative cases and review the technical steps involved where this strategy was used successfully to the patients' advantage.

CASE PRESENTATIONS

Case 1

The first patient was a 77-year-old female whose chief complaint was difficulty walking and standing erect, typical of lumbar spinal stenosis. Symptoms recently had worsened over the past 2 months when walking endurance was reduced to 20 meters. The patient’s motor strength on spot testing did not show obvious deficits. However, there was tenderness in the lower back, hyporeflexia in the lower extremities, a negative straight leg raise test bilaterally, and normal vascular examination suggesting that the patient’s symptoms were predominately related to neurogenic claudication. Advanced CT and MRI imaging studies of the lumbar spine showed severe central, lateral recess and foraminal stenosis with associated grade 1 spondylolisthesis at the L4/5 level (Fig. **1**).

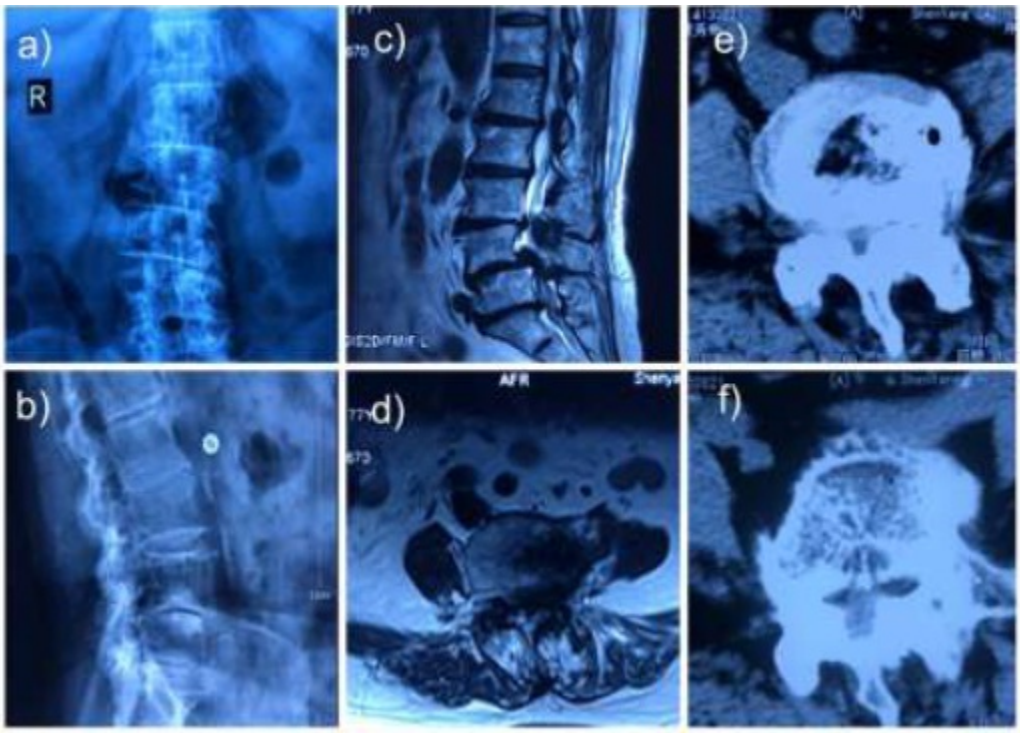

Fig. (1). Shown are the preoperative anteroposterior (a) and lateral (b) views of a 77-year-old female patient with claudication symptoms. Sagittal (c) and axial (d) MRI scans and axial CT scan sections (e-f) through the L4/5 level showed severe central, lateral recess, and foraminal stenosis preoperatively associated with rigid grade 1 spondylolisthesis. Dynamic extension-flexion views did not demonstrate any radiographic evidence of translational instability.

The indication for decompression surgery was established given the patient's severe disability with corresponding findings on the imaging studies and failed non-operative care. The patient has clear symptoms of degenerative lumbar spondylolisthesis leading to lumbar spinal stenosis, and imaging confirmed lumbar spondylolisthesis and lumbar spinal stenosis. The surgical decompression was planned with use of the endoscopic spinal surgery techniques and transforaminal approach in prone position under local anesthesia with 1% lidocaine and fluoroscopic image-guidance was adopted. Employing standard transforaminal endoscopic surgery protocol, the symptomatic right-sided neuroforamen was accessed with an 18-G spinal needle through which a guidewire was placed. A serial dilation over the guidewire, an endoscopic working channel was placed posterolaterally onto the hypertrophic facet joins. The authors preferred decompression tool is a motorized endoscopic drill which fits right through the central working channel of the endoscope. Thus, resection of the superior articular process to the base of the pedicle inferiorly, and to the

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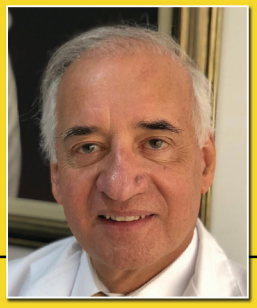
KAI-UWE LEWANDROWSKI

Dr. Lewandrowski has dedicated his career to developing and implementing formalized endoscopic spinal surgery protocols by applying his NIH- and SBIR-funded academic research background to clinical investigation with sophisticated statistical analysis. His acumen has enabled him to build an entrepreneurial outpatient spinal surgery program that provides quality medical care to many patients.



JORGE FELIPE RAMÍREZ LEÓN

Dr. Ramirez is the number one key opinion leader in the Spanish-speaking world - an entrepreneur innovator spine surgeon who has advanced spinal endoscopy as a physician, business owner, and current or past president of the leading Latinamerican spine societies.

ANTHONY YEUNG

Dr. Yeung is the world's most renowned spinal endoscopist who was there at the beginning when it all started some 35 years ago. He was one of the first in the United States to begin his own vertically integrated ambulatory surgery center focused on endoscopic outpatient spine care.

Endoscopic ablation and decompression procedures of the lumbar spine are now routine in many countries. Driven by technological advances, the clinical protocols have gone through several iterations since they were initially popularized in the mid 1980ies for simple discectomies. This modern technology platform enables many surgeons to perform more sophisticated operations, even on complex clinical problems. Backed up by a growing body of high-grade clinical evidence, it is clear that lumbar endoscopic surgery is not only here to stay but will likely replace some of the traditional image-based open spine surgery protocols. In the second volume of Contemporary Endoscopic Spine Surgery: Lumbar Spine, the editors intended to give the reader a most up-to-date snapshot of the current state-of-the-art of lumbar endoscopy. This multi-authored and clinically focused medical monograph explains the staged management protocols of validated pain generators advocated for by the editors and their expert surgical execution.

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