ENDOSCOPIC SPINE ACADEMY
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MOST IMPORTANT SCIENTIFIC STUDIES

ENDOSCOPIC SPINE SURGERY AND ENDOSCOPIC PAIN THERAPY

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PREFACE

ESPINEA® was founded by joimax®, the market leader in endoscopic spine surgery, with the clear aim of offering an open platform for training, education, research and development in spinal therapies. Since 23 years joimax® offers highly specialized products for endoscopic minimally invasive spinal procedures. These years of experience and the strength in the development of instruments and methods ensures the most sophisticated devices and applications and a highly gentle treatment of patients, always having their best interest in mind.

Responding to the variation of diagnoses related to spinal pathologies and its unique challenges, joimax® on the forefront in this market segment is constantly expanding its range of methods, instrument sets and corresponding electronic devices to address each pathology and vertebral segment in a precisely designed way.

Most important studies show the successful use of all systems on a scientific basis. As the market leader in endoscopic spine surgery, joimax® is committed to outstanding medical education and training worldwide. Within ESPINEA® we continuously review latest literature and support future research.

The increasing number of publications worldwide are also reflecting the high interest in endoscopic spine surgery (Fig. 1).

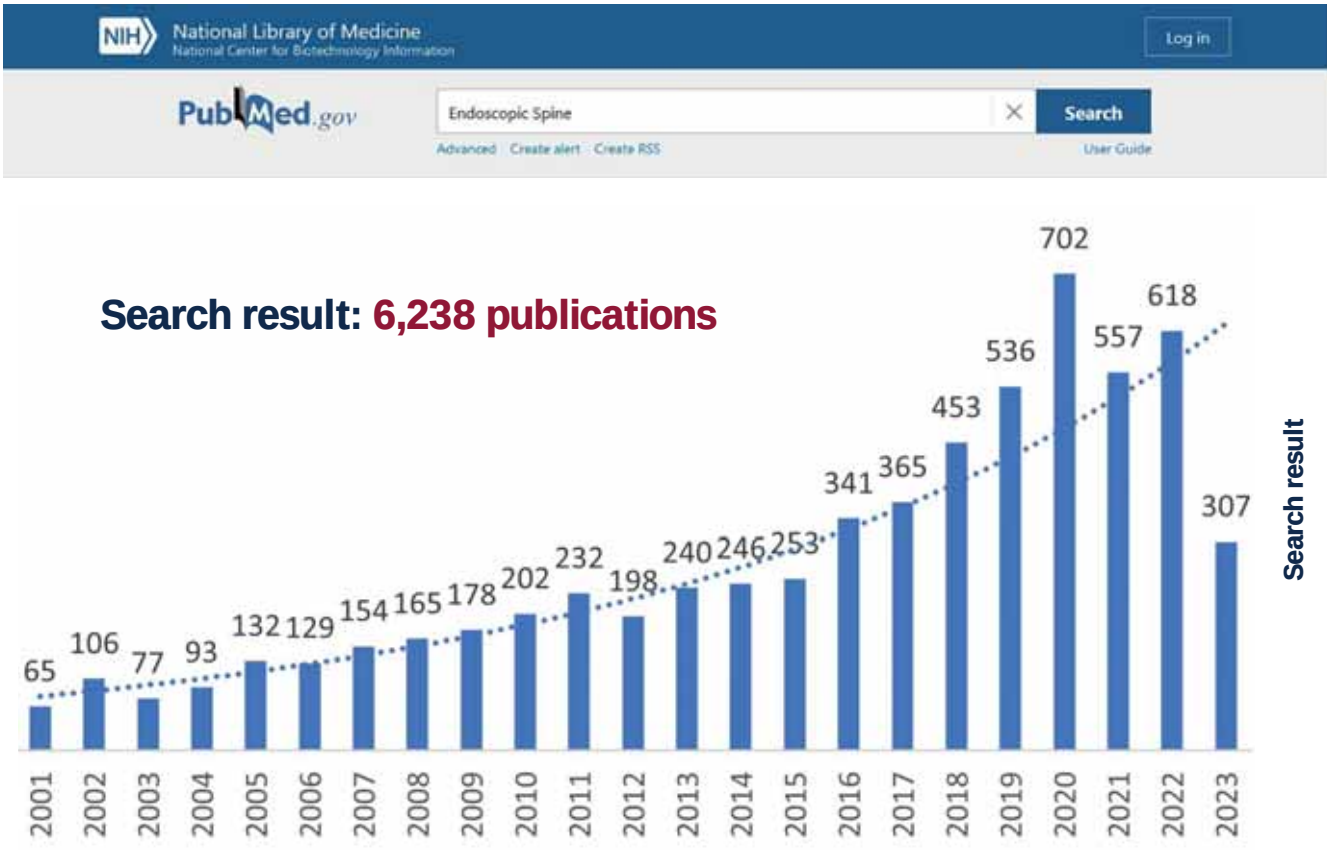

Fig. 1: Number of results for a search using the search terms “Endoscopic Spine” in PubMed [2023-05-30]: since the foundation of joimax® in 2001 the number of publications rose drastically within the last 23 years and is now approaching exponential growth.

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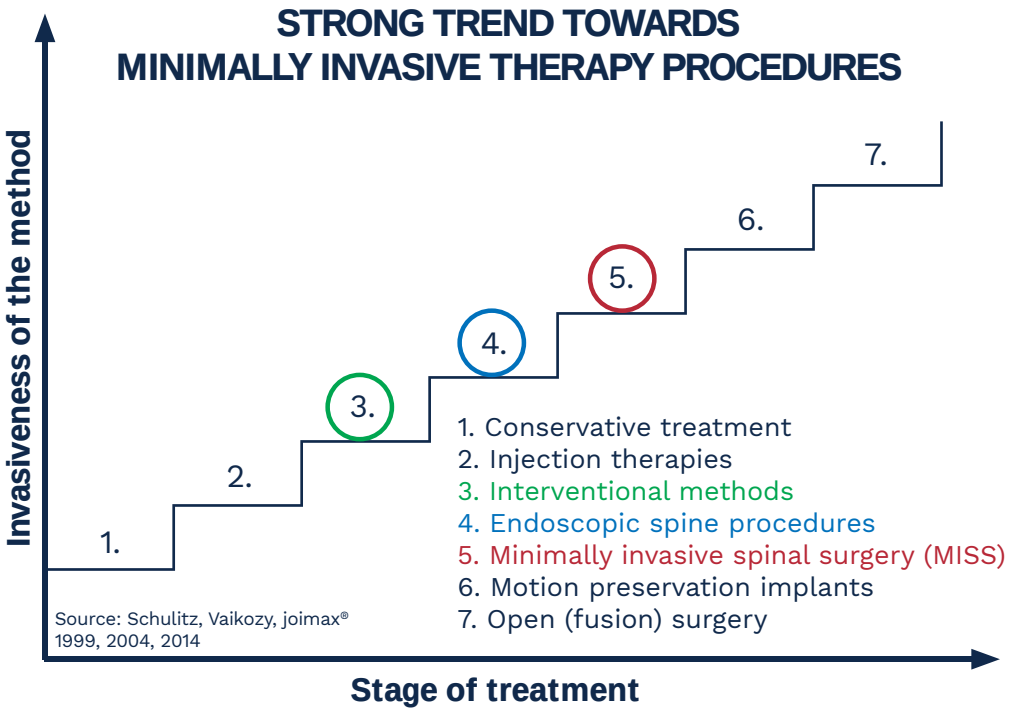
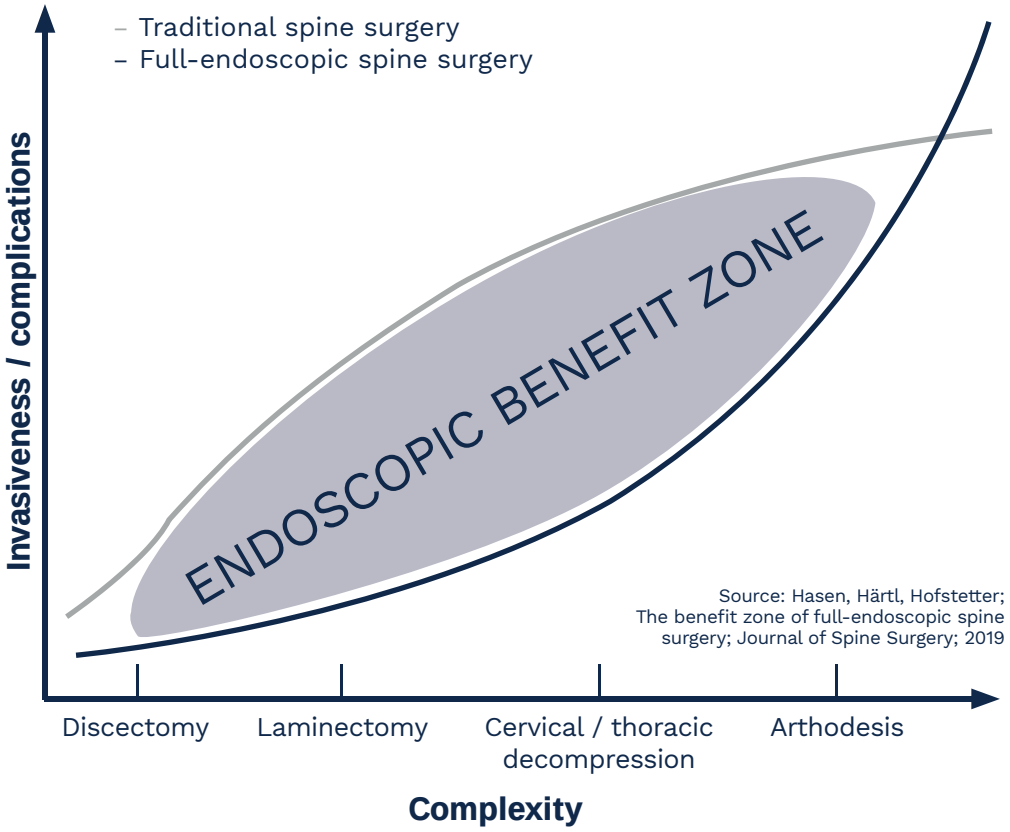

STRONG TREND TOWARDS
MINIMALLY INVASIVE THERAPY PROCEDURES
Invasiveness of the method
1.
2.
3.
4.
5.
6.
7.
1. Conservative treatment
2. Injection therapies
3. Interventional methods
4. Endoscopic spine procedures
5. Minimally invasive spinal surgery (MISS)
6. Motion preservation implants
7. Open (fusion) surgery
Source: Schulitz, Vaikozy, joimax®
1999, 2004, 2014
Stage of treatment


– Traditional spine surgery
– Full-endoscopic spine surgery
Invasiveness / complications
ENDOSCOPIC BENEFIT ZONE
Source: Hasen, Härtl, Hofstetter;
The benefit zone of full-endoscopic spine
surgery; Journal of Spine Surgery; 2019
Discectomy
Laminectomy
Cervical / thoracic
decompression
Arthodesis
Complexity

ADVANTAGES

Most of the innovative endoscopic procedures offer treatment solutions with gentle access to the spinal canal for a wide range of spinal pathologies. Full-endoscopic surgical treatment of herniated discs and spinal stenosis for example with TESSYS®, iLESSYS® or CESSYS® is safe and effective and has multiple advantages over open and microsurgical methods. Clear advantages and the overall success of endoscopic surgical procedures are proven in clinical studies with the following outcomes summarized.

For patients:

- Very good clinical results, many cases with significant clinical and functional improvements (VAS, ODI, MacNab) with an overall success rate of up to 93.8%
- Minimal operative damage to soft tissue; no dissection of muscles, ligaments or tendons; maintenance of spinal stability; lower complication rate and systemic wound response; almost no scar tissue
- Faster postoperative recovery, fast return to work
- Less use of analgesics / opioids

For surgeons:

- Continuous visual control of surgical site with sophisticated technology and optimal visualization
- Small intraoperative radiation exposure
- Endoscopic interbody fusion is safe and effective
- Endoscopic surgery allows the use of local anesthesia only

For hospitals:

- Low recurrence rate after endoscopic transforaminal discectomy
- Patients travel far distances, if endoscopic methods are not available close by
- high patient satisfaction

For insurance companies:

- Overall lower hospitalization and postoperative costs of care

STUDIES WITH SCIENTIFICALLY PROVEN OUTCOMES

Scientific prove of these conclusions can be found in the subsequent publications.

The results allow a glimpse into the near future, in which endoscopic spinal surgery is increasingly regarded as the new «gold standard».

LITERATURE OVERVIEW

EVOLUTION OF ENDOSCOPIC SPINE SURGERY

Current Status and research hotspots in the field of full endoscopic spine surgery: A bibliometric analysis **P 38**
Lin G-X, Zhu M-T, Kotheeranurak V, Lyu P, Chen C-M, Hu B-S; *Front. Surg.* (2022) 9

> **Conclusions:** From January 1, 1993, to June 10, 2022, 1064 articles were identified. Following a surge in 2016, the number of publications increased significantly, reaching 211 in 2020, which is more than 100 times the number in 1993. Additionally, the 1064 articles were cited 13404 times. between 1997 and 2018.

Evolution of endoscopic transforaminal lumbar approach for degenerative lumbar disease **P 39**
Kim HS, Raorane HD, Wu PH, Yi YJ, Jang IT; *Spine Surg* 2020;6(2):424-437

> **Quote**: It is equally safe as 'inside-out' technique and provides careful handling of structures like extruded fragments avoiding neural structures.

Worldwide research productivity in the field of full-endoscopic spine surgery: a bibliometric study **P 40**
Lin G-X, Kotheeranurak V, Mahatthanatrakul A, Ruetten S, Yeung A, Lee S-H, Ahn Y, Kim H-S, Hofstetter C, Lee J-H, Choi K-C, Lewandrowski K-U, Kim J-S; *European Spine Journal* (2020) 29: 153-160

> **Quote**: The improvement of endoscopic tools drives the evolution of the IESS by widening the interlaminar window. Furthermore, it also broadens the indications of the endoscopic lumbar spine surgery.

The evolution of interlaminar endoscopic spine surgery **P 41**
Chen KT, Jabri H, Lokanath YK, Song M-S, Kim J-S; *J Spine Surg* (2020) 6(2): 502–512

> **Quote**: The improvement of endoscopic tools drives the evolution of the IESS by widening the interlaminar window. Furthermore, it also broadens the indications of the endoscopic lumbar spine surgery.

The evolution of minimally invasive spine surgery **P 42**
Yoon JW, Wang MY; *J Neurosurg Spine* (2019) 30:149-158

> **Quote**: The principle of minimizing soft-tissue disruption while maximizing the goal of surgery remains a core surgical tenet. It is likely that these trends will continue as neurosurgeons seek to improve the care they provide for an ever-growing and aging population that is beginning to demand healthcare as a right.

A History of Endoscopic Lumbar Spine Surgery: What Have We Learnt? **P 43**
Mayer MH; *Hindawi BioMed Research Int* (2019): ID 4583943

> **Quote**: The acceptance of this technology is high among young surgeons but it is the task and duty of the protagonists of the older generation, the hospitals, and the scientific societies to develop learning- and training-concepts to shorten learning curves and to improve technical quality and clinical outcomes.

Unsuccessful Percutaneous Endoscopic Lumbar Discectomy: A Single-Center Experience of 10,228 Cases **P 44**

Choi K-C, Lee J-H, Kim J-S, Sabal LA, Lee S, Kim H, and Lee S-H; *Neurosurgery* (2015) 76, no. 4: 372–80

Conclusions: In 12 years, 10 228 patients had undergone PELD; 436 (4.3%) cases were unsuccessful. [...] Proper surgical indications and good working channel position are important for successful PELD.

Learning curve of full-endoscopic lumbar discectomy **P 45**

Hsu HT, Chang SJ, Yang SS, Chai CL; *Eur. Spine J* (2013) 22 (4): 727-733

Conclusions: The learning curve of the transforaminal approach was steep and easy to learn, while the learning curve of the interlaminar approach was flat and hard to master.

Full-Endoscopic Interlaminar and Transforaminal Lumbar Discectomy Versus Conventional Microsurgical Technique: A Prospective, Randomized, Controlled Study **P 46**

Ruetten S, Komp M, Merk H, Godolias G; *Spine* (2008) 33 (9):931-939

Conclusions: The clinical results of the full-endoscopic technique are equal to those of the microsurgical technique. At the same time, there are advantages in the operation technique and reduced traumatization. [...] Full-endoscopic surgery is a sufficient and safe supplementation and alternative to micro-surgical procedures.

Endoscopic Transforaminal Discectomy for Recurrent Lumbar Disc Herniation: A Prospective, Cohort Evaluation of 262 Consecutive Cases **P 47**

Hoogland D, van den Brekel-Dijkstra K, Schubert M, Miklitz B; *Spine* (2008) 33.9:973-978

Conclusions: ETD for recurrent disc herniation seems to be an effective method with few complications and a high patient satisfaction.

Posterolateral Endoscopic Excision for Lumbar Disc Herniation: Surgical Technique, Outcome, and Complications in 307 Consecutive Cases **P 48**

Yeung AT, Tsou PM; *Spine* (2002) 27 (7): 722-731

Conclusions: The surgical outcome of posterolateral endoscopic discectomy for lumbar disc herniation is comparable with that for the traditional open transcanal microdiscectomy. Intracanal and extracanal herniations, reherniations, and incidental lateral recess stenosis can be addressed by the same approach.

Percutaneous Posterolateral Lumbar Discectomy and Decompression with a 6.9-Millimeter Cannula **P 49**

Schaffer JL, Kambin P; *The Journal of Bone and Joint Surgery* (1991); 73 (6): 822–831

Conclusions: There were no major complications, including superficial or deep infection, and no patient had neurovascular compromise.

SUPERIORITY OF ENDOSCOPIC SPINE SURGERY

Full-endoscopic Transforaminal Discectomy Versus Open Microdiscectomy for Sciatica: Update of a Systematic Review and Meta-analysis **P 52**
Gadjradj PS, Harhangi BS; Spine (Phila Pa 1976). 2022 Sep 15; 47(18): E591-E594

Original article:
Percutaneous Transforaminal Endoscopic Discectomy Versus Open Microdiscectomy for Lumbar Disc Herniation: A Systematic Review and Meta-analysis
Gadjradj PS, Harhangi BS, Amelink J, van Susante J, Kamper S, van Tulder M, Wilco PC, Vleggert-Lankamp C, Rubinstein SM; ; Spine (Phila Pa 1976) (2021) 46(8): 538-549.

Summary: There is high quality evidence in the literature regarding equivocal outcomes e.g. leg pain reduction for PTED compared to microdiscectomy in both the intermediate and long term. Furthermore, there was moderate level evidence of better functionality after PTED at the intermediate term and, high level evidence of better functionality after PTED in the long term, compared to microdiscectomy.

Full endoscopic versus open discectomy for sciatica: randomised controlled non-inferiority trial **P 53**
Gadjradj PS, Rubinstein SM, Peul WC, Depauw PR, Vleggeert-Lankamp CL, Seiger A, van Susante JLC, de Boer MR, van Tulder MW, Harhangi BS; BMJ (2022) 376: e065846

Quote: PTED was non-inferior to open microdiscectomy in reduction of leg pain. PTED resulted in more favourable results for self-reported leg pain, back pain, functional status, quality of life, and recovery.

Comparative Effects and Safety of Full-Endoscopic Versus Microscopic Spinal Decompression for Lumbar Spinal Stenosis: A Meta-Analysis and Statistical Power Analysis of 6 Randomized Controlled Trials **P 54**
Yang Z, Wang H, Li W, Hu W; Neurospine (2022) 19: 996–1005

Quote: Full-endoscopic spinal decompression is a better treatment for lumbar spinal stenosis, showing more effective leg pain improvement, shorter operative time, and fewer complications than microscopic decompression.

Biomechanics of Transforaminal Endoscopic Approaches **P 55**
Farshad M, Hagel V, Spirig JM, Fasser M-R, Burkhard MD, Widmer J, Calek A-K; Spine (Phila Pa 1976) (2022)

Quote: Biomechanically, the transforaminal endoscopic intracanal technique preserves the native range of motion of lumbar vertebral segments and shows a trend towards biomechanically superiority to the inside-out technique and open decompression procedures.

Endoscopic decompression for the treatment of lumbar spinal stenosis: an updated systematic review and meta-analysis **P 56**
Perez-Roman RJ, Gaztanaga W, Lu VM, Wang MY; J Neurosurg Spine (2021): 1–9

> **Quote:** Both endoscopic and MIS techniques are safe and effective methods for treating patients with symptomatic lumbar stenosis. Patients who undergo endoscopic surgery seem to report less postoperative low-back pain and significantly reduced hospital stay with a trend toward less perioperative blood loss.

Spinal endoscopy: evidence, techniques, global trends, and future projections **P 57**
Simpson AK, Lightsey HM 4th, Xiong GX, Crawford AM, Minamide A, Schoenfeld AJ; *Spine J.* 2021 Jul 13:S1529-9430(21)00819-6

> **Quote:** While the extent of endoscopic spine growth is uncertain, consideration of these factors and their associated system dynamics makes it hard to imagine a future state where spinal endoscopy does not occupy a recognizable portion of the standard spine surgical armamentarium.

Percutaneous endoscopic lumbar discectomy compared with other surgeries for lumbar disc herniation: A meta-analysis **P 58**
Bai X, Lian Y, Wang J, Zhang H, Jiang M, Zhang H, Pei B, Hu C, Yang Q; *Medicine (Baltimore).* 2021 Mar 5; 100(9):e24747

> **Quote:** PELD was associated with better effects and similar complications with other surgeries in LDH.

Expanded Indications of Full Endoscopic Spine Sugery **P 59**
Krishnan A, Kim HS, Raj A, and Dave BR; *J Minim Invasive Spine Surg Tech* (2021): 6(Suppl 1): S130-S156

> **Quote:** The techniques and indications of FESS has evolved. The scientific evidence has moved away from inferiority to non-inferiority when comparing results with conventional techniques. Its superiority in all aspects would soon get established and is likely to be the future of spine surgery with further innovations in technology and learnings.

Comparison of clinical and radiological outcomes of full-endoscopic versus microscopic lumbar decompression laminectomy for the treatment of lumbar spinal stenosis: a systematic review and meta-analysis **P 60**
Tang S, Mok TN, He Q, Li L, Lai X, Sin TH, Deng J, Yu S, Li J, Wu H, ; Ann Palliat Med (2021): apm-21-198

> **Quote:** Compared to MI decompression, the FE decompression method resulted in better pain control in the early postoperative period, both in the lower back and legs, as well as shorter operative and shorter hospitalization times.

AOSpine Consensus Paper on Nomenclature for Working-Channel Endoscopic Spinal Procedures **P 61**

Hofstetter CP, Ahn Y, Choi G, Gibson JNA, Ruetten S, Zhou Y, Li ZZ, Siepe CJ, Wagner R, Lee JH, Sairyo K, Choi KC, Chen CM, Telfeian AE, Zhang X, Banhot A, Lokhande PV, Prada N, Shen J, Cortinas FC, Brooks NP, Van Daele P, Kotheeranurak V, Hasan S, Keorochana G, Assous M, Härtl R, Kim JS;
Global Spine J (2020) 10(25): 111-121

Conclusions: This will hopefully facilitate development, standardization of procedures, teaching, and widespread acceptance of full-endoscopic spinal procedures.

Is Endoscopic Discectomy the Next Gold Standard in the Management of Lumbar Disc Disease? Systematic Review and Superiority Analysis **P 62**

Muthu S, Ramakrishnan E, Chellamuthu G; *Global Spine J.* (2020) Sept: 1-17

Conclusions: With recent advances in the field of ED, the procedure has the potential to take over the place of MD as the gold standard of care in management of lumbar disc disease.

The Endoscopic Approach to Lumbar Discectomy, Fusion, and Enhanced Recovery: A Review **P 63**

Liounakos JI, Wang MY; *Global Spine J.* 2020 Apr;10(2 Suppl):65S-69S

Quote: The indications for endoscopic spine surgery are growing, with applications for fusion being the newest addition. Coupled with newly developed ERAS programs, endoscopic spine surgery may represent a means by which to increase access to care, while minimizing overall cost and maximizing quality, in a health market that today is burdened by crippling cost and regulatory constraints.

The benefit zone of full-endoscopic spine surgery **P 64**

Hasan S, Härtl R, Hofstetter CP; *J. Spine Surg.* (2019) 5(Suppl 1): S41-S56

Conclusions: We believe that endoscopic techniques offer a more powerful and less morbid approach to spinal pathology that ultimately elevates the standard of care when treating our patients.

Outcomes of endoscopic discectomy compared with open microdiscectomy and tubular discectomy for lumbar disc herniations: a meta-analysis **P 65**

Barber SM, Nakhla J, Konakondla S, Fridley JS, Oyelese AA, Gokaslan ZL, Telfeian AE;
J. Neurosurg Spine (2019) 6: 1-14

Conclusions: We believe that endoscopic techniques offer a more powerful and less morbid approach to spinal pathology that ultimately elevates the standard of care when treating our patients.

Endoscopic spine discectomy: indications and outcomes **P 66**
Ahn Y; International Orthopaedics (2019) 43: 909–916

> **Quote:** Endoscopic spine surgery for soft disc herniation can be effective with benefits of minimal tissue trauma in properly selected cases.

A randomised controlled trial of transforaminal endoscopic discectomy vs microdiscectomy **P 67**
Gibson JNA, Subramanian AS, Scott CEH; *Eur Spine J* (2017) 26:847–856

> **Quote**: Functional improvements were maintained at 2 years in both groups with less ongoing sciatica after TED. A greater revision rate after TED was offset by a more rapid recovery.

Endoscopic Spine Surgery: Distance Patients Will Travel for Minimally Invasive Spine Surgery **P 68**
Telfeian AE, Iprenburg M, Wagner R; *Pain Physician* (2017) 20:E145-E149

> **Quote**: [...] distance patients are willing to travel for elective spine surgical care may be a quality metric that reflects the broader spectrum of quality and reminds health care providers that in the end what we provide may not be as important as what the patient wants.

Transforaminal endoscopic spinal surgery: The future 'gold standard' for discectomy? A review **P 69**
Gibson JNA, Cowie JG, Iprenburg M; *The Surgeon* (2012) 10.5:290-296

> **Conclusions**: there are good arguments supporting a more widespread adoption of transforaminal endoscopic surgery for the treatment of lumbar disc prolapse with or without foraminal stenosis.

COST-EFFECTIVENESS OF ENDOSCOPIC SPINE SURGERY

Cost-effectiveness of full endoscopic versus open discectomy for sciatica **P 72-73**
Gadjradj PS, Broulikova HM, Dongen JM van, Rubinstein SM, Depauw PR, Vleggeert C, Seiger A, Peul WC, van Susante JL, van Tulder MW, Harhangi BS; Br J Sports Med (2022): doi:10.1136/bjsports-2021-104808

> **Conclusions:** Cost-effectiveness acceptability curves indicated that the probability of PTED being less costly and more effective (ie, dominant) compared with open microdiscectomy was 99.4% for leg pain and 99.2% for QALYs, suggestting that PTED is more cost-effective from the societal perspective compared with open microdiscectomy for patients with sciatica.

Comparison of direct costs of percutaneous full-endoscopic interlaminar lumbar discectomy and microdiscectomy: Results from Turkey **P 74**
Ünsal ÜÜ, Şentürk S.; Ideggyogy Sz (2021) 74: 197–205

> **Quote:** The sum of total costs was $1,249.50 in the PELD-Local group, $1,741.50 in the PELD-General group, $2,015.60 in the MD-Spinal group, and $2,348.70 in the MD-General group. The sum of total costs was higher in the MD-Spinal and MD-General groups than in the PELD-Local and PELD-General groups.

Cost-effectiveness of microdiscectomy versus endoscopic discectomy for lumbar disc herniation **P 75**
Choi K-C, Shim H-K, Kim J-S, Cha KH, Lee DC, Kim ER, Kim MJ, Park C-K; Spine J (2019) 19: 1162–1169

> **Conclusions:** Compared with MD, ED saved an additional net of $8,064 per QALY (cost/quality-adjusted life year) (p<.01). ED was more cost-effective compared with MD at 1-year follow-up.

A Cost-utility Analysis of Percutaneous Endoscopic Lumbar Discectomy for L5-S1 Lumbar Disc Herniation: Transforaminal versus Interlaminar **P 76**
Wang D, Xie W, Cao W, He S, Fan G, Zhang H; Spine (Phila Pa 1976) (2019) 44: 563–570

> **Quote:** Observed costs per QALY gained for L5-S1 LDH with PETD or PEID were similar for patients, demonstrating that the two different approaches of PELD are equally cost-effective and valuable interventions.

Efficacy of Transforaminal Endoscopic Spine System (TESSYS) Technique in Treating Lumbar Disc Herniation **P 77**
Pan Z, Ha Y, Yi S, Cao K; *Med Sci Monit* (2016) 22:530-539

> **Conclusions:** TESSYS had clinical advantages over FD and entails less trauma and quicker postoperative recovery, suggesting that TESSYS is well tolerated by patients and is a better approach than FD in surgical treatment of LDH.

CERVICAL SPINE

Learning curve for endoscopic posterior cervical foraminotomy **P 80**
Perfetti DC, Rogers-LaVanne MP, Satin AM, Yap N, Khan I, Kim P, Hofstetter CP, Derman PB; Eur Spine J (2023): doi:10.1007/s00586-023-07623-6

Conclusions: PECF is an advanced endoscopic technique with an initial improvement in operative time that occurred after as few as 8 cases to as many as 28 cases in this series. A second learning curve may occur with additional cases. Patient-reported outcomes improve following surgery independently from the surgeon's position on the learning curve. PECF is a safe and effective technique that current and future spine surgeons should consider as part of their armamentarium.

Microscopic Anterior Cervical Discectomy and Fusion Versus Posterior Percutaneous Endoscopic Cervical Keyhole Foraminotomy for Single-level Unilateral Cervical Radiculopathy: A Systematic Review and Meta-analysis **P 81**
Guo L, Wang J, Zhao Z, Li J, Zhao H, Gao Y, Chen C; Clinical Spine Surgery (2023) 36: 59

Quote: Both MI-ACDF and PPEKF can provide a relatively safe and reliable treatment for single-level unilateral cervical radiculopathy. The 2 techniques are not significantly different in terms of effective rate, total complication rate, and reoperation rate.

The first experience with fully endoscopic posterior cervical foraminotomy and discectomy for radiculopathy performed in Viet Duc University Hospital **P 82**
Dinh SN, Dinh HT; Sci Rep (2022) 12: 8314

Conclusions: The results obtained confirmed the safety and efficiency of full-endoscopic PCFD at soft lateral or intraforaminal disk herniation, as well as foraminal stenosis and lateral recess stenosis. At the same time, the described surgical technique provides much less tissue traumatization while accessing the operational area, reduced hospital stay and decreased need for pain meds in the postoperative period.

Clinical efficacy and learning curve of posterior percutaneous endoscopic cervical laminoforaminotomy for patients with cervical spondylotic radiculopathy **P 83**
Yao R, Yan M, Liang Q, Wang H, Liu Z, Li F, Zhang H, Li K, Sun F; Medicine (2022) 101: e30401

Quote: Decompression with PPECLF was safe and effective in the treatment of CSR. With the accumulation of cases, the operative time was gradually shortened, and the clinical efficacy was significant. According to the learning curve, the 26th case was the cutoff point.

Comparison of Percutaneous Endoscopic Cervical Keyhole Foraminotomy versus Microscopic Anterior Cervical Discectomy and Fusion for Single Level Unilateral Cervical Radiculopathy **P 84**
Ma W, Peng Y, Zhang S, Wang Y, Gan K, Zhao X, Xu D; IJGM (2022) 15: 6897–6907

Quote: Percutaneous endoscopic cervical keyhole foraminotomy could be the alternative method for anterior cervical discectomy and fusion in selective cases.

Clinical Efficacy of Posterior Percutaneous Endoscopic Unilateral Laminotomy with Bilateral Decompression for Symptomatic Cervical Spondylotic Myelopathy **P 85**
Zhao X-B, Ma Y-J, Ma H-J, Zhang X-Y, Zhou H-G; Orthop Surg (2022): doi:10.1111/os.13237

> **Quote:** PPEUL has the advantages of reduced trauma, rapid recovery and remarkable curative efficacy, so it is a new choice for the treatment of CSM.

Outcome of Anterior and Posterior Endoscopic Procedures for Cervical Radiculopathy Due to Degenerative Disk Disease: A Systematic Review and Meta-Analysis **P 86**
Alomar SA, Maghrabi Y, Baeesa SS, Alves ÓL; Global Spine J (2021); 21925682211037270

> **Quote:** There is a higher success rate and lower complication rate with the posterior approach than with the anterior approach.

Comparative evaluation of posterior percutaneous endoscopy cervical discectomy using a 3.7 mm endoscope and a 6.9 mm endoscope for cervical disc herniation: a retrospective comparative cohort study **P 87**
Yu T, Wu J-P, Zhang J, Yu H-C, Liu Q-Y; BMC Musculoskelet Disord (2021) 22: 131

> **Quote:** The application of both the 3.7 mm endoscope and 6.9 mm endoscope represent an effective method for the treatment of CDH in selected patients, and no significant difference can be observed in the clinical outcomes of the endoscopes. The 6.9 mm endoscope shows superiority to the 3.7 mm endoscope in terms of the efficiency of «V» point identification, the removal of overlying soft tissue and the prevention of spinal cord injury.

Full endoscopic cervical spine surgery **P 88**
Shen J, Telfeian AE, Shaaya E, Oyelese A, Fridley J, Gokaslan ZL; J Spine Surgery (2020) 6(2): 383–390

> **Quote:** Fully endoscopic cervical spine surgery is an emerging surgical technique for addressing cervical radiculopathy and myelopathy through a minimally invasive approach.

Full endoscopic unilateral laminotomy for bilateral decompression of the cervical spine: surgical technique and early experience **P 89**
Carr DA, Abecassis IJ, Hofstetter CP; J Spine Surg (2020) 6: 447–456

> **Quote:** Severe central cervical stenosis is a safe and viable target for full-endoscopic decompression via an interlaminar approach.

THORACIC SPINE

Full-endoscopic discectomy for thoracic disc herniations: a single-arm meta-analysis of safety and efficacy outcomes **P 92**
Silva JDS, Carelli LE, de Oliveira JAA, de Araújo RML; Eur Spine J (2023)

Quote: Full-endoscopic discectomy has a low incidence of adverse outcomes in patients with thoracic disc herniations.

Comparison of the Short-Term Efficacy of Percutaneous Endoscopic Thoracic Decompression and Laminectomy in the Treatment of Thoracic Ossification of the Ligamentum Flavum **P 93**
Bian F, Zhang J, Bian G, Wang D, Chen B, An Y; World Neurosurgery (2022): doi:10.1016/j.wneu.2022.11.093

Quote: The PETD under local anesthesia for T-OLF has many advantages, such as high patient acceptance, good short-term clinical outcomes, and few complications; therefore, this procedure should be promoted as a viable treatment option for thoracic ossification of the ligamentum flavum.

Comparative Analysis of Transforaminal Endoscopic Thoracic Discectomy and Microscopic Discectomy for Symptomatic Thoracic Disc Herniation **P 94**
Bae J, Kim J, Lee S-H, Kim J-S; Neurospine (2022) 19: 555–562

Quote: TETD for the symptomatic TDH is a feasible and safe procedure that could be used for a wider range of surgical levels with a shorter operative time and hospital stay and less blood loss. While achieving similar outcomes, TETD achieved better patient satisfaction because of the use of local anesthesia and its minimal invasiveness.

Treatment of Refractory Multilevel Thoracic Spondylodiscitis Using Ultra-Minimally Invasive Endoscopic Approach for Debridement and Drainage: A Technical Note, Intraoperative Video and Literature Review **P 95**
Barber SM, Sofoluke N, Reardon T, Telfeian A, Konakondla S; World Neurosurgery (2022)

Quote: Endoscopic treatment for thoracic spondylodiscitis is a viable alternative to traditional open surgery in many cases.

Full Endoscopic Surgery for Thoracic Pathology: Next Step after Mastering Lumbar and Cervical Endoscopic Spine Surgery? **P 96**
Bae J, Lee S-H, Wagner R, Shen J, Telfeian AE; BioMed Research International (2022): e8345736

Quote: Full endoscopic surgery is a safe and effective minimally invasive surgical option for thoracic pathology. With high-resolution visualization and a tissue-preserving surgical approach, endoscopic surgery enhances patient outcomes. One obstacle is the learning curve problem. With sufficient experience in cervical and lumbar spine endoscopic surgery, it will be possible to safely operate on the thoracic spine.

Comparative Clinical and Radiographic Cohort Study: Uniportal Thoracic Endoscopic Laminotomy With Bilateral Decompression by Using the 1-Block Resection Technique and Thoracic Open Laminotomy With Bilateral Decompression for Thoracic Ossified Ligamentum Flavum **P 97**

Kim HS, Wu PH, Kim J-Y, Lee YJ, Kim DH, Lee JH, Jeon JB, Jang I-T; Oper Neurosurg (Hagerstown) 2022

Quote: Uniportal TE-ULBD achieved significantly improved pain and neurological recovery with sufficient spinal canal decompression, as compared with thoracic open laminectomy for patients with myelopathy secondary to OLF in our cohort.

Comparison of percutaneous endoscopic thoracic decompression and posterior thoracic laminectomy for treating thoracic ossification of the ligamentum flavum: a retrospective study **P 98**

Yang F-K, Li P-F, Dou C-T, Yu R-B, Chen B; BMC Surgery (2022) 22: 85

Quote: There were significant differences between PETD group and PTL group in operative time (min) (95.0±18.8 vs 131.1±19.0), postoperative drainage (mL) (20.2±7.9 vs 586.1±284.2), hospital stay (days) (4.4±1.2 vs 10.4±2.6) ($P<0.05$ for all). Both groups had similar and significant improvement in VAS and mJOA scores.

Full endoscopic surgery for thoracic pathology: an assessment of supportive evidence **P 99**

Gibson R, Wagner R, Gibson A; EOR, volume 6, January 2021

Quote: Overall, there is now a moderate expectation of Excellent/Good postoperative outcomes with fewer complications than after open surgery.

Endoscopic Spine Surgery of the Cervicothoracic Spine: A Review of Current Applications **P 100**

Shen J, Shaaya E, Bae J, Telfeian AE; Int J Spine Surg (2021) 15: S93–S103

Quote: Each endoscopic approach in the cervicothoracic spine has its technical nuances, outcomes, advantages, and disadvantages, making fully endoscopic cervicothoracic spine surgery an exciting and growing field.

Five-Year Outcomes After Transforaminal Endoscopic Foraminotomy and Discectomy for Soft and Calcified Thoracic Disc Herniations **P 101**

Houra K, Saftic R, Knight M; Int J Spine Surg (2021): doi:10.14444/8071

Quote: Transforaminal full endoscopic discectomy and foraminotomy with manual reamers performed under local anesthesia produces sustained reduction in pain and improves functionality in patients with mid and lower thoracic spine soft and calcified disc herniations. The surgery is safe and straightforward to perform with the correct training.

Thoracic Endoscopic Spine Surgery: A Comprehensive Review **P 102**
Fiani B, Siddiqi I, Reardon T, Sarhadi K, Newhouse A, Gilliland B, Davati C, Villait A; Int J Spine Surg (2020); 14(5): 762-7713

Quote: There is growing evidence demonstrating the success of endoscopic thoracic spinal surgery.

Transforaminal endoscopic thoracic discectomy with foraminoplasty for the treatment of thoracic disc herniation **P 103**
Bae J, Chachan S, Shin S-H, Lee S-H; J. Spine Surg (2020) 6(2): 397-404

Quote: TETD for soft, paramedian or lateral symptomatic TDH is a feasible and effective minimally invasive treatment option with favorable clinical results.

Fully Endoscopic 360° Decompression Surgery for Thoracic Spinal Stenosis: Technical Note and Report of 8 Cases **P 104**
Shen J, Telfeian AE; Pain Physician (2020) 23: E659–E663

Quote: Combining fully endoscopic transforaminal and posterior approaches for both ventral and dorsal decompression under local anesthesia with IV sedation is an effective and safe minimally invasive surgical treatment for thoracic spinal stenosis.

Percutaneous Endoscopic Thoracic Decompression for Thoracic Spinal Stenosis Under Local Anesthesia **P 105**
Cheng X-K, Chen B; World Neurosurgery (2020) 139: 488–494

Quote: This retrospective analysis showed that PETD under local anesthesia may be a feasible alternative to treat TSS in elderly patients with other underlying complications for whom general anesthesia or major surgical trauma would be harmful.

Percutaneous Endoscopic Thoracic Discectomy in the Upper and Midthoracic Spine: A Technical Note **P 106**
Bae J, Chachan S, Shin S-H, Lee S-H; Neurospine (2019) 16: 148–153

Quote: PETD for upper and midthoracic disc herniation is a feasible and effective minimally invasive treatment option with favorable clinical results.

LUMBAR SPINE

Full-Endoscopic Lumbar Discectomy Approach Selection — A Systematic Review And Proposed Algorithm **P 108**

Kotheeranurak V, Liawrungrueang W, Quillo-Olvera J, Siepe CJ, Li ZZ, Lokhande PV, Choi G, Ahn Y, Chen CM, Choi KC, Van Isseldyk F, Hagel V, Koichi S, Hofstetter CP, Del Curto D, Zhou Y, Bolai C, Bae JS, Assous M, Lin GX, Jitpakdee K, Liu Y, Kim J-S; Spine (2023)

> **Quote:** The proposed algorithm suggests a TELD for LDH located in the foraminal or extra-foraminal zones at upper and lower levels and for central and subarticular discs at the upper levels considering the anatomical foraminal features and the craniocaudal pathology location. An IELD is preferred for LDH in the central or subarticular zones at L4/L5 and L5/S1, especially if a high iliac crest or high-grade migration is found.

Impact of the learning curve of percutaneous endoscopic lumbar discectomy on clinical outcomes: a systematic review **P 109**

Ali R, Hagan MJ, Bajaj A, Alastair Gibson JN, Hofstetter CP, Waschke A, Lewandrowski K-U, Telfeian AE; Interdisciplinary Neurosurgery (2023):101738

> **Conclusions:** The learning curve affects only a subset of surgery metrics: cannula placement time, postoperative dural sac cross-sectional area; fluoroscopy time; and operative time. The learning curve's effect on certain outcomes, such as ODI and herniation rate, is equivocal. Percutaneous endoscopic lumbar discectomy can be learned.

Initial learning curve after switching to uniportal endoscopic discectomy for lumbar disc herniations **P 110**

Olinger C, Coffman A, Campion C, Thompson K, Gardocki R; Eur Spine J 2023

> **Quote:** Endoscopic discectomy was shown to be safe and effective for symptomatic disc herniations in an ambulatory setting. Median operative time decreases by half over the first 50 patients in our learning curve, while reoperation rates remained similar without the need for hospital transfer or conversion to an open procedure in an ambulatory setting.

Clinical efficacy of transforaminal endoscopic lumbar discectomy for lumbar degenerative diseases: A minimum 6-year follow-up **P 111**

Tang J, Li Y, Wu C, Xie W, Li X, Gan X, Lu Q; Front Surg (2022) 9: 1004709

> **Quote:** TELD has a satisfactory mid-term efficacy, and has no significant effect on the DH, the stability of the intervertebral disc space, or on intervertebral disc degeneration. However, as expected, TELD was associated with some complications including recurrent disc herniation and POD.

A comparative study of percutaneous endoscopic interlaminar discectomy and transforaminal discectomy for L5-S1 calcified lumbar disc herniation **P 112**
Cheng Y-P, Cheng X-K, Wu H; BMC Musculoskeletal Disorders (2022) 23: 244

Quote: PEID has achieved good clinical efficacy as PETD for L5-S1 CLDH. Compared with PETD, PEID has the advantages of shorter operative time and a reduced number of fluoroscopy times in the treatment of CLDH.

Indications and Contraindications of Full-Endoscopic Interlaminar Lumbar Decompression **P 113**
Wagner R, Haefner M; World Neurosurg (2021) 145: 657–662

Quote: This technique is safe for lumbar spinal decompression and more minimally invasive than a microendoscopic approach. However, this technique should be performed by surgeons with advanced skills. Endoscopy could become the gold standard for treatment of canal stenosis in the near future.

Comparison of Interlaminar and Transforaminal Approaches for Treatment of L_5/S_1 Disc Herniation by Percutaneous Endoscopic Discectomy **P 114**
Gao A, Yang H, Zhu L, Hu Z, Lu B, Jin Q, Wang Y, Gu X; Orthop Surg (2021) 13: 63–70

Quote: For L5/S1 disc herniation, PEID and PETD provide similar results for patients. However, PEID has the advantage over PETD in that it is a shorter procedure and exposes the patient to less radiation.

Technical Considerations of Interlaminar Approach for Lumbar Disc Herniation **P 115**
Chen KT, Tseng C, Sun LW, Chang KS, Chen CM. World Neurosurg. 2021 Jan;145:612-620

Quote: The technical considerations for each anatomical structure can help surgeons recognize the advantages and difficulties of each surgical technique.

Technical Considerations of the Transforaminal Approach for Lumbar Disk Herniation **P 116**
Ju CI; World Neurosurg. 2021 Jan;145:597-611

Quote: we propose several technical guidelines for TELD to increase the possibility of successful lumbar diskectomy and to reduce the incidence of complications.

Endoscopic and Microscopic Interlaminar Discectomy for the Treatment of Far-Migrated Lumbar Disc Herniation: A Retrospective Study with a 24-Month Follow-Up **P 117**
Yang F, Ren L, Ye Q, Qi J, Xu K, Chen R, Fan X; Journal of Pain Research. 2021

Quote: Both IELD and IMLD achieve favorable clinical results in the treatment of far-migrated LDH, with only minor complications. Compared to IMLD, LBP was significantly reduced with IELD presumably because it involved less trauma.

Clinical Efficacy Study of the Quadrant Channel and Delta Large Channel Technique in the Treatment of Lumbar Degenerative Diseases **P 118**
Zhang J-J, Zhou C-L, Sun C, Xu D-R, Bao M, Liu Y; Journal of General Medicine. 2021

Quote: Both surgical methods achieved a good clinical outcome in the treatment of lumbar degenerative diseases. The delta large channel technique may offer some advantages over quadrant channel technology, such as less trauma and bleeding and faster recovery time.

Comparison of the Outcomes of Percutaneous Endoscopic Interlaminar Lumbar Discectomy and Open Lumbar Microdiscectomy at the L5-S1 Level **P 119**
Song SK, Son S, Choi SW, Kim HK; Pain Physician (2021) 24: E467–E475

Quote: Our findings indicate that the PEILD group achieved better perioperative outcomes despite no significant intergroup difference in mid-term clinical and radiological outcomes.

Clinical Comparison of Full-Endoscopic and Microscopic Unilateral Laminotomy for Bilateral Decompression in the Treatment of Elderly Lumbar Spinal stenosis: A Retrospective Study with 12-Month Follow-Up **P 120**
Yang F, Chen R, Gu D, Ye Q, Liu W, Qi J, Xu K, Fan Xiaohong; J Pain Res (2020) 13: 1377–1384

Quote: Both full-endoscopic and microscopic decompression have achieved favorable clinical results in treating elderly lumbar spinal stenosis, and the complications are minor. Full-endoscopic decompression has the advantages of small incision and rapid recovery, which can be used as an alternative for the treatment of lumbar spinal stenosis, especially the elderly with comorbidities.

Minimum 2-Year Efficacy of Percutaneous Endoscopic Lumbar Discectomy versus Microendoscopic Discectomy: A Meta-Analysis **P 121**
Xu J, Li Y, Wang B, Lv G, Li L, Dai Y, Jiang B, Zheng Z; World Neurosurg (2020) 138: 19-26

Quote: PELD could obtain better midterm and long-term clinical outcomes compared with MED.

Clinical outcomes of MED and iLESSYS® Delta for the treatment of lumbar central spinal stenosis and lateral recess stenosis: A comparison study **P 122**
Wu B, Xiong C, Tan L, Zhao D, Xu F, Kang H; Experimental Therapeutic Medicine (2020); 20:252-262

Quote: The iLESSYS® Delta approach may reduce the short-term back pain and promote faster recovery compared with the MED.

The Endoscopic Trans-Superior Articular Process Approach: A Novel Minimally Invasive Surgical Corridor to the Lateral Recess **P 123**
Hasan S, White-Dzuro B, Barber JK, Wagner R, Hofstetter CP; Oper Neurosurg (Hagerstown) 2020; 19: E1–E10

Quote: The trans-SAP approach is a novel approach that utilizes a safe surgical corridor via the SAP to access lateral recess pathology. Our initial clinical experience suggests that the trans-SAP approach allows for treatment of lateral recess and foraminal pathology with low complication rates.

Comparison of clinical outcomes following minimally invasive or lumbar endoscopic unilateral laminotomy for bilateral decompression **P 124**

McGrath LB, White-Dzuro GA, Hofstetter CP; J Neurosurg Spine (2019): 1–9

Quote: Lumbar endoscopic unilateral laminotomy for bilateral decompression is a safe and effective surgical procedure with favorable complication profile and patient outcomes.

Comparison of full-endoscopic and minimally invasive decompression for lumbar spinal stenosis in the setting of degenerative scoliosis and spondylolisthesis **P 125**

Hasan S, McGrath LB, Sen RD, Barber JK, Hofstetter CP; Neurosurg Focus (2019) 46: E16

Quote: Endoscopic and MIS-ULBD result in similar functional outcomes for LSS with mild to moderate deformity, while the endoscopic approach demonstrates a favorable rate of complications.

Contralateral facet-sparing sublaminar endoscopic foraminotomy for the treatment of lumbar lateral recess stenosis: technical note **P 126**

Krzok G, Telfeian AE, Wagner R, Hofstetter CP, Iprenburg M; J Spine Surg (2017) 3(2): 260-266

Quote: The acceptance of this technology is high among young surgeons but it is the task and duty of the protagonists of the older generation, the hospitals, and the scientific societies to develop learning- and training-concepts to shorten learning curves and to improve technical quality and clinical outcomes.

Foraminoplastic Superior Vertebral Notch Approach with Reamers in Percutaneous Endoscopic Lumbar Discectomy: Technical Note and Clinical Outcome in Limited Indications of Percutaneous Endoscopic Lumbar Discectomy **P 127**

Lee CW, Yoon KJ, Ha SH, Kang JK; J Korean Neurosurg Soc (2016) 59 (2): 172-181

Quote: FSVNA with foraminoplasty with reamers is an effective and affordable minimally invasive procedure for patients in relatively limited indications for PELD, showing both a high success rate in terms of clinical outcomes and a low complication rate due to its safe approach.

Efficacy of Transforaminal Endoscopic Spine System (TESSYS) Technique in Treating Lumbar Disc Herniation **P 128**

Pan Z, Ha Y, Yi S, Cao K; Med Sci Monit (2016) 22:530-539

Quote: TESSYS had clinical advantages over FD and entails less trauma and quicker postoperative recovery, suggesting that TESSYS is well tolerated by patients and is a better approach than FD in surgical treatment of LDH.

ENDOSCOPIC ONCOLOGICAL SURGERY

The Role of the Endoscope in Spinal Oncology: A Systematic Review of Applications and Systematic Analysis of Patient Outcomes **P 130**
Sofoluke N, Barber SM, Telfeian AE, Hofstettet CP, Konakondla S; World Neurosurg (2022) 164, 33-40

Quote: The utility of FES in spinal oncology is not well understood. Literature results of this technique show promise.

Endoscopic Techniques for Spinal Oncology: A Systematic Literature Review **P 131**
Ali R, Hagan MJ, Shaaya E, Leary OP, Feler J, Bajaj A, Gokaslan Z, Konakondla S, Mahan MA, Wagner R, Lewandrowski KU, Telfeian AE; Int J Spine Surg. 2022 Nov 28:8412

Quote: Endoscopic techniques have been successfully applied across the spectrum of care in spinal oncology, from diagnosis to definitive treatment.

The History of Neurosurgical Spinal Oncology: From Inception to Modern-Day Practices **P 132**
Shao MM, Rubino S, DiRisio DJ, German JW. World Neurosurg. 2021 Jun;150:101-109

Quote: These minimally invasive surgical techniques have emerged in neurosurgical spine oncology with the incorporation of microsurgery, endoscopy, percutaneous procedures, and robotics.

Evaluation of open and minimally invasive spinal surgery for the treatment of thoracolumbar metastatic epidural spinal cord compression: a systematic review **P 133**
Alshareef M, Klapthor G, Alawieh A, Lowe S, Frankel B. Eur Spine J. 2021 May 30

Quote: MIS techniques offer a viable alternative to traditional OS approaches with lower overall morbidity and complications.

A Novel Endoscopic Technique for Biopsy and Tissue Diagnosis for a Paraspinal Thoracic Tumor in a Pediatric Patient: A Case Report **P 134**
Konakondla S, Nakhla J, Xia J, Barber SM, Fridley JS, Oyelese AA, Gokaslan ZL, Rainov NG, Haritonov DG, Wagner R, Telfeian AE. Int J Spine Surg. 2021 Feb;14(s4): S66-S70

Quote: This minimal approach can prove to achieve similar results as other approaches that may otherwise necessitate more extensive or transthoracic procedures.

Full-Endoscopic Resection of Osteoid Osteoma in the Thoracic Spine: A Case Report **P 135**
Bergamaschi JPM, Costa CAM, Sandon LH. Int J Spine Surg. 2021 Feb; 14(s4):S78-S86

Quote: full-endoscopic resection appears as an innovative and potentially promising option for diagnosis and treatment, especially since it is a safe, effective, and not too morbid intervention.

Percutaneous Endoscopic Excision and Ablation of Osteoid Osteoma of the Lumbar Spine and Sacrum: A Technical Note and Outcomes **P 136**
Xie T, Xiu P, Song Y, Zeng J, Huang S. World Neurosurg. 2020 Jan;133:121-126

> **Quote:** PEEA is a safe and effective technique for OO in the lumbar spine and sacrum in which the nidus is located in the posterior element.

Transforaminal Endoscopic Approach for Large-Sample Tumor Biopsy using Beveled Working Channel for Core Technique: A Technical Note **P 137**
Konakondla S, Sofoluke N, Xia J, Grant R, Telfeian AE, Hofstetter CP, Slotkin JR; World Neurosurg. (2020) 141: 346-351

> **Quote:** We demonstrate the successful application of the ultra-minimally invasive endoscopic transforaminal approach in spine oncology.

The Role of Minimal Access Surgery in the Treatment of Spinal Metastatic Tumors **P 138**
Barzilai O, Bilsky MH, Laufer I; Global Spine J. (2020) 10(2S): 79-87

> **Quote:** MAS has a significant role in the treatment of spinal metastases. [...] The purported advantages include reduced blood loss, shorter length of stay, decreased systemic stress of surgery, lower risk of complications, and most important, rapid return to systemic and radiation therapy.

Endoscopic surgical treatment for symptomatic spinal metastases in long-term cancer survivors **P 139**
Telfeian AE, Oyelese A, Fridley J, Doberstein C, Gokaslan ZL; J. Spine Surgery (2020) 6(2): 372-382

> **Quote:** Awake endoscopic surgery for the treatment of symptomatic metastatic spine disease is an effective outpatient surgical option for the treatment of patients suffering from radicular pain due to nerve compression from metastatic spine disease.

Percutaneous Full-Endoscopic Removal of Lumbar Intradural Extramedullary Tumor via Translaminar Approach **P 140**
Şentürk S, Ünsal ÜÜ. World Neurosurg. 2019 May;125:146-149

> **Quote:** full endoscopic spinal intradural extramedullary mass excision may give good results in selected cases and in experienced hands.

“Microendoscopic” versus “pure endoscopic” surgery for spinal intradural mass lesions: a comparative study and review **P 141**
Dhandapani S, Karthigeyan M. Spine J. 2018 Sep;18(9):1592-1602

> **Quote:** Endoscopy is effective and safe for even large tumors with better visualization of sides and angles.

ENDOSCOPICALLY ASSISTED FUSION

Endoscopic Techniques for Lumbar Interbody Fusion: Principles and Context **P 144**
Zheng B, Shaaya E, Feler J, Leary OP, Hagan MJ, Bajaj A, Fridley JS, Hassel F, Gardocki R, Grau CR, Lewandrowski K-U, Telfeian AE; BioMed Research International (2022): e4979231

> **Quote:** Though considerable variation exists within endoscopic LIF, similar principles and techniques are common to all types. Two illustrative cases of endoscopic transforaminal lumbar interbody fusion are presented with a comprehensive literature review of the different approaches to endoscopic LIF procedures.

Learning Curve and Initial Outcomes of Full-Endoscopic Posterior Lumbar Interbody Fusion **P 145**
Tan R, Lv X, Wu P, Li Y, Dai Y, Jiang B, Ren B, Lv G, Wang B; Front Surg (2022) 9: 890689

> **Quote:** FE-PLIF is an effective and safe method for treating low back pain caused by short-segmental degenerative diseases. The learning curve of this technique is steep at the initial stage but acceptable and shows great potential for improvement.

Comparison of Clinical Outcomes and Complications Between Endoscopic and Minimally Invasive Transforaminal Lumbar Interbody Fusion for Lumbar Degenerative Diseases: A Systematic Review and Meta-analysis **P 146**
Guo H, Song Y, Weng R, Tian H, Yuan J, Li Y; Global Spine J 2022

> **Quote:** Endo-TLIF was similar to MIS-TLIF in the long-term clinical outcomes, fusion and complication rates. Endo-TLIF prolongs the operation time, but shortens the length of hospital stay, and has the advantages of less surgical trauma, less blood loss, faster recovery, and early postoperative back pain relief.

Endoscopic Lumbar Interbody Fusion and Minimally Invasive Transforaminal Lumbar Interbody Fusion for the Treatment of Lumbar Degenerative Diseases: A Systematic Review and Meta-Analysis **P 147**
Kou Y, Chang J, Guan X, Chang Q, Feng H. World Neurosurg. 2021 Aug;152:e352-e368

> **Quote:** there is no significant difference in clinical efficacy and safety between Endo-LIF and MIS-TLIF in the treatment of lumbar degenerative diseases. Although Endo-LIF has a longer operative time, it has the advantages of less tissue trauma and rapid recovery after operation.

Full-Endoscopic Posterior Lumbar Interbody Fusion with Epidural Anesthesia: Technical Note and Initial Clinical Experience with One-Year Follow-Up **P 148**
Jiang C, Yin S, Wei J, Zhao W, Wang X, Zhang Y, Hao D, Du H. JPR 2021; 14: 3815–3826

> **Quote:** Endo-PLIF with EA is a feasible and valuable technique for the treatment of single-segment lumbar degenerative diseases in selected patients.

Technical Considerations of Uniportal Endoscopic Posterolateral Lumbar Interbody Fusion: A Review of Its Early Clinical Results in Application in Adult Degenerative Scoliosis **P 149**
Kim HS, Wu PH, Lee YJ, Kim DH, Jang IT. World Neurosurg. 2021 Jan; 145:682-692

> **Quote:** Endo-TLIF is a safe and effective procedure in mild to moderate degenerative scoliosis with good early clinical results and improvement in coronal Cobb angle.

Technical Considerations of Endoscopic Kambin's Triangle Lumbar Interbody Fusion **P 150**
Basil GW, Wang MY. World Neurosurg. 2021 Jan;145:670-681

> **Quote:** [...] endoscopic interbody fusion represents an excellent surgical option in a select patient population.

Uniportal Endoscopic Lumbar Interbody Fusion **P 151**
Wagner R, Haefner M; Neurospine (2020) 17:120-128

> **Quote:** Endoscopy could become the gold standard for treatment of canal stenosis in the near future.

Surgical Outcomes After Single-Level Endoscopic Transforaminal Lumbar Interbody Fusion: A Systematic Review and Meta-Analysis **P 152**
Stone CE, Myers BL, Gupta S, Giles TX, Patel NA, Gendreau JL, Abraham ME, Mammis A; Cureus (2020) 12(10): e11052

> **Quote:** Initial data reveal that endoscopic TLIF with local anesthesia may offer patients outcomes similar to those in patients undergoing endoscopic TLIF with general anesthesia, with lower operative times and length of stay.

Clinical Results and Complications of Endoscopic Lumbar Interbody Fusion for Lumbar Degenerative Disease: A Meta-Analysis **P 153**
Heo DH, Lee DC, Kim HS, Park CK, Chung H; World Neurosurg. (2020) 145: 396-404

> **Quote:** The early clinical results of endoscopic TLIF with percutaneous pedicle screw fixation are favorable.

Enhanced Recovery Following Interbody Fusion by Transforaminal Endoscopic Techniques **P 154**
Gibson JNA, Wagner R, Illerhaus B; Conference Paper Global Spine Congress 2019, Toronto

> **Quote:** Endoscopic fusion via transforaminal approach is safe and effective. Mean hospital stay was significantly shorter than for other methods

Fully Endoscopic Lumbar Laminectomy and Transforaminal Lumbar Interbody Fusion Under Local Anesthesia with Conscious Sedation: A Case Series **P 155**
Shen J; World Neurosurg (2019) 127: 745-750

> **Quote:** Fully endoscopic laminectomy and interbody fusion under conscious sedation is an effective treatment with minimal complications for patients with lumbar spondylolisthesis and severe spinal stenosis.

Percutaneous Endoscopic Lumbar Interbody Fusion: Technical Note and Preliminary Clinical Experience with 2-Year Follow-Up **P 156**
Wu J; Liu H Ao S, Zheng W, Li C, Li H, Pan Y, Zhang C, Zhou Y; BioMed Research International (2018) 5806037

> **Quote:** The clinical results of attempt in PELIF technique support the minimal invasive advantages in decreased blood, shortage of ambulation time, and hospital stay, compared with MIS-TLIF.

Reduced Acute Care Costs With the ERAS® Minimally Invasive Transforaminal Lumbar Interbody Fusion Compared With Conventional Minimally Invasive Transforaminal Lumbar Interbody Fusion **P 157**
Wang MY, Chang HK, Grossman J; Neurosurg (2018) 83:827-834

> **Quote:** Enhancing Recovery After Surgery ERAS® programs for spinal fusion surgery have the potential to reduce the costs of acute care. This is made possible by leveraging less invasive interventions to minimize soft tissue damage.

ENDOSCOPIC PAIN THERAPY

Endoscopic Facet Joint Denervation on the Lumbar Spine: A Retrospective Analysis **P 160**
Wallscheid F, Manthey M, Olsen J, Oikonomidis S, Meyer C, Eysel P, Löhrer L, Bredow J; Asian Spine J (2022)

Quote: EFJD is a good treatment alternative for CLBP originating from the facet joints, particularly in patients with isolated facet joint osteoarthritis. Moreover, this method can address not only the dorsal medial ramus but also the surrounding tissue (e.g.,facet joint capsule, facet joint effusion, and osteophytes) as the origin of CLBP.

Endoscopic Rhizotomy for Facetogenic Back Pain: A Review of the History, Financial Considerations, Patient Selection Criteria and Clinical Outcomes **P 161**
Streetman D, Fricker JG, Garner GL, Webb AL, Pierzchajlo N, Patel NA, Howard NA, Hardin EM, Smith TE, Hagley AJ, Brown NJ, Gendreau JL; World Neurosurgery (2022)

Quote: ER is an effective treatment for refractory CBP with notable advantages.

Endoscopic radiofrequency facet joint treatment in patients with low back pain: technique and long-term results. A prospective cohort study **P 162**
Meloncelli S, Germani G, Urti, I, Divizia M, Rosciano M, Puntillo F, Paladini A, Varrassi G; Therapeutic Advances in Musculoskeletal Disease (2020) 12: 1-10

Quote: The results obtained demonstrate that ER for denervation of the facet joint is an effective treatment in patients with chronic LBP, with consistent and stable results at 2-year follow up.

Endoscopic rhizotomy for chronic lumbar zygapophysial joint pain **P 163**
Xue Y, Ding T, Wang D, Zhao J, Yang H, Gu X, Feng D, Zhang Y, Liu H, Tang F, Wang W, Lu M, Wu C. J Orthop Surg Res. 2020 Jan 3;15(1):4

Quote: ERFA may achieve more accurate and definite denervation on the nerves, which leads to longer lasting pain relief.

Endoscopic facet joint denervation for treatment of chronic lower back pain **P 164**
Walter SG, Struwe C, Scheidt S, Strohmenger L, Bornemann R, Wirtz DC, Clin Neurol Neurosurg (2020) 195: 105904

Quote: EFJD is a promising technique for the treatment of facet joint syndrome caused CLBP as it contributes to sustaining significant pain reduction and improvement of subjective quality of life parameters.

Endoscopic Sacrolumbar Facet Joint Denervation in Osteoarthritic and Degenerated Zygapophyseal Joints **P 165**

Walter SG, Schildberg FA, Rommelspacher Y; Arthrosc Tech. 2018 Nov 12;7(12):e1275-e1279

Quote: This technique has the advantage of directly visualizing the facet joint as well as its surrounding structures including the medial branches.

Endoscopic Radiofrequency Ablation of the Sacroiliac Joint Complex in the Treatment of Chronic Low Back Pain: A Preliminary Study of Feasibility and Efficacy of a Novel Technique **P 166**

Choi WS, Kim JS, Ryu KS, Hur JW, Seong JH, Cho HJ; BioMed Res International (2016) ID2834259

Quote: Our preliminary results suggest that endoscope-guided RFA may be alternative option to treat CLBP secondary to SIJ complex.

COMPLICATIONS

Full-endoscopic spine surgery diminishes surgical site infections – a propensity score-matched analysis **P 168**
Mahan MA, Prasse T, Kim RB, Sivakanthan S, Kelly KA, Kashlan ON, Bredow J, Eysel P, Wagner R, Bajaj A, Telfeian AE, Hofstetter CP; The Spine Journal 2023

Conclusions: The SSI rate in the matched population was 1.1%, compared to 0.001% in endoscopic patients favoring FESS. FESS compares favorably for risk reduction in SSI following spinal decompression surgeries with similar operative characteristics. As a consequence, FESS may be considered the optimal strategy for minimizing SSI morbidity.

Contraindications and Complications of Full Endoscopic Lumbar Decompression for Lumbar Spinal Stenosis: A Systematic Review **P 169**
Ju C-I, Kim P, Ha S-W, Kim S-W, Lee S-M; World Neurosurgery 2022; 168: 398–410

Quote: Full endoscopic lumbar surgery, including transforaminal and interlaminar decompression, is a safe and effective surgical option for treating lumbar spinal stenosis; however, it is important to select the transforaminal or interlaminar approach according to the indication.

Complications of Full-Endoscopic Lumbar Discectomy versus Open Lumbar Microdiscectomy: A Systematic Review and Meta-Analysis **P 170**
Yang C-C, Chen C-M, Lin MH-C, Huang W-C, Lee M-H, Kim J-S, Chen K-T; World Neurosurgery (2022) 168: 333–348

Quote: The current evidence showed a lower risk of overall complications for FELD.

Comparison of hidden blood loss and clinical efficacy of percutaneous endoscopic transforaminal lumbar interbody fusion and minimally invasive transforaminal lumbar interbody fusion **P 171**
Ge M, Zhang Y, Ying H, Feng C, Li Y, Tian J, Zhao T, Shao H, Huang Y; International Orthopaedics (SICOT) 2022

Quote: Endo-TLIF significantly reduced HBL, VBL, and TBL compared to Mis-TLIF and improved short-term clinical outcomes; however, long-term clinical outcomes and fusion rates remained comparable between the two groups, as did the incidence of peri-operative complications.

Enhanced recovery after surgery pathway reduces the length of hospital stay without additional complications in lumbar disc herniation treated by percutaneous endoscopic transforaminal discectomy **P 172**
Duojun W, Hui Z, Zaijun L, Yuxiang G, Haihong C. J Orthop Surg Res. 2021 Jul 17;16(1):461

Quote: The ERAS pathway reduced LOS without resulting in additional complications after PETD.

P 173

Eight Surgical Interventions for Lumbar Disc Herniation: A Network Meta-Analysis on Complications
Wei F-L, Li T, Gao Q-Y, Yang Y, Gao H-R, Qian J-X, Zhou C-P, Front Surg (2021) 8: 679142

Quote: The results of this study provided evidence that PELD and PLDD were with lower intraoperative and post-operative complication rates, respectively. TD, PELD, PLDD, and MED were the safest procedures for LDH according to complications, reoperation, operation time, and blood loss.

P 174

Complications and risk factors of percutaneous endoscopic transforaminal discectomy in the treatment of lumbar spinal stenosis
Fan N, Yuan S, Du P, Wu Q, Wang T, Wang A, Li J, Kong X, Zhu W, Zang L; BMC Musculoskelet Disord (2021) 22: 1041

Quote: Complications in the treatment of LSS using PELD included rLSS, persistent pain of the lumbosacral or lower extremity, dural tear, incomplete decompression, surgical site infection, epidural hematoma, and intraoperative posterior neck pain. In addition, old age, severe grade of surgical-level disc degeneration and more disc degeneration levels significantly increased the incidence of complications.

P 175

Complication rates of different discectomy techniques for symptomatic lumbar disc herniation: a systematic review and meta-analysis
Chen X, Chamoli U, Vargas Castillo J, Ramakrishna VAS, Diwan AD. Eur Spine J. 2020 Jul;29(7):1752-1770

Quote: Compared with the OD/MD, results of this meta-analysis suggest that PELD has a lower risk of overall complications and a lower risk of complications necessitating conservative treatment.

P 176

Incidental Durotomy During Endoscopic Stenosis Lumbar Decompression: Incidence, Classification, and Proposed Management Strategies
Kim HS, Raorane HD, Wu PH, Heo DH, Sharma SB, Jang I-T; World Neurosurg (2020) 139: e13–e22

Quote: ID is a more common surgical complication in ESLD compared with the transforaminal approach. The endoscopic patch blocking dura repair technique should be considered in type 1 to type 3A of dura tear with good prognosis and clinical outcome. Consideration is made for conversion to open repair in types 3B, 3C and 4 dura tears with fair to poor outcome.

Is Full Endoscopic Lumbar Discectomy Less Invasive Than Conventional Surgery? A Randomized MRI Study **P 177**

Tacconi L, Signorelli F, Giordan E; World Neurosurg (2020) 138: e867–e875

Quote: We found a significant difference in signal intensity of the paravertebral muscles between the FELD and OD groups, reflective of the minor surgical invasiveness of endoscopic discectomy. FELD resulted in less trauma to the paraspinal muscles, possibly also reducing inflammatory cytokine release and, therefore, is a valuable tool for spinal surgeons.

Incidence and Implications of Incidental Durotomy in Transforaminal Endoscopic Spine Surgery: Case Series **P 178**

Telfeian AE, Shen J, Ali R, Oyelese A, Fridley J, Gokaslan ZL; World Neurosurg (2020) 134: e951–e955

Quote: Glues, patches, and bedrest were among the various methods used after durotomy. In this series there were no cases of symptomatic spinal fluid leakage or pseudomeningocele seen. Only 20% of patients who had durotomies noted a headache in the immediate postoperative period.

Comparison of tissue damages caused by endoscopic lumbar discectomy and traditional lumbar discectomy: A randomised controlled trial **P 179**

Pan L, Zhang P, Yin Q; International Journal of Surgery (2014) 12: 534–537

Quote: The PELD had less damage to human tissues than the traditional OD. PELD has a clear promotional value in clinical.

Transforaminal percutaneous endoscopic lumbar discectomy: technical tips to prevent complications **P 180**

Ahn Y; Expert Med Dev Revises (2012) 9 (4): 361-366

Conclusions: Transforaminal percutaneous endoscopic lumbar discectomy is regarded as an effective alternative to open discectomy.

EVOLUTION OF ENDOSCOPIC SPINE SURGERY

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Current Status and research hotspots in the field of full endoscopic spine surgery: A bibliometric analysis

Guang-Xun Lin[1,2], Ming-Tao Zhu[3], Vit Kotheeranurak[4,5], Pengfei Lyu[6†*], Chien-Min Chen[7,8,9†*] and Bao-Shan Hu[1,2†*]

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Purpose: We aimed to comprehensively analyze the current status, hotspots, and trends in full endoscopic spine surgery (FESS) research using bibliometric analysis and knowledge domain mapping.

Methods: The Web of Science database was used to screen FESS-related articles published between January 1, 1993 and June 10, 2022. The evaluation involved the following criteria: total number of articles; H-index; and contributions from countries/regions, institutions, journals, and authors.

Results: A total of 1,064 articles were included. Since 2016, there have been a significant number of publications in the field of FESS. The country/region contributing the largest number of articles was China (37.8%), followed by South Korea (24%), the United States (16.1%), Japan (5.7%), and Germany (5.1%). South Korea (35) had the highest H-index, followed by the United States (27), China (22), Japan (21), and Germany (20). World Neurosurgery (15.7%) published the largest number of FESS-related articles. However, among the top 10 most cited articles, six were published in *Spine*. The author who contributed the most was S.H. Lee (5.4%), and the largest number of contributions in this field originated from Wooridul Spine Hospital (South Korea; 6.1%). Notably, six of the 10 most published authors in this field were from South Korea. Of the top five productive institutions, three were from South Korea. The keywords with the strongest citation bursts in the field of FESS were "lumbar spine," "discectomy," "interlaminar," "surgical technique," "follow-up," "excision," "thoracic spine," and "endoscopic surgery." The 10 clusters generated in this study were: "endoscopic discectomy" (#0), "thoracic myelopathy" (#1), "recurrent lumbar disc herniation" (#2), "low back pain" (#3), "cervical vertebrae" (#4), "lumbar spinal stenosis" (#5), "transforaminal lumbar interbody fusion" (#6), "radiation exposure" (#7), "management" (#8), and "lumbar spine" (#9).

Conclusion: Global research on FESS is mostly concentrated in a few countries/regions and authors. South Korea has made the largest

Review Article on Full-endoscopic Spine Surgery

Evolution of endoscopic transforaminal lumbar approach for degenerative lumbar disease

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Abstract: Endoscopic spine surgery has evolved dramatically in last 30 years; with the development of new improved endoscopic optics and instrumentation limitation of endoscopic spine surgery has significantly reduced. The transforaminal approach has been limited in its indications due to its optimized approach and obstacles of bony or neural structures. As the initial transforaminal approach is based on the inside out technique, there were many limitations on the indications. Outside-in approach has been developed to address these limitations. However, the outside-in approach was not free from anatomical obstacles. The mobile outside-in approach technique has advantage of both inside-out and outside-in technique. It is equally safe as inside-out technique and provides an easy handling of structures, while it is equally versatile as outside-in technique in managing different types of disc prolapse such as central, paracentral, foraminal, far lateral, and up and down migration, and in high-canal compromise cases. The mobile outside in technique, however, demands a longer learning curve and beginners need to be patient while learning the technique.

Keywords: High grade migration; high canal compromise; Kambin's triangle; inside-out technique; outside-in technique; mobile outside-in technique; intervertebral route; foraminal route; suprapedicular route

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Introduction

The increase in life expectancy and the change in lifestyle caused an increase in incidence of degenerative spinal disease along with the increase number of surgeries performed in degenerative spine conditions. There is a rise in minimally invasive spine surgery along with these increases in trend. Endoscopic spine surgery is the most advanced form of minimally invasive spine surgery, and has recently undergone rapid development (1,2). For endoscopic spine surgery with aim of minimal soft tissue damage during the surgery, the transforaminal approach has been limited to indications due to itsoptimized approach and obstacles of bony or neural structures. Since the initial transforaminal approach is based on the 'inside out' technique, there were many limitations on the indications. 'Outside-in' technique has been developed to address the limitation of 'inside-out' technique. However, the 'outside-in' approach was not free from anatomical obstacles and the 'mobile outside-in' approach was developed to further resolve the limitations.

Current review article provides an overview of the evolution of transforaminal approach with its future application in the endoscopic spine surgery.

History

Endoscopic spinal surgery began as percutaneous discectomy as blind image guided procedure around 1960.

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ORIGINAL ARTICLE

Worldwide research productivity in the field of full-endoscopic spine surgery: a bibliometric study

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Abstract

Purpose To investigate the quantity and quality of articles in the field of full-endoscopic spine surgery (FESS) from different countries and assess characteristics of worldwide research productivity.

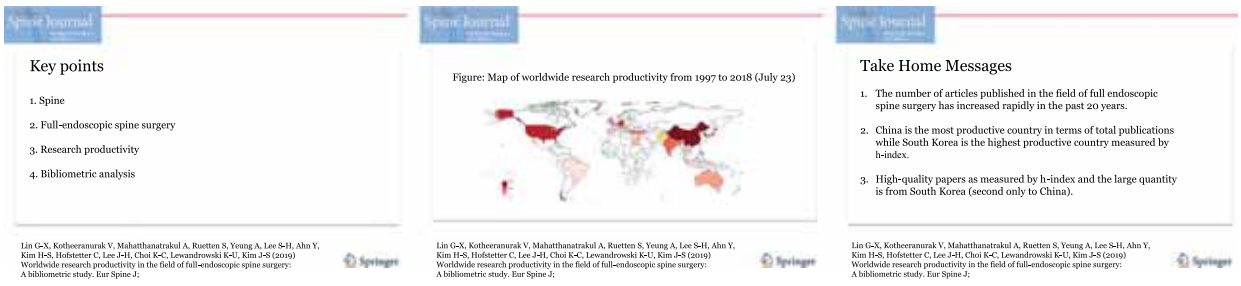
Methods Articles published from 1997 to July 23, 2018, were screened using the Web of Science database. All studies were assessed for the following parameters: the number of total publications, h-index, contribution of countries, authors, journals, and institutions.

Results A total of 408 articles were identified between 1997 and 2018. Between 1997 and 2017, the number of published articles tended to increase by 41 times. The largest number of articles was from China (30.15%), followed by South Korea (28.68%), the USA (13.97%), Germany (9.31%), and Japan (4.90%). The highest h-index was found for articles from South Korea (23), followed by the USA (18), Germany (16), China (11), and Japan (7). The highest number of articles was published in *World Neurosurgery* (12.50%), followed by *Pain Physician* (10.29%), *Spine* (6.62%), *European Spine Journal* (4.66%), and *Journal of Neurosurgery: Spine* (4.17%). Wooridul Spine Hospital published the largest number of articles (10.29%), followed by Tongji University (5.88%), University of Witten/Herdecke (5.39%), Brown University (5.15%), and Third Military Medical University (3.43%).

Conclusions The number of articles published in the field of FESS has increased rapidly in the past 20 years. In terms of quantity, China is the most contributive country based on the number of publications. High-quality papers as measured by h-index and the large quantity is from South Korea (second only to China).

Graphic abstract

These slides can be retrieved under Electronic Supplementary Material.



Keywords Spine · Endoscopic spine surgery · Research productivity · Bibliometric analysis

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Extended author information available on the last page of the article

Review Article on Full-endoscopic Spine Surgery

The evolution of interlaminar endoscopic spine surgery

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Abstract: Due to the aging population, patients required spinal surgery for degenerative spondylopathy is increasing. With the advent of surgical instruments and techniques, minimally invasive spine surgery is prevalent worldwide. Besides microscopic techniques, endoscopic spine surgery has gotten attention gradually in this surgical field for the past two decades. There are two essential approaches developed currently, including transforaminal and interlaminar approach. These innovative equipment and skills promote the progression of endoscopic surgery from discectomy to decompression of spinal stenosis. Meanwhile, they also opened up the application of endoscopic surgery in a complicated situation. From the perspective of emerging technologies and techniques, the authors will review the evolution and describe the prospects of the interlaminar endoscopic spine surgery (IESS).

Keywords: Endoscopic spine surgery; interlaminar; minimally invasive spine surgery; endoscopic spine decompression

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Introduction

Degenerative lumbar spine disorder is a common and significant cause of disability in the world (1). With the trend of an aging population, degenerative spine disorders lead to an increase of the global burden and a rise of the need for spinal care (2). The concepts of functional preservation and enhancing post-operative recovery have been general consensus in modern spinal care. Therefore, the field of minimally invasive spine surgery has progressed significantly during the past two decades. The advancement of image modalities provides accurate preoperative radiological evaluation and plan. Moreover, with the development of surgical technologies, minimally invasive spine surgery has been prevalent gradually due to minimize damage to non-pathogenic structures, durable effectiveness with less complication rates, and shorter hospital stay (3).

As for minimally invasive spine surgery, full-endoscopic spine surgery has been a viable option in recent decades. The full-endoscopic surgery is performed with the application of an endoscope that consists of a 20–30-degree rod-lens camera system with a light source, a working channel and an irrigation channel. The design of endoscope provides clear visual control during operation and minimize traumatization to normal soft tissue with uni-portal tract. In comparison to traditional surgery, endoscopic spine surgery provides advantages such as less soft tissue trauma, reduced blood loss, decreased damage to the epidural blood supply and consequent epidural fibrosis, shorter hospital stays, shorter time to return to work (4-8). Through the past decade, the advancement of endoscopic instruments, such as different designs of endoscope and endoscopic burrs or punches, has promoted the technical progress and extensive application of the full-endoscopic spine surgery.

The interlaminar and transforaminal endoscopic spine surgeries have been the representatives for the

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JNS SPINE

LITERATURE REVIEW

J Neurosurg Spine 30:149–158, 2019

The evolution of minimally invasive spine surgery

JNSPG 75th Anniversary Invited Review Article

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The field of minimally invasive spine surgery (MISS) has rapidly evolved over the past 3 decades. This review follows the evolution of techniques and principles that have led to significant advances in the field. While still representing only a subset of spine surgeries, MISS's goals of reducing soft-tissue trauma and mitigating the morbidity of surgery are being realized, translating into more rapid recovery, lower infection rates, and higher cost savings. Future advances in technology and techniques can be anticipated.

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KEYWORDS minimally invasive; cost; economic; spine; percutaneous; XLIF; TLIF; endoscopic

The field of spinal surgery has advanced significantly over the past half century. Along with the proliferation of techniques and technologies in general, there has been a concomitant movement to reduce the morbidity of surgery. Minimally invasive surgical (MIS) approaches have thus been popularized, with its core principles being the following: 1) to minimize the collateral damage, 2) to preserve the normal anatomy, and 3) to reduce the overall stress to the patient, all while achieving the same surgical goals as open surgery.

The roots in minimally invasive spine surgery (MISS) are based primarily on technique modifications. The Williams microdiscectomy, described in 1978, revolutionized MISS by starting the evolution of lumbar discectomy from an open surgery through a 6-inch incision to a microsurgical approach through as small an opening as possible.[68] The Wiltse approach, described in 1968, was revolutionary insomuch as the dissection in the spine was achieved *between* muscular planes, as opposed to through the soft-tissue envelope or the subperiosteal plane.[69] Subsequent developments have heavily leveraged new technologies, including enhanced retraction, fixation, biologics, visualization, monitoring, and navigation, further disrupting the landscape (Fig. 1).

However, it is instructive to first pose the question of "What is minimally invasive spine surgery?" Is it:

- A technique?
- A technology?
- A product?
- A surgical approach?
- A marketing ploy?
- A surgical philosophy?
- A systems-based approach for minimizing the overall impact of surgery?

In this review we retrace the history and evolution of MISS and attempt to highlight the major breakthroughs in the field.

MISS for Neural Decompression

One of the principal goals and indications for spinal surgery is decompression of the neural elements. As such, MISS has its roots here. Unlike open spine surgical procedures where the surgeon has the luxury of wide exposure to identify anatomy as well as multiple trajectories for tissue manipulation, an MIS approach by definition is more restrictive. The compromise between finding a surgical corridor that provides a large enough window to perform decompression while being minimally disruptive has been a perpetual challenge in MISS.

Microdiscectomy

The concept of microscopic discectomy introduced by Williams[68] was the precursor to the modern microdiscectomy in use today. Reducing soft-tissue dissection resulted in less postoperative back pain for patients; using the

ABBREVIATIONS MIS = minimally invasive surgical; MISS = minimally invasive spine surgery; TLIF = transforaminal lumbar interbody fusion.

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Review Article

A History of Endoscopic Lumbar Spine Surgery: What Have We Learnt?

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The new development and finally the general acceptance of surgical techniques among the worldwide surgical community sometimes create fascinating stories. This is also true for the history of endoscopic lumbar spine surgery. In the last 100 years there was a "natural" evolution of surgical techniques with continuous improvement and "refinement" of lumbar decompression techniques towards less invasive operations with the final "endpoint" of microsurgery. However the application of percutaneous, image-guided, and endoscopic technologies has revolutionized minimally invasive surgery. This article describes the history of endoscopic lumbar spine surgery and its major milestones and protagonists which have helped to make endoscopic lumbar spine surgery "disruptive" minimally invasive surgical technology which has changed the world of lumbar decompression surgery.

"The past is the mother of the future"
Henri Cartier Bresson, French Photographer, 1908-2004

1. Introduction

Development and progress in spinal surgery have always been characterized by "back-and-forth movements" in clinical applications of technical innovations. Most evolutionary technical improvements which seemed to have a logical indication spectrum, with adequate feasibility and a perspective to improve early or late outcomes, have sooner or later become "standard" with a worldwide market penetration. A good example of such a development is anterior cervical discectomy and fusion (ACDF). It all started with the Cloward and Smith-Robinson technique [1, 2], which was improved with the development of plates [3–5] to support and fix the bone grafts. The bone grafts were replaced by cages made from different materials, and further technical improvement has led to the use of cages as stand-alone devices recently. This is a typical simple example of a continuous evolution of a surgical technique.

The lesson we can learn from this is that if a technical improvement follows the needs of the surgeon and if it improves or standardizes a surgical technique and its outcomes, the acceptance among the surgical community will be logical and high.

2. History of Lumbar Disc Surgery

2.1. Part 1: From Complete Laminectomy to Microsurgical/Microendoscopic Techniques. The history of lumbar discectomy and lumbar decompression is one of the most fascinating chapters of spine surgery which has taught us a number of important lessons.

It was in 1909 when Krause and Oppenheim described the first lumbar discectomy [6] (Figure 1). Erroneously they described the herniated disc as a chondroma of the lumbar spinal canal. Only 2 years later Goldthwaite and Middleton were the first to describe a herniated nucleus pulposus as a reason of low back pain and sciatica [7, 8](Figure 2)

And it took another 11 years until Adson came up with the first report about surgical removal of herniated nucleus pulposus [9](Figure 3).

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CME

Unsuccessful Percutaneous Endoscopic Lumbar Discectomy: A Single-Center Experience of 10 228 Cases

BACKGROUND: Percutaneous endoscopic lumbar discectomy (PELD) has remarkably evolved with successful results. Although PELD has gained popularity for the treatment of herniated disc (HD), the risk of surgical failure may be a major obstacle to performing PELD. We analyzed unsuccessful cases requiring reoperation.
OBJECTIVE: To find common causes of surgical failure and elucidate the limitations of the conventional PELD technique.
METHODS: A retrospective review was performed on all patients who had undergone PELD between January 2001 and December 2012. Unsuccessful PELD was defined as a case requiring reoperation within 6 weeks after primary surgery. Chart review was done, and preoperative, intraoperative, and postoperative radiographic reviews were performed. All unsuccessful PELD cases were classified according to the type of HD, location of herniation, extruded disc migration, working channel position, and intraoperative and postoperative findings.
RESULTS: In 12 years, 10 228 patients had undergone PELD; 436 (4.3%) cases were unsuccessful. The causes were incomplete removal of HDs in 283 patients (2.8%), recurrence in 78 (0.8%), persistent pain even after complete HD removal in 41 (0.4%), and approach-related pain in 21 (0.2%). Incomplete removal of the HD was caused by inappropriate positioning (95 cases; 33.6%) of the working channel and occurred in central HDs (91 cases; 32.2%), migrated HDs (70 cases; 24.7%), and axillary type HDs (63 cases; 22.3%).
CONCLUSION: Proper surgical indications and good working channel position are important for successful PELD. PELD techniques should be specifically designed to remove the disc fragments in various types of HD.

KEY WORDS: Incomplete removal, Percutaneous endoscopic lumbar discectomy, Recurrence, Reoperation

Neurosurgery 76:372–381, 2015 DOI: 10.1227/NEU.0000000000000628 www.neurosurgery-online.com

Percutaneous endoscopic lumbar discectomy (PELD) is a minimally invasive spinal technique that has several advantages over open discectomy, including less paravertebral muscle injury, preservation of bony structure, and rapid recovery. PELD has gained popularity for removal of herniated disc (HD) material over the past few years since Kambin[1] introduced the percutaneous posterolateral approach in 1983. Despite the remarkable evolution of endoscopic techniques and instrumentation leading to successful outcomes comparable to conventional open surgery,[2-4] surgeons still have some difficulty in PELD. Most concerns are about the incomplete removal of disc fragments, a steep learning curve, recurrence, and radiation exposure.[5-7] The risk of surgical failure may be a major obstacle to performing PELD. We analyzed unsuccessful cases requiring reoperation. The purpose of this study was to find the common causes of surgical failure and to elucidate the limitations of the conventional PELD technique. We also discuss techniques to address these limitations.

ABBREVIATIONS: HD, herniated disc; **PELD,** percutaneous endoscopic lumbar discectomy

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ORIGINAL ARTICLE

Learning curve of full-endoscopic lumbar discectomy

Hsien-Ta Hsu · Shang-Jen Chang · Stephen S. Yang · Chung Liang Chai

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Abstract
Purpose To report the learning curve of full-endoscopic lumbar discectomy for a surgeon naive to endoscopic surgery but trained in open microdiscectomy.
Methods From July 2006 to July 2009, 57 patients underwent full-endoscopic lumbar discectomy and 66 underwent open microdiscectomy. The clinical results were evaluated with a visual analog scale (VAS) and the Oswestry Disability Index (ODI). Spearman's coefficient of rank correlation (rho) was used to assess the learning curves for the transforaminal and interlaminar procedures of full-endoscopic lumbar discectomy.
Results After full-endoscopic lumbar discectomy, the VAS and ODI results of the patients followed up were comparable with those of open microdiscectomy. A steep learning curve was observed for the transforaminal procedure, but not the interlaminar procedure.
Conclusions The learning curve of the transforaminal approach was steep and easy to learn, while the learning curve of the interlaminar approach was flat and hard to master.

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Keywords Learning curve · Disc herniation · Endoscopic lumbar discectomy · Transforaminal procedure · Interlaminar procedure

Introduction

Open midline lumbar discectomy is a familiar procedure to most spine surgeons and results in good outcomes [1]. However, open surgery often requires muscle retraction, bone resection of the lamina and facet joint, and dural sac and nerve retraction. This can cause instability and scarring of the epidural space, which becomes clinically symptomatic in 10 % or more of patients [2].

In 1973, Kambin and Gellman [3] proposed the idea of posterolateral percutaneous lumbar disc decompression. Both the lateral approach for full-endoscopic transforaminal discectomy and the full-endoscopic interlaminar discectomy entrance method have been carried out since the late 1990s [4, 5]. Using new optics, shavers and burrs, Ruetten et al. [6] used the aforementioned techniques to make a truly minimally invasive procedure.

However, the percutaneous approach poses challenges to surgeons and the difficulty of the approach is daunting to many potential users [6]. Indeed, so far only a few surgeons in the world have performed endoscopic lumbar spine surgery. Although the learning curve for endoscopic lumbar discectomy is often described as steep [7], few published studies have specifically addressed this aspect of the procedure.

In this study, we retrospectively reviewed our experience with full-endoscopic lumbar discectomy to outline the learning curve of transforaminal approach and interlaminar approach for a single surgeon learning this technique.

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Full-Endoscopic Interlaminar and Transforaminal Lumbar Discectomy *Versus* Conventional Microsurgical Technique

A Prospective, Randomized, Controlled Study

Sebastian Ruetten, MD, PhD,* Martin Komp, MD, PhD,* Harry Merk, MD,† and Georgios Godolias, MD‡

Study Design. Prospective, randomized, controlled study of patients with lumbar disc herniations, operated either in a full-endoscopic or microsurgical technique.

Objective. Comparison of results of lumbar discectomies in full-endoscopic interlaminar and transforaminal technique with the conventional microsurgical technique.

Summary of Background Data. Even with good results, conventional disc operations may result in subsequent damage due to trauma. Endoscopic techniques have become the standard in many areas because of the advantages they offer intraoperatively and after surgery. With the transforaminal and interlaminar techniques, 2 full-endoscopic procedures are available for lumbar disc operations.

Methods. One hundred seventy-eight patients with full-endoscopic or microsurgical discectomy underwent follow-up for 2 years. In addition to general and specific parameters, the following measuring instruments were used: VAS, German version North American Spine Society Instrument, Oswestry Low-Back Pain Disability Questionnaire.

Results. After surgery 82% of the patients no longer had leg pain, and 14% had occasional pain. The clinical results were the same in both groups. The recurrence rate was 6.2% with no difference between the groups. The full-endoscopic techniques brought significant advantages in the following areas: back pain, rehabilitation, complications, and traumatization.

Conclusion. The clinical results of the full-endoscopic technique are equal to those of the microsurgical technique. At the same time, there are advantages in the operation technique and reduced traumatization. With the surgical devices and the possibility of selecting an interlaminar or posterolateral to lateral transforaminal procedure, lumbar disc herniations outside and inside the spinal canal can be sufficiently removed using the full-endoscopic technique, when taking the appropriate criteria into account. Full-endoscopic surgery is a sufficient and safe supplementation and alternative to microsurgical procedures.

Key words: endoscopic discectomy, transforaminal discectomy, interlaminar discectomy, percutaneous discectomy, lumbar disc herniation. **Spine 2008;33:931–939**

In spine surgery, the open interlaminar access has been described since the early 20th century.[1–6] Thirty years after its introduction, alternative methods for operating disc pathologies were developed.[7] The posterolateral access for vertebral body biopsies was described in the late 1940s.[8] Percutaneous operations have been performed since the early 1970s.[9–14] In the late 1970s, a microsurgical procedure involving a microscope was developed to gain interlaminar (IL) access.[9,15–17] Endoscopes have been used since the early 1980s to inspect the intervertebral space after completed open surgery.[18] The full-endoscopic (FE) transforaminal (TF) operation with posterolateral access evolved out of this.[19–34] Endoscope-assisted IL procedures were reported in the literature in the late 1990s.[2,35–38] The lateral access in FE TF surgery to optimize the route to the spinal canal under continuous visualization has been performed since the late 1990s.[39] The development of the FE IL access was seen at the same time.[40–42]

Conventional surgeries have been associated with good results.[43–50] Nonetheless, 1 operative consequence is scarring of the epidural space,[43,51–55] which may be apparent on magnetic resonance imaging[43,56] but becomes clinically symptomatic in 10% or more of cases[51,52,55] and makes revision surgery more difficult. An analysis of study results revealed the occurrence of operation-induced destabilization due to the necessary resection of spinal canal structures.[1,47,57–62] The point of access influences the stabilization and coordination system in the innervation area of the dorsal nerve roots of the spinal nerves.[53,63,64] The combination of these parameters may explain poor revision-related results.[52,65,66] The use of microsurgical techniques has reduced tissue damage and its consequences.[38,67,68] Although conditions of postoperative pain are treatable,[54,69,70] continuous technical optimization should be attempted. The goal of a new procedure must be to achieve results that commen-

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Endoscopic Transforaminal Discectomy for Recurrent Lumbar Disc Herniation

A Prospective, Cohort Evaluation of 262 Consecutive Cases

Thomas Hoogland, MD, PhD, Karolien van den Brekel-Dijkstra, MD, PhD, Michael Schubert, MD, and Boris Miklitz, BSc

Study Design. A prospective, cohort evaluation of 262 consecutive patients who underwent transforaminal endoscopic excision for recurrent lumbar disc herniation, after previous discectomy.

Objective. To review complications and results of the endoscopic transforaminal discectomy (ETD) for recurrent herniated disc with a 2-year follow-up.

Summary of Background Data. Recurrent herniation is a significant problem, as scar formation and progressive disc degeneration may lead to increased morbidity after traditional posterior reoperation. The studies published until now on recurrent disc herniation concern various operative techniques, mostly the lumbar microdiscectomy, which is still seen as the standard. The advantage of ETD could be that there is no need to go through the old scar tissue and the procedure can be performed in local anesthesia. The disadvantage may be a long learning curve for the surgeon.

Method. Between January 1994 and November 2002, 262 patients with primarily radicular problems underwent an ETD for a recurrent herniated disc. Two hundred and thirty-eight of these patients (90.84%) completed our 2-year follow-up questionnaire. Initial surgery of 82 patients was performed in-house, 180 external. Average age was 46.4 years. The female/male ratio was 29/71%.

Results. At 2-year follow-up 85.71% of patients rated the result of the surgery as excellent or good. 9.66% reported a fair and 4.62% patients an unsatisfactory result. Average improvement of back pain of 5.71 points and 5.85 points of leg pain on the VAS scale (1–10). According to Mac Nab, 30.67% of the patients felt fully regenerated, 50% felt their functional capacity to be slightly restricted, 16.81% felt their functional capacity noticeably restricted, and 2.52% felt unimproved or worse. All patients participated in a 3-month follow-up to establish the perioperative complications. The overall complication rate was 10/262 (3.8%), including 3 nerve root irritations and 7 early recurrent herniations (<3 month). There was no case of infection or discitis.

After 3 months and within 2 years, 4 patients have been treated for a recurrent herniated disc in our own center and 7 patients have been treated elsewhere, resulting in a recurrence rate 11/238 (4.62%).

Conclusion. ETD for recurrent disc herniation seems to be an effective method with few complications and a high patient satisfaction.

Key words: endoscopy, transforaminal discectomy, recurrent disc herniation, lumbar disc herniation, ETD, lumbar spine, recurrence rate. **Spine 2008;33:973–978**

Compression of the neurologic elements of the lumbar spine is a clear indication for surgical decompression. At present, it seems that microdiscectomy is distinguished worldwide as the standard for the decompression of a radicular syndrome caused by disc-herniation.[1,2] The evaluation of the results of disc discectomy is complicated. The primary indication is leg-pain, and besides the complication rate, the absence or improvement of leg-pain is the most important outcome parameter for the patient. The potential increase of back-pain is probably the second most important parameter for the overall satisfaction; therefore, the visual analog scale (VAS) for back pain, VAS for radicular pain and the subjective satisfaction, and judgment of the patient should be the main parameter to rate the result of HNP-surgery.

The rate of revision after a lumbar discectomy is a recognized objective measure of the failure of primary surgery and is included in many outcome studies.[3] A recurrent herniation after a lumbar discectomy has been reported in 5% to 18% of the patients and depends on the duration of the follow-up[1,4–15] (Table 1). Reports of results of recurrent disc herniation requiring repeat operation, however, quote percentages with differences in the length of follow-up and analyzed mixed patient populations, including patients with other diagnoses than a true recurrent disc herniation (for example, spinal stenosis, herniation at a new level, perineural fibrosis, or failed back surgery).[16] Studies on recurrent disc herniation published until now concern various operative techniques, which makes comparison of the effect of these different operations difficult.

Since 1963, new, less invasive decompressive procedures for herniated disc have been developed by the introduction of chymopapain by Smith,[17] later Hijikata and Craig developed the closed percutaneous nucleotomy,[18,19] and in 1987, the percutaneous laser-nucleolyzers have been introduced for the decompression of a lumbar disc-herniation.[20] The technique has been evolved with a transforaminal access to the herniation site,[21] and in addition, endoscopes were introduced to visualize the intraforaminal nerve-root.[13,22–23] In 1994, Hoogland in-

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Posterolateral Endoscopic Excision for Lumbar Disc Herniation

Surgical Technique, Outcome, and Complications in 307 Consecutive Cases

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Study Design. A retrospective review involving 307 consecutive cases of lumbar disc herniation managed by posterolateral endoscopic discectomy was conducted.

Objectives. To describe a contemporary posterolateral endoscopic decompression technique for radiculopathy secondary to lumbar disc herniation; to evaluate the efficacy of the technique as it is applied to lumbar disc herniation including primary herniation, reherniation, intracanal herniation, and extracanal herniation; and to report outcome and complications.

Summary of Background Data. The concept of percutaneous posterolateral nucleotomy was introduced in 1973. The development of the related equipment and technique had witnessed a slow and lengthy evolution.

Method. A retrospective assessment of 307 patients was performed at least 1 year after their index operation. The outcome was graded according to a modified MacNab method. A patient-based outcome questionnaire also was incorporated into the study.

Results. The surgeon-performed assessment showed satisfactory results in 89.3% of the cases. The rate of response to the questionnaire was 91%. The responses indicated that 90.7% of the respondents were satisfied with their surgical outcome and would undergo the same endoscopic procedure again if faced with a similar herniation in the future. The poor outcome occurred in 10.7% of the primary group and 9.7% of the questionnaire group. The combined major and minor complication rate was 3.5%.

Conclusions. The surgical outcome of posterolateral endoscopic discectomy for lumbar disc herniation is comparable with that for the traditional open transcanal microdiscectomy. Intracanal and extracanal herniations, reherniations, and incidental lateral recess stenosis can be addressed by the same approach. [Key words: anatomic disc center, disc inclination, foraminal anular window, posterolateral endoscopic discectomy foraminal decompression, skin window] **Spine 2002;27:722–731**

From a prospective and randomized study in 1999, Hermantin et al[8] reported a favorable outcome for video-assisted arthroscopic lumbar microdiscectomy, as compared with open discectomy. In a prospective study the year before, Kambin et al[19] had reported a success rate of 88.2% for arthroscopic microdiscectomy including foraminal and extraforaminal herniation. The exclusion criteria for these studies involved high iliac crest, large herniations, and sample uniformity. These exclusions reflect the restrictiveness of the procedure. The versatility and reliability of this procedure and its outcome have yet to be validated by other clinicians.

During the study period, there were accelerated refinements in both surgical technique and operating equipment. These factors have enhanced the capabilities of posterolateral endoscopic procedure. This report describes the authors' current posterolateral endoscopic operative technique, including placement of the operating endoscope and excision techniques for the varied lumbar disc herniations that cause radiculopathy. The outcome and complications from percutaneous posterolateral endoscopic excision of lumbar disc herniation in 307 consecutive cases were subjected to retrospective reviews. There were no exclusions on the basis of location or size of herniation, payer type, liability status, or prior surgical intervention at the index level.

Historical Background

In 1934, from exploratory laminectomy for radicular pain, Mixter and Barr[25] reported 19 surgical cases of lumbar, thoracic, and cervical prolapse of the nucleus pulposus or fracture of the anulus. The concept of indirect spinal canal decompression by nucleotomy using the anterolateral abdominal extra peritoneal approach was first introduced by Hult[11] in 1951. Indirect percutaneous spinal canal decompression through a posterolateral extracanal, nonvisualized approach by limited nucleotomy and decompression using a Craig[4] cannula in conjunction with a standard posterior transcanal exploration was initiated by Kambin in January 1973.[18] Stand-alone nonvisualized posterolateral percutaneous nucleotomy was first introduced by Hijikata in 1975,[9,10] followed by Kamin and Gellman's[18] report of nine cases in 1983. A nonvisualized motorized aspiration nucleotomy shaver 2.8 mm in diameter was used by Onik et al[26] in 1985. Mathews[24] published a report of the foraminoscopic approach in 1996. Schreiber et al[28] in 1989 used a biportal approach, injecting a nontoxic vital dye, indigo carmine, to blue stain the abnormal nucleus pulposus and anular fissure. In 1998, Kambin et al[19] used the transforaminal approach biportally to excise central herniations and nonmigrated sequestrated disc fragments in 59 cases.

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Percutaneous Posterolateral Lumbar Discectomy and Decompression with a 6.9-Millimeter Cannula

Analysis of Operative Failures and Complications*†

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Abstract: The operative failures and complications of percutaneous posterolateral lumbar discectomy were analyzed in 100 patients who had a herniated nucleus pulposus and were prospectively studied and treated with use of a 6.9-millimeter outer-diameter (4.9-millimeter inner-diameter) sheath and manual insertion of the instruments. Twelve operations were considered to have failed, regardless of the length of postoperative follow-up or the incidence of reinjury; eleven patients had a repeat operation at the index level, and one patient was a chronic drug-abuser. In eight of the eleven patients, subsequent laminectomy was successful. Two patients had a psoas hematoma and one had a transitory sensory and distal motor deficit; all of these complications resolved without sequelae. There were no major complications, including superficial or deep infection, and no patient had neurovascular compromise.

The percutaneous posterolateral approach to a herniated lumbar intervertebral disc is an alternative method for the treatment of protrusion of a lumbar disc and its associated radiculopathy. Although most patients who have radicular pain secondary to protrusion of a disc respond to conservative management, operative treatment is often considered necessary in patients who have unremitting, persistent radiculopathy that has not responded to appropriate conservative therapy. In addition, in order to maximize the incidence of successful operative results, the patients must have demonstrable neurological impairment, positive nerve-root tension signs, and correlative findings on imaging studies[11,15,16]. There are three operative alternatives: laminectomy and discectomy (including microdiscectomy), chemonucleolysis, and percutaneous posterolateral discectomy.

The operative goal is the removal of all pathological material, without damage to normal structures. Chemonucleolysis does not permit removal of the collagenized disc at the time of the procedure[35,38]. The rates of failure and complications associated with chemonucleolysis have included anaphylaxis, unexplained neurological complications, and death[8,29,34]. Because laminectomy permits direct visualization of the nerve-roots and the structures compressing them during removal of the disc, it continues to be an effective and reliable method for the treatment of lumbar radiculopathy due to a protruded intervertebral disc.

Posterolateral discectomy through a seven-millimeter incision permits evacuation of the herniated material and decompression of the nerve-root without entrance into the spinal canal and without destruction of the articular processes. Patients are spared the pain and morbidity that are often associated with an open operative procedure. The slight damage to muscular and ligamentous structures allows for rapid rehabilitation and restoration of function. The advantages of percutaneous discectomy include the avoidance of epidural bleeding and subsequent development of perineural fibrosis; elimination of recurrent herniation in the spinal canal through the annular fenestration created during a laminectomy, by establishment of a portal away from the neural elements; and preservation of spinal stability[18-24]. In addition, the selection of future operative procedures is not compromised, and the hospitalization is more cost-effective than that for traditional approaches, as the time needed for the operating room and for hospitalization are decreased[22].

Kambin and Gellman[20] reported on the combination of conventional lumbar laminectomy with posterolateral percutaneous decompression of the intervertebral disc that had been done as early as 1973. Two types of instrumentation are currently used for percutaneous discectomy. Many investigators[3,10,12-14,18-24,26,31,32,36,37] have reported favorable results with cannulas that were five to eight millimeters in diameter, which permit the introduction of straight, up-biting, and back-biting forceps and curets, facilitating evacuation of the nuclear fragments.

Davis and Onik[5] and Onik et al.[27] used a straight automated probe with an external diameter of 2.8 millimeters, permitting cannulation and central evacuation of the nuclear material. These authors have reported satisfactory results using their own criteria for inclusion.

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SUPERIORITY OF ENDOSCOPIC SPINE SURGERY

Spine

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RESEARCH LETTER

Full-endoscopic Transforaminal Discectomy *Versus* Open Microdiscectomy for Sciatica: Update of a Systematic Review and Meta-analysis

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Key words: endoscopic discectomy, PTED, microdiscectomy, meta-analysis

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Percutaneous transforaminal endoscopic discectomy (PTED) was intended as a less invasive surgical technique to treat sciatica caused by a lumbar disk herniation. In contrast to conventional open microdiscectomy, PTED is performed under conscious sedation during which the disk herniation is removed from a transforaminal approach. Furthermore, PTED is performed on an outpatient basis. Concerns, however, exist on its learning curve and effectiveness compared with microdiscectomy.[1] We previously published the results of a systematic review and meta-analysis that relied on available literature in April 2020 and compared clinical outcomes of PTED with those of microdiscectomy.[2] As the field of endoscopic spine surgery is growing in both clinical practice and research, an update of the previously conducted review is warranted.[2,3]

MATERIALS AND METHODS

Full methods of the current review have been previously published, and the study protocol was registered in the international prospective register of systematic reviews before the update was commenced (Prospero CRD 42020177053).[2] In brief, (quasi)randomized controlled trials (RCTs) comparing PTED with open microdiscectomy in clinical outcomes [Visual Analog Scale for leg pain, back pain, functionality as measured by the Oswestry Disability Index (ODI)] or costs, published in English, Dutch, and German were included. Prospective nonrandomized studies and retrospective studies were excluded for this update, as the level of evidence from these studies is lower than that of RCTs.

An experienced librarian performed a systematic search in multiple online databases such as PubMed, Embase, and MEDLINE on April 1, 2022. Based on these search results, two reviewers independently screened articles, read the full texts, and performed data extraction. A third reviewer was available to solve disagreements. Data extraction and risk of bias assessment of the newly identified articles was performed by two reviewers that were not part of the research group of the current study and thus were independent.

Treatment effects such as leg pain, back pain, and functional status were expressed as standardized mean differences (SMDs) with their 95% confidence intervals (CIs). Treatment effects were estimated at short term (1 d), intermediate term (3–6 mo), and long term (12 mo). Random effect models were used for all analyses, as available on RevMan 5.3 (The Cochrane Collaboration). Statistical heterogeneity was tested by the I^2. The overall quality of the evidence for the clinical outcomes leg pain, functionality, and back pain was summarized using the GRADE method.

RESULTS

Studies

The updated search resulted in two additional studies, which were also included in the meta-analysis. Both studies were publications of the same RTC.[3–5] Therefore, in addition to the nine (quasi)randomized studies included in the previous meta-analysis, 10 RCTs were included in the current study.[2] Based on the independent review of the risk of bias of the newly added study of Gadjradj and colleagues had a low level of selection bias and reporting bias, an unknown level of attrition bias, and a high risk of performance and detection bias. Finally, conflict of interest was only apparent evident in one of the studies, which was included in the previous version of the review.

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Full endoscopic versus open discectomy for sciatica: randomised controlled non-inferiority trial

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ABSTRACT

OBJECTIVE

To assess whether percutaneous transforaminal endoscopic discectomy (PTED) is non-inferior to conventional open microdiscectomy in reduction of leg pain caused by lumbar disc herniation.

DESIGN

Multicentre randomised controlled trial with non-inferiority design.

SETTING

Four hospitals in the Netherlands.

PARTICIPANTS

613 patients aged 18-70 years with at least six weeks of radiating leg pain caused by lumbar disc herniation. The trial included a predetermined set of 125 patients receiving PTED who were the learning curve cases performed by surgeons who did not do PTED before the trial.

INTERVENTIONS

PTED (n=179) compared with open microdiscectomy (n=309).

MAIN OUTCOME MEASURES

The primary outcome was self-reported leg pain measured by a 0-100 visual analogue scale at 12 months, assuming a non-inferiority margin of 5.0. Secondary outcomes included complications, reoperations, self-reported functional status as measured with the Oswestry Disability Index, visual analogue scale for back pain, health related quality of life, and self-perceived recovery. Outcomes were measured until one year after surgery and were longitudinally analysed according to the intention-to-treat principle. Patients belonging to the PTED learning curve were omitted from the primary analyses.

RESULTS

At 12 months, patients who were randomised to PTED had a statistically significantly lower visual analogue scale score for leg pain (median 7.0, interquartile range 1.0-30.0) compared with patients randomised to open microdiscectomy (16.0, 2.0-53.5) (between group difference of 7.1, 95% confidence interval 2.8 to 11.3). Blood loss was less, length of hospital admission was shorter, and timing of postoperative mobilisation was earlier in the PTED group than in the open microdiscectomy group. Secondary patient reported outcomes such as the Oswestry Disability Index, visual analogue scale for back pain, health related quality of life, and self-perceived recovery, were similarly in favour of PTED. Within one year, nine (5%) in the PTED group compared with 14 (6%) in the open microdiscectomy group had repeated surgery. Per protocol analysis and sensitivity analyses including the patients of the learning curve resulted in similar outcomes to the primary analysis.

CONCLUSIONS

PTED was non-inferior to open microdiscectomy in reduction of leg pain. PTED resulted in more favourable results for self-reported leg pain, back pain, functional status, quality of life, and recovery. These differences, however, were small and may not reach clinical relevance. PTED can be considered as an effective alternative to open microdiscectomy in treating sciatica.

TRIAL REGISTRATION

NCT02602093ClinicalTrials.gov NCT02602093.

WHAT IS ALREADY KNOWN ON THIS TOPIC

Percutaneous transforaminal endoscopic discectomy (PTED) is intended as a minimally invasive surgical technique to treat sciatica caused by lumbar disc herniation

Data from randomised controlled trials with adequate sample size and low risk of bias comparing PTED with open microdiscectomy are lacking

WHAT THIS STUDY ADDS

PTED was non-inferior to open microdiscectomy in the reduction of leg pain caused by lumbar disc herniation

PTED resulted in statistically more favourable results for patients' self-reported leg pain, back pain, functional status, quality of life, and recovery

PTED had a reoperation rate comparable to that for open microdiscectomy

Although these differences were small and may not reach established clinical relevance thresholds, PTED can be considered as an effective alternative to open microdiscectomy to treat sciatica

Introduction

With a lifetime prevalence of up to 43%, sciatica is a common health problem in the general population.[1] Sciatica is typically characterised by radiating leg pain starting from the low back, at times accompanied by sensory or motor deficits, and most frequently caused by lumbar disc herniation.[2 3] Sciatica has a favourable natural course in most people; however, surgery may be indicated when conservative treatment fails or progressive neurological deficits develop.[4] Previous studies have shown the short term benefits of surgery for pain relief, function, and perceived recovery, with similar long term outcomes to prolonged conservative management for people with sciatica lasting from six to 12 weeks. Recent studies showed that surgery led to a greater reduction in leg pain on long term follow-up compared with conservative management for sciatica lasting from four to 12 months.[5 6]

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Original Article

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Comparative Effects and Safety of Full-Endoscopic Versus Microscopic Spinal Decompression for Lumbar Spinal Stenosis: A Meta-Analysis and Statistical Power Analysis of 6 Randomized Controlled Trials

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Objective: This meta-analysis with statistical power analysis aimed to evaluate the difference between full-endoscopic and microscopic spinal decompression in treating spinal stenosis.
Methods: We searched PubMed, Embase, CENTRAL (Cochrane Central Register of Controlled Trials), and CNKI (China National Knowledge Infrastructure) for relevant randomized controlled trials (RCTs) regarding the comparison of full-endoscopic versus microscopic spinal decompression in treating lumbar spinal stenosis through February 28, 2022. Two independent investigators selected studies, extracted information, and appraised methodological quality. Meta-analysis was conducted using RevMan 5.4 and STATA 14.0, and statistical power analysis was performed using G*Power 3.1.
Results: Six RCTs involving 646 patients met selection criteria. Meta-analysis suggested that, compared with microscopic decompression, full-endoscopic spinal decompression achieved more leg pain improvement (mean difference [MD], -0.20; 95% confidence interval [CI], -0.30 to -0.10; p = 0.001), shortened operative time (MD, -12.71; 95% CI, -18.27 to -7.15; p < 0.001), and decreased the incidence of complications (risk ratio, 0.43; 95% CI, 0.22–0.82; p = 0.01), which was supported by a statistical power of 98.57%, 99.97%, and 81.88%, respectively.
Conclusion: Full-endoscopic spinal decompression is a better treatment for lumbar spinal stenosis, showing more effective leg pain improvement, shorter operative time, and fewer complications than microscopic decompression.

Keywords: Full-endoscopic spinal decompression, Microscopic spinal decompression, Lumbar stenosis, Meta-analysis

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INTRODUCTION

Lumbar spinal stenosis is described as pathological spinal canal narrowing,[1] which will result in a series of neurological symptoms due to subsequent compression of nerve roots, including back and leg pain, claudication, and walking difficulty.[2,3] As one of the most prevalent degenerative conditions,[4-6] lumbar spinal stenosis was associated with an increased social and economic burden because it leads to pain and disability and reduces patients' quality of life.[7]

For patients diagnosed with lumbar spinal stenosis at the initial phase, conservative treatments are always recommended,[8] including physical therapy, anti-inflammatory agents, and drugs for relieving pain.[9-11] However, patients will be advised to receive

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BIOMECHANICS

OPEN

Biomechanics of Transforaminal Endoscopic Approaches

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Study Design. Biomechanical cadaveric study.

Objective. The aim of this study was to compare the effect of transforaminal endoscopic approaches with open decompression procedures.

Summary of Background Data. Clinical studies have repeatedly highlighted the benefits of endoscopic decompression, however, the biomechanical effects of endoscopic approaches (with and without injury to the disk) have not been studied up to now.

Materials and Methods. Twelve spinal segments originating from four fresh-frozen cadavers were biomechanically tested in a load-controlled endoscopic transforaminal approach study. Segmental range of motion (ROM) after endoscopic approach was compared with segmental ROM after (1) microsurgical decompression with unilateral laminotomy and (2) midline decompression with bilateral laminotomy. In the intact state and after decompression, the segments were loaded in flexion-extension (FE), lateral shear (LS), lateral bending (LB), anterior shear (AS), and axial rotation (AR).

Results. Vertebral segment ROM was comparable between the two endoscopic transforaminal approaches. However, there was a —statistically nonsignificant—trend for a larger ROM after accessing via the inside-out technique. FE: +3% *versus* +7%, $P=0.484$; LS: +1% *versus* +12%, $P=0.18$; LB: +0.6% *versus* +9%, $P=0.18$; AS: +2% *versus* +11%, $P=0.31$; AR: −4% *versus* +5%, $P=0.18$. No significant difference in vertebral segment ROM was seen between the transforaminal endoscopic approaches and open unilateral decompression. Vertebral segment ROM was significantly smaller with the transforaminal endoscopic approaches compared with midline decompression for almost all loading scenarios: FE: +4% *versus* +17%, $P=0.005$; AS: +6% *versus* 21%, $P=0.007$; AR: 0% *versus* +24%, $P=0.002$.

Conclusion. The transforaminal endoscopic intracanal technique preserves the native ROM of lumbar vertebral segments and shows a trend toward relative biomechanical superiority over the inside-out technique and open decompression procedures.

Key words: endoscopy, endoscopic spine surgery, endoscopic approach, endoscopic decompression, transforaminal, intracanal technique, inside-out technique, biomechanics, lumbar disk herniation, lumbar spine

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The estimated lifetime incidence of lumbar radiculopathy ranges from 13% to 40%,[1] with lumbar disk herniation accounting for the most common pathology leading to decompression surgery. As in many areas of orthopedics, spine surgery has experienced a trend towards minimally invasive surgery.[2] Endoscopic spine surgery, whose initial description dates back to the 1960s,[3] represents the most advanced form of minimally invasive spine surgery in this regard. In the last decade, the technique has evolved significantly due to rapid technological advances with improvements in optics design, surgical instruments, and specific surgical approaches.[4,5]

Transforaminal endoscopic decompression, which originated from the concept of indirect neural decompression by removal of the nucleus pulposus, has expanded its scope over time to include the epidural space, resulting in an increasing number of indications.[6] Depending on the approach, the inside-out technique is distinguished from the intracanal technique.[7] The intracanal technique is based on serial foraminoplasty, which is used to enter the spinal canal. The inside-out technique enters directly into the disk, inevitably resulting in damage to the annulus fibrosus.[8] Clinical studies have repeatedly highlighted the benefits of endoscopic decompression: reducing the surgical "footprint" to a minimum, less muscle trauma,

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Endoscopic decompression for the treatment of lumbar spinal stenosis: an updated systematic review and meta-analysis

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OBJECTIVE Lumbar stenosis treatment has evolved with the introduction of minimally invasive surgery (MIS) techniques. Endoscopic methods take the concepts applied to MIS a step further, with multiple studies showing that endoscopic techniques have outcomes that are similar to those of more traditional approaches. The aim of this study was to perform an updated meta-analysis and systematic review of studies comparing the outcomes between endoscopic (uni- and biportal) and microscopic techniques for the treatment of lumbar stenosis.

METHODS Following PRISMA guidelines, a systematic search was performed using the Cochrane Central Register of Controlled Trials, Cochrane Database of Systematic Reviews, Ovid Embase, and PubMed databases from their dates of inception to December 14, 2020. All identified articles were then systematically screened against the following inclusion criteria: 1) studies comparing endoscopic (either uniportal or biportal) with minimally invasive approaches, 2) patient age ≥ 18 years, and 3) diagnosis of lumbar spinal stenosis. Bias was assessed using quality assessment criteria and funnel plots. Meta-analysis using a random-effects model was used to synthesize the metadata.

RESULTS From a total of 470 studies, 14 underwent full-text assessment. Of these 14 studies, 13 comparative studies were included for quantitative analysis, totaling 1406 procedures satisfying all criteria for selection. Regarding postoperative back pain, 9 studies showed that endoscopic methods resulted in significantly lower pain scores compared with MIS (mean difference [MD] −1.0, 95% CI −1.6 to −0.4, $p < 0.01$). The length of stay data were reported by 7 studies, with endoscopic methods associated with a significantly shorter length of stay versus the MIS technique (MD −2.1 days, 95% CI −2.7 to −1.4, $p < 0.01$). There was no significant difference with respect to leg visual analog scale scores, Oswestry Disability Index scores, blood loss, surgical time, and complications, and there were not any significant quality or bias concerns.

CONCLUSIONS Both endoscopic and MIS techniques are safe and effective methods for treating patients with symptomatic lumbar stenosis. Patients who undergo endoscopic surgery seem to report less postoperative low-back pain and significantly reduced hospital stay with a trend toward less perioperative blood loss. Future large prospective randomized trials are needed to confirm the findings in this study.

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KEYWORDS endoscopic; decompression; uniportal; biportal; spinal stenosis; lumbar

Lumbar spinal stenosis, characterized by pathological spinal canal narrowing and compression of the thecal sac along with the nerve roots, is one of the most prevalent degenerative conditions that affects older individuals.[1] Symptomatology usually consists of a combination of low-back pain, neurogenic claudication, lower-extremity pain, and decreased ability in ambulating. Initial treatment typically consists of conservative management, including physical therapy, medications, and epidural steroid injections.[2] However, in patients with more acutely severe symptoms such as incapacitating pain and neurological deficits or those in whom conservative management has failed, surgical treatment is often offered.[3] Overall, studies have indicated better clinical outcomes with surgical treatment than with more conservative therapies.[3,4]

The traditional surgical method for lumbar spinal stenosis consists of an open decompression in an effort to decompress the neural structures.[3,4] However, this conventional approach can disrupt the paraspinal muscles and ligaments, which may result in muscle atrophy and low-back

ABBREVIATIONS BESS = biportal endoscopic system; MD = mean difference; MIS = minimally invasive surgery; MOOSE = Meta-analysis of Observational Studies in Epidemiology; ODI = Oswestry Disability Index; UPFE = uniportal full-endoscopic system; VAS = visual analog scale.

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Narrative Review

Spinal endoscopy: evidence, techniques, global trends, and future projections

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Abstract The utilization of indirect visualization during procedures has been increasingly replacing traditional forms of direct visualization across many different surgical specialties. The adoption of arthroscopy, using small cameras placed inside joints, has transformed musculoskeletal care over the last several decades, allowing surgeons to provide the same anatomic solutions with less tissue dissection, resulting in lower requirements for inpatient care, reduced costs, and expedited recovery. For a variety of reasons, spine surgery has lagged behind other specialties in the adoption of indirect visualization. Nonetheless, patient demand for less invasive spine procedures and surgeon drive to provide these solutions and improve care quality has driven global adoption of spinal endoscopy. There are numerous endoscopic platforms and techniques currently utilized, and these systems are rapidly evolving. Additionally, the variance in technology and health system incentives across the globe has generated tremendous regional heterogeneity in the utilization of spinal endoscopic procedures. We present a consolidated review, including the background, evidence, techniques, and trends in spinal endoscopy, so that clinicians can gain a deeper understanding of this rapidly evolving domain of spinal healthcare. © 2021 The Author(s). Published by Elsevier Inc. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/)

Keywords: Biportal endoscopy; Endoscopic decompression; Endoscopic Spine Surgery; Full Endoscopy; Microendoscopy; Spine endoscopy

Rationale for spinal endoscopy and the role of anatomic perspective during surgery

The vast majority of spinal procedures being performed throughout the world currently rely on direct visualization aided by magnification, either through eyewear (eg, loupes with a headlamp) or the use of an operating microscope. A frequent goal of most spine procedures for degenerative pathologies involves addressing and relieving extrinsic neural compression. As the tools and techniques to perform these procedures have evolved, surgeons have been able to perform these procedures with more limited operative exposures. Furthermore, as the working area of access to the spinal canal decreases, direct external visualization begins to create substantial limitations, and moving the point of anatomic perspective into the body of the patient, and closer to the surgical site, dramatically increases the area and quality

FDA device/drug status: Not applicable.

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Systematic Review and Meta-Analysis

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Percutaneous endoscopic lumbar discectomy compared with other surgeries for lumbar disc herniation

A meta-analysis

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Abstract

Objective: This meta-analysis was performed to investigate whether percutaneous endoscopic lumbar discectomy (PELD) had a superior effect than other surgeries in the treatment of patients with lumbar disc herniation (LDH).

Method: We searched PubMed, Embase, and Web of Science through February 2018 to identify eligible studies that compared the effects and complications between PELD and other surgical interventions in LDH. The outcomes included success rate, recurrence rate, complication rate, operation time, hospital stay, blood loss, visual analog scale (VAS) score for back pain and leg pain, 12-item Short Form Health Survey (SF12) physical component score, mental component score, Japanese Orthopaedic Association Score, Oswestry Disability Index. A random-effects or fixed-effects model was used to pool the estimate, according to the heterogeneity among the included studies.

Results: Fourteen studies (involving 2,528 patients) were included in this meta-analysis. Compared with other surgeries, PELD had favorable clinical outcomes for LDH, including shorter operation time (weight mean difference, WMD=−18.14 minutes, 95%CI: −25.24, −11.05; $P < .001$) and hospital stay (WMD = −2.59 days, 95%CI: −3.87, −1.31; $P < .001$), less blood loss (WMD = −30.14 ml, 95%CI: −43.16, −17.13; $P < .001$), and improved SF12- mental component score (WMD = 2.28, 95%CI: 0.50, 4.06; $P = .012$)) and SF12- physical component score (WMD = 1.04, 95%CI: 0.37, 1.71; $P = .02$). However, it also was associated with a significantly higher rate of recurrent disc herniation (relative risk [RR] = 1.65, 95%CI: 1.08, 2.52; $P = .021$). There were no significant differences between the PELD group and other surgical group in terms of success rate (RR = 1.01, 95%CI: 0.97, 1.04; $P = .733$), complication rate (RR = 0.86, 95%CI: 0.63, 1.18; $P = .361$), Japanese Orthopaedic Association Score score (WMD = 0.19, 95%CI: −1.90, 2.27; $P = .861$), visual analog scale score for back pain (WMD = −0.17, 95%CI: −0.55, 0.21; $P = .384$) and leg pain (WMD = 0.00, 95%CI: −0.10, 0.10; $P = .991$), and Oswestry Disability Index score (WMD = −0.29, 95%CI: −1.00, 0.43; $P = .434$).

Conclusion: PELD was associated with better effects and similar complications with other surgeries in LDH. However, it also resulted in a higher recurrence rate. Considering the potential limitations in the present study, further large-scale, well-performed randomized trials are needed to verify our findings.

Abbreviations: JOA = Japanese Orthopaedic Association Score, LDH = lumbar disc herniation, MCS = mental component score, MED = microendoscopic discectomy, ODI = Oswestry Disability Index, OLM = open lumbar microdiscectomy, PCS = physical component score, PELD = percutaneous endoscopic lumbar discectomy, RR = relative risk, SF12 = 12-item Short Form Health Survey, VAS = visual analog scale, WMD = weighted mean difference.

Keywords: lumbar disc herniation, meta-analysis, percutaneous endoscopic lumbar discectomy

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The authors have no conflicts of interest to disclose.

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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Expanded Indications of Full Endoscopic Spine Sugery

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Treatment of spine surgeries has evolved from traditional surgeries to open surgeries. Endoscopic spine surgeries (ESS) and endoscope assisted surgeries along with microscopic and tubular surgeries has developed significantly over the last three decades. With improvement in the diagnostic methods it is now possible to find and differentiate the spinal pathologies. ESS was initially limited to the lumbar disc herniations (DH). But, now it can be used for cervical and thoracic DH. Minimized technical problems has been brought by evolutions in endoscopy, better optics, instruments, access, and safety. Similarly acquired knowledge and skills are being extrapolated to advanced indications in different spinal pathologies. Due to the further advantages of ESS within the ambit of minimal invasive spine surgeries, many misnomers are as well getting added. This confuses the new learners and potential patients as well. ESS should be classified for uniformity in reporting and common nomenclature like FESS (Full endoscopic spine surgery) should be used. It specifically refers to surgery through one working channel under irrigation with incorporated optics. This will make easier understanding for novice surgeons and general population. It will lead to standardised reporting of high quality clinical studies, trials, and meta-analysis for the publications. Rising misnomers and complex nomenclature of endoscopy is suggesting along with the exponential publications in last decade that ESS is entering into its golden era. This review is undertaken to throw light on the techniques, advances and literature review of only FESS and clear the misnomers. This review also describes the evolution of different techniques and goals that led to impeccable advances in the field of FESS. Further improvement of technologies and techniques in future will soon establish FESS as the Gold Standard in spine surgery.

Key Words: Full Endoscopy, Spine, Surgery, Working Channel, Lumbar, Cervical, Thoracic, Sacral

INTRODUCTION

Patients have started demanding for the least invasive procedures for all spine surgeries and its equally evident with the training desires of the novice and accomplished spine surgeons. In the last quarter of the 20th century and early 21st century, there has been an evident shift from traditional open to minimal invasive spinal surgical techniques (MIS). Endoscopic Spine surgeries (ESS) are also a spectrum of this MIS[1-4]. In the last ten years, there has been an exponential increase in ESS practice. It is evolving from individual spine surgeons practice to institutional practice and is getting better incorporated[1,3,5-7]. Now even universities and spine societies are incorporating spine endoscopy in their curriculum and guidelines exemplified by North American Spine Society (NASS).

There are numerous reasons for this development. In general, minimal incision reduces the extent of underlying tissue disruption and blood loss. This leads to cascading events of reduced tissue dissection and trauma leading to negligible disruption of structural and functional ability of spine. This further reduces postoperative pain and incidence of complications. Moreover it increases patient confidence, cosmesis, improved clinical outcomes with quality of life, early ambulation with return to work and reduced length of hospital stay[1,3,5].

Initially, ESS technique was restricted to the lumbar, cervical and thoracic disc herniations (DH). But gradually it has also found use for stenosis and ESS fusion[3,5,8]. Although validating higher evidence is much needed to support the advanced ESS techniques and surgical indications, it now appears that the ESS is

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Original Article

Comparison of clinical and radiological outcomes of full-endoscopic versus microscopic lumbar decompression laminectomy for the treatment of lumbar spinal stenosis: a systematic review and meta-analysis

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Background: To determine the clinical and radiological outcomes of full-endoscopic (FE) versus microscopic (MI) lumbar decompression laminectomy in the treatment of lumbar spinal stenosis (LSS), we performed a meta-analysis to explore the best choice for patients with LSS requiring surgical relief.

Methods: Literature searches of the PubMed, the Cochrane Library, Embase, Medline, Embase, and Web of Science databases were performed. The searches covered all indexed studies published between 2008 and 2020, using keywords identifying the patient group (lumbar spine stenosis) and the interventions (full-endoscopic lumbar decompression laminectomy and microscopic lumbar decompression laminectomy). A total of 1,727 patients were included in 10 studies. The primary outcomes of the analysis were visual analogue scale (VAS) scores for leg and back pain, and Oswestry Disability Index (ODI) score.

Results: The meta-analysis of the VAS score for low back pain showed that in the first 24 hours postoperatively, participants who underwent FE had better pain control than those who underwent MI [FE: mean difference (MD) =–0.78, 95% confidence interval (CI): –1.11, –0.45; MI: MD =–1.53, 95% CI: –1.94, –1.12]. In all subgroup analyses, the VAS score for back pain was lower in the FE group than in the MI group (MD =–0.71, 95% CI: –0.96, –0.47). Regarding the VAS score for leg pain, the FE group had a significantly lower score than the MI group in the first 24 hours (Total: MD =–1.02, 95% CI: –1.31, –0.73). The meta-analysis demonstrated that the FE group had a significantly lower ODI score than the MI group (MD =–1.03, 9% CI: –1.54, –0.51). At 6 months, the MI group had a significantly lower score than the FE group (MD =1.09, 95% CI: 0.53, 1.64), but at 12 months, the FE group had a significantly lower score than the MI group (MD =–2.40, 95% CI: –3.12, –1.67).

Discussion: Compared to MI decompression, the FE decompression method resulted in better pain control in the early postoperative period, both in the lower back and legs, as well as shorter operative and shorter hospitalization times.

Keywords: Biportal endoscopic spinal surgery; lumbar decompression laminectomy; microscopic surgery; percutaneous full-endoscopic surgery; spinal stenosis

Training

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AOSpine Consensus Paper on Nomenclature for Working-Channel Endoscopic Spinal Procedures

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Abstract

Study Design: International consensus paper on a unified nomenclature for full-endoscopic spine surgery.

Objectives: Minimally invasive endoscopic spinal procedures have undergone rapid development during the past decade. Evolution of working-channel endoscopes and surgical instruments as well as innovation in surgical techniques have expanded the types of spinal pathology that can be addressed. However, there is in the literature a heterogeneous nomenclature defining approach corridors and procedures, and this lack of common language has hampered communication between endoscopic spine surgeons, patients, hospitals, and insurance providers.

Methods: The current report summarizes the nomenclature reported for working-channel endoscopic procedures that address cervical, thoracic, and lumbar spinal pathology.

Results: We propose a uniform system that defines the working-channel endoscope (full-endoscopic), approach corridor (anterior, posterior, interlaminar, transforaminal), spinal segment (cervical, thoracic, lumbar), and procedure performed

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Systematic Review

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Is Endoscopic Discectomy the Next Gold Standard in the Management of Lumbar Disc Disease? Systematic Review and Superiority Analysis

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Abstract

Study Design: Systematic review and meta-analysis.

Objectives: We performed this meta-analysis to evaluate whether endoscopic discectomy (ED) shows superiority compared with the current gold standard of microdiscectomy (MD) in management of lumbar disc disease.

Materials and Methods: We conducted independent and duplicate electronic database search including PubMed, Embase, and Cochrane Library from 1990 till April 2020 for studies comparing ED and MD in the management of lumbar disc disease. Analysis was performed in R platform using OpenMeta[Analyst] software.

Results: We included 27 studies, including 11 randomized controlled trials (RCTs), 7 nonrandomized prospective, and 9 retrospective studies involving 4018 patients in the meta-analysis. We stratified the results based on the study design. Considering the heterogeneity in some results between study designs, we weighed our conclusion essentially based on results of RCTs. On analyzing the RCTs, superiority was established at 95% confidence interval for ED compared with MD in terms of functional outcomes like Oswestry Disability Index (ODI) score ($P = .008$), duration of surgery ($P = .023$), and length of hospital stay ($P < .001$) although significant heterogeneity was noted. Similarly, noninferiority to MD was established by ED in other outcomes like visual analogue scale score for back pain ($P = .860$) and leg pain ($P = .495$), MacNab classification ($P = .097$), recurrences ($P = .993$), reoperations ($P = .740$), and return-to-work period ($P = .748$).

Conclusion: Our meta-analysis established the superiority of endoscopic discectomy in outcome measures like ODI score, duration of surgery, overall complications, length of hospital stay and noninferiority in other measures analyzed. With recent advances in the field of ED, the procedure has the potential to take over the place of MD as the gold standard of care in management of lumbar disc disease.

Keywords

endoscopic discectomy, microdiscectomy, lumbar disc disease, disc herniation, gold standard, PROM

Introduction

Lumbar disc herniation is a common cause of low back pain and radicular symptoms of patients presenting to any spine outpatient department.[1,2] Compression of nerve root by the herniated nucleus pulposus of the disc and associated inflammatory reaction are the 2 crucial factors that result in disabling lumbosacral radicular syndrome.[3] Although conservative trial relieves the pain in most of the cases, around 15% to 20% fail to improve necessitating surgical management.[4] Among the array

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Technique

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The Endoscopic Approach to Lumbar Discectomy, Fusion, and Enhanced Recovery: A Review

Jason I. Liounakos, MD[1] and Michael Y. Wang, MD[1]

Abstract

Study Design: Review.

Objectives: To review the current state of endoscopic spine surgery with regard to discectomy, interbody fusion, and combination with Enhanced Recovery After Surgery programs in order to evaluate its relevance to the future of spine care.

Methods: A review of the literature and expert opinion is used to accomplish the objectives.

Results: The greatest strength of endoscopic spine surgery lies in its adherence to the basic tenets of minimally invasive surgery and its innate compatibility with Enhanced Recovery After Surgery programs, which aim to improve outcomes and reduce health care costs. The greatest challenge faced is the unique surgical skill set and significant learning curve.

Conclusions: Endoscopic spine surgery strives to achieve the core goals of minimally invasive surgery, while reducing cost and enhancing quality. In a healthcare market that is becoming increasingly burdened by cost and regulatory constraints, the utilization of endoscopy may become more widespread in the coming years.

Keywords
endoscopy, spine, minimally invasive surgical procedures

Introduction

The trend toward minimally invasive surgery (MIS) is widespread among all surgical specialties, including spine surgery. The reasons for this are numerous. In general, MIS strives to offer equivalent or better surgical outcomes compared to open surgery, while minimizing the surgical "footprint." True minimally invasive spine surgery approaches should not only minimize incision size but also reduce the extent of underlying tissue disruption and blood loss. The cascade of events following a minimally invasive approach should ultimately reduce postoperative pain, minimize narcotic reliance, encourage early ambulation, reduce the incidence of complications, and reduce hospital length of stay (LOS). The overarching effect should thereby be improved clinical outcomes and a reduced economic burden on patient and society by expediting return to normal daily activities, and reducing healthcare costs, respectively.

Endoscopic spine surgery as it is today, represents the culmination of approximately 50 years of surgical innovation, beginning with the work of Parvis Kambin and others in the development of the percutaneous nucleotomy in the early 1970s[1-5] With both the advancement of technology and our understanding of anatomy (ie, Kambin's triangle), the endoscope has found its place in spine surgery. We will review the strengths and challenges faced by spinal endoscopy, its role in decompression and fusion procedures, and keenly suited adjunctive perioperative programs in an attempt to quantify its potential long-term impact on our field.

Open/Tubular Microdiscectomy Versus Percutaneous Endoscopic Discectomy

The true potential of endoscopic spine surgery lies in the fact that it adheres to the tenets of MIS, including minimal

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Review Article

The benefit zone of full-endoscopic spine surgery

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Contributions: (I) Conception and design: All authors; (II) Administrative support: All authors; (III) Provision of study materials or patients: All authors; (IV) Collection and assembly of data: All authors; (V) Data analysis and interpretation: All authors; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

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Abstract: Minimally invasive spine procedures have undergone rapid development during the last decade. Efforts to decrease muscle crush injuries during prolonged retraction, avoid significant soft tissue stripping and minimize bony resection are surgical principles that are employed to prevent iatrogenic instability and provide patients with decreased post-operative pain and disability. Full-endoscopic spine surgery represents a tool for the spine surgeon to provide targeted access to spinal pathology utilizing these principles. Endoscopic techniques have seen over 30 years of evolution and innovation, however, early iterations of these techniques largely focused on transforaminal lumbar microdiscectomies. Currently, endoscopic techniques are utilized for approaching pathology in the cervical, thoracic and lumbar spine. There has been a growing body of literature that not only confirms the efficacy of these procedures but also underscores the advantages these procedures offer with respect to less morbidity and safer complication profiles. Endoscopic decompressions have been utilized in the settings of degenerative spinal stenosis, spondylolisthesis, scoliosis, previous fusion, tumor and infection. Furthermore, endoscopic interbody fusion has also been utilized in the lumbar spine as technology continues to advance. As technological innovation continues to facilitate reproducible surgical technique and expand the indications for use, we believe that endoscopic spine surgical techniques will provide surgeons with a more powerful and less morbid approach to spinal pathology that ultimately elevates the standard of care when treating our patients. We present a brief review of the history of endoscopic spine surgery, an overview of current techniques and review current outcomes of endoscopic spine surgical procedures in the context of an invasiveness/complexity index to elucidate the benefit zone of these newer techniques.

Keywords: Endoscopic spine surgery; minimally invasive spine surgery; invasiveness index

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Introduction

Over the past 50 years, the field of spine surgery has seen an increasing emphasis in techniques designed to minimize approach-related tissue trauma and, hence, reduce post-operative pain and disability. The term "minimally invasive" represents a shift in the philosophical framework of spine surgery and echoes the fundamental Hippocratic aphorism "do no harm". The actualization of this paradigm shift is predicated upon a precision diagnosis and a targeted treatment which takes into account patient comorbidities and short-term and long-term expectations. Rather than focusing on the length of an incision, the "invasiveness" or collateral damage that is associated with a surgical procedure, must be taken into account when selecting the optimal treatment.

The emphasis on decreasing muscle crush injuries during prolonged retraction, avoiding soft tissue stripping and muscular denervation, minimizing bony resection to prevent iatrogenic instability and utilizing a surgical

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JNS SPINE

LITERATURE REVIEW

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Outcomes of endoscopic discectomy compared with open microdiscectomy and tubular microdiscectomy for lumbar disc herniations: a meta-analysis

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OBJECTIVE Endoscopic discectomy (ED) has been advocated as a less-invasive alternative to open microdiscectomy (OM) and tubular microdiscectomy (TM) for lumbar disc herniations, with the potential to decrease postoperative pain and shorten recovery times. Large-scale, objective comparisons of outcomes between ED, OM, and TM, however, are lacking. The authors' objective in this study was to conduct a meta-analysis comparing outcomes of ED, OM, and TM.

METHODS The PubMed database was searched for articles published as of February 1, 2019, for comparative studies reporting outcomes of some combination of ED, OM, and TM. A meta-analysis of outcome parameters was performed assuming random effects.

RESULTS Twenty-six studies describing the outcomes of 2577 patients were included. Estimated blood loss was significantly higher with OM than with both TM ($p = 0.01$) and ED ($p < 0.00001$). Length of stay was significantly longer with OM than with ED ($p < 0.00001$). Return to work time was significantly longer in OM than with ED ($p = 0.001$). Postoperative leg ($p = 0.02$) and back ($p = 0.01$) VAS scores, and Oswestry Disability Index scores ($p = 0.006$) at latest follow-up were significantly higher for OM than for ED. Serum creatine phosphokinase ($p = 0.02$) and C-reactive protein ($p < 0.00001$) levels on postoperative day 1 were significantly higher with OM than with ED.

CONCLUSIONS Outcomes of TM and OM for lumbar disc herniations are largely equivalent. While this analysis demonstrated that several clinical variables were significantly improved in patients undergoing ED when compared with OM, the magnitude of many of these differences was small and of uncertain clinical relevance, and several of the included studies were retrospective and subject to a high risk of bias. Further high-quality prospective studies are needed before definitive conclusions can be drawn regarding the comparative efficacy of the various surgical treatments for lumbar disc herniations.

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KEYWORDS herniated disc; microdiscectomy; minimally invasive; endoscopy; spine surgery; lumbar

With an estimated lifetime incidence of 13%–40%,[51] lumbar radiculopathy is a source of considerable morbidity and socioeconomic burden.[33] For patients who do not respond to conservative therapies for radicular pain, open microdiscectomy remains the standard surgical intervention. Efforts to shorten recovery times and reduce postoperative disability, however, have galvanized interest in minimally invasive surgical interventions for lumbar disc herniations.[5,13,52]

Endoscopic discectomy (ED) is a minimally invasive surgical technique for removing herniated disc material using an endoscope with one or more working channels,[16,53] potentially minimizing approach-related tissue trauma while still achieving the end goals of the operation. Early results from several case series appear promising,[17,23–25,31,36] but whether the minimally invasive nature of the ED approach translates into improvements in outcomes such as postoperative pain and recovery time when compared with traditional open microdiscectomy (OM) and other minimally invasive techniques (e.g., tubular microdiscectomy

ABBREVIATIONS CPK = creatine phosphokinase; CRP = C-reactive protein; ED = endoscopic microdiscectomy; ODI = Oswestry Disability Index; OM = open microdiscectomy; TM = tubular microdiscectomy; VAS = visual analog scale.

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REVIEW ARTICLE

Endoscopic spine discectomy: indications and outcomes

Yong Ahn[1]

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Abstract

Purpose Percutaneous endoscopic discectomy is an effective minimally invasive spine surgery (MISS) for soft disc herniations. The objective of this review was to describe the current indications, surgical techniques, and clinical outcomes of endoscopic spine surgery.

Methods A narrative review was performed with a focus on surgical indication of percutaneous endoscopic discectomy and the clinical outcomes in lumbar and cervical spine. Percutaneous endoscopic or full-endoscopic discectomy using a working channel endoscope was described.

Results The basic principles, surgical techniques, and clinical outcomes in lumbar and cervical disc herniations were demonstrated. For the lumbar disc herniation (LDH), transforaminal and interlaminar approaches were reviewed, whereas for the cervical disc herniation (CDH), anterior and posterior approaches were reviewed.

Conclusions Endoscopic spine surgery for soft disc herniation can be effective with benefits of minimal tissue trauma in properly selected cases. Given the recent technical advancements, the surgical indications for endoscopic spine surgery are still expanding and the clinical results have become more practical and reliable.

Keywords Discectomy · Endoscopic · Indication · Interlaminar · Transforaminal

Introduction

Radiculopathy which stemmed from lumbar, cervical, or thoracic disc herniations is the most common reason why patients require extensive and special treatment. The conventional surgical technique for disc herniations is open discectomy with or without fusion surgery. However, considerable sequelae related to the surgical trauma and long recovery time have been the major problems of spinal surgery. For that reason, the need for minimally invasive spine surgery (MISS) is growing as the aging population in many countries is dramatically increasing and the quality of life is given more importance nowadays [1, 2].

Since Hijikata [3] and Kambin [4] independently introduced the posterolateral percutaneous lumbar nucleotomy technique, a group of endoscopic spine surgery has been a significant minimally invasive surgical alternative for spinal disc herniations.

The advantages of endoscopic spine surgery are as follows: a stab skin incision, do not require muscular retraction, avoidance of excessive bone removal, minimal neural manipulation, feasibility under local anaesthesia, minimal blood loss, shorter operative time, and early return to normal activities of daily living [5–7].

Given the technical development of endoscopic spine surgery, including optics design, surgical instruments, and specific surgical approach, its clinical application became practical and standardized [8, 9].

This review article presents a discussion of the proper indications of endoscopic spine discectomies and to demonstrate their outcomes. Furthermore, we describe the technical considerations for endoscopic spine surgery to achieve a clinical success.

Basic concepts and history

The basic concept of endoscopic spine discectomy is to provide a direct access to the disc pathology with minimal tissue trauma and to remove the herniated disc under endoscopic

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ORIGINAL ARTICLE

A randomised controlled trial of transforaminal endoscopic discectomy vs microdiscectomy

J. N. Alaistair Gibson[1] · Ashok S. Subramanian[1] · Chloe E. H. Scott[1]

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Abstract
Purpose Transforaminal endoscopic discectomy (TED) minimises paraspinal muscle damage. The aim of this trial was to compare clinical outcomes of TED to Microdiscectomy (Micro).
Methods 143 patients, age 25–70 years and <115 kg, with single level lumbar prolapse and radiculopathy, were recruited and randomised. 70 received TED under conscious sedation and 70 Micro under general anaesthesia. Oswestry Disability Index (ODI), visual analogue scores (VAS) of back and leg pain, and Short Form Health Survey indices (SF-36) were measured preoperatively and at 3, 12 and 24 months.
Results All outcome measures improved significantly in both groups ($p < 0.001$). Affected side leg pain was lower in the TED group at 2 years (1.9 ± 2.6 vs 3.5 ± 3.1, $p = 0.002$). Hospital stay was shorter following TED (0.7 ± 0.7 vs 1.4 ± 1.3 days, $p < 0.001$). Two Micro patients and five TED patients required revision giving a relative risk of revision for TED of 2.62 (95% CI 0.49–14.0).
Conclusions Functional improvements were maintained at 2 years in both groups with less ongoing sciatica after TED. A greater revision rate after TED was offset by a more rapid recovery.

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Keywords Lumbar discectomy · Microdiscectomy · Transforaminal endoscopic surgery · Randomised controlled trial

Introduction

Open spinal surgery comes at a cost of approach related morbidity. The importance of reducing muscle damage, particularly to the multifidus muscle that maintains segmental stability, has become well-recognised [1]. The concept that less aggressive decompression may yield better results has led to the development of minimally invasive techniques with microdiscectomy becoming commonplace in most centres.

In 1990, Kambin highlighted the potential access to the lumbar disc via the 'safe-working' zone or 'Kambin triangle' [2]. This precipitated interest in the transforaminal approach to the disc from within the canal [3–5], as an alternative to minimally invasive central nucleotomies (blind percutaneous endoscopic, automated percutaneous and laser discectomy) that lacked evidence of efficacy [6]. The ability to safely resect disc tissue by this method from inside the disc out [7], or outside in [8, 9], has been recognised. Whether the theoretical advantages of transforaminal endoscopic (TED) surgery for symptomatic lumbar disc herniation are borne out by patient outcomes remains unclear. A systematic review has highlighted a paucity of evidence for the TED technique [9], in comparison to data now available in respect of microendoscopic approaches [10, 11]. In view of the increasing use of transforaminal approaches to the spine, there is clearly a need for high-quality randomised controlled trials (RCTs) to determine whether TED is as effective as traditional microdiscectomy.

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Retrospective Review

Endoscopic Spine Surgery: Distance Patients Will Travel for Minimally Invasive Spine Surgery

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Background: Transforaminal lumbar endoscopic discectomy is a minimally invasive spine surgery procedure performed principally for the treatment of lumbar herniated discs. Endoscopic spine surgeons around the world have noted how far patients will travel to undergo this minimally invasive spine surgery, but the actual distance patients travel has never been investigated.

Objective: We present here our analysis of how far patients will travel for endoscopic spine surgery by studying the referral patterns of patients to 3 centers in 3 different countries.

Study Design: Retrospective chart review of de-identified patient data was performed to analyze the distance patients travel for spine surgery.

Methods: Patient demographic data was analyzed for patients undergoing transforaminal lumbar endoscopic discectomy procedures over the same 8 month period in 2015 at centers in the United States (U.S.), Netherlands, and Germany.

Results: Travel distances for patients were determined for 327 patients. The average distance traveled for the U.S. center was 91 miles, the Dutch center was 287 miles, and the German center was 103 miles. For the U.S. center 16% of patients traveled out of state for surgery and for the European centers combined, 4% of patients traveled out of the country for surgery.

Limitations: The period of data analyzed was less than one year and the data collected was analyzed retrospectively.

Conclusions: Quality metrics in health care tend to be focused on how health care is delivered. Another health care metric that focuses more on what patients desire is presented here: how far patients will travel for innovative spine care.

Key words: Endoscopic spine surgery, transforaminal, minimally invasive, travel, lumbar disc herniation

Pain Physician 2017; 20:E145-E149

Transforaminal lumbar endoscopic discectomy is a minimally invasive surgical option for the treatment of lumbar herniated discs. The development of improved endoscopes and instruments, the increased experience of endoscopic spine surgeons, and the continued demand by patients for minimally invasive spine techniques have led to an explosion of innovation in endoscopic spine surgical techniques since the first endoscopic views of a herniated nucleus pulposus were published by Kambin et al in 1988 (1). Published experience is available to patients and physicians on cervical approaches (2), thoracic approaches (3), and approaches to the thoracolumbar junction (4), as well as the treatment of far lateral disc herniations (5-7), reherniations (8-9), extruded discs (10-13), spondylolisthesis (14-15), radiculopathy in the setting of instrumented fusion (16), discitis (17), discogenic back pain (18), and spinal tumors (19-20).

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Review

Transforaminal endoscopic spinal surgery: The future 'gold standard' for discectomy? – A review

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ABSTRACT

Background: Lumbar disc prolapse is common and the primary method of care in most centres is still open discectomy facilitated by microscope or loupe magnification and illumination. Hospitalisation may be less than 24 h, but post-operative pain usually requires an overnight stay. This review describes transforaminal endoscopic spinal surgery (TESS) using HD-video technology, that is generally performed as a day case procedure under sedation or light general anaesthesia, and collates the evidence comparing the technique to microdiscectomy.

Methods: The method of TESS is described and an electronic literature search performed to identify papers reporting clinical outcomes. International data were translated where necessary and proceedings' abstracts included. In addition, papers held by the authors and colleagues in personal libraries were carefully cross-referenced to the obtained database.

Results: Analysis of the data supports the use of a transforaminal endoscopic approach to the lumbar intervertebral disc and suggests that outcomes following surgery are at least equivalent to those following microdiscectomy. Significant cost-savings in terms of in-patient stay may be generated. In addition, there is also some evidence supporting endoscopic surgery for relief of foraminal stenosis.

Conclusion: Based on current evidence there are good arguments supporting a more widespread adoption of transforaminal endoscopic surgery for the treatment of lumbar disc prolapse with or without foraminal stenosis.

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Introduction

Lumbar disc herniation, with a reported prevalence of 1–3%[1] is the commonest pathological process leading to spinal surgery. However, despite dramatic advancements in minimally invasive surgery in other fields, the treatment of disc prolapse in many centres has made only small advances since the initial description of the pathology in the early 1930s.[2,3] This is a recognition of the fact that laminotomy and discectomy produce good to excellent results in up to 90% of patients, even without use of an operating microscope.[4] However, whether a ten percent failure rate from an

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SUPERIORITY OF ENDOSCOPIC SPINE SURGERY

COST-EFFECTIVENESS OF ENDOSCOPIC SPINE SURGERY

OPEN ACCESS

Cost-effectiveness of full endoscopic versus open discectomy for sciatica

Pravesh Shankar Gadjradj ,[1,2] Hana M Broulikova,[3] Johanna M van Dongen,[3] Sidney M Rubinstein,[4] Paul R Depauw,[5] Carmen Vleggeert,[6] Ankie Seiger,[4] Wilco C Peul,[6] Job L van Susante,[7] Maurits W van Tulder,[4,8] Biswadjiet S Harhangi[2]

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ABSTRACT

Objective To assess the costs and cost-effectiveness of percutaneous transforaminal endoscopic discectomy (PTED) compared with open microdiscectomy among patients with sciatica.

Methods This economic evaluation was conducted alongside a 12-month multicentre randomised controlled trial with a non-inferiority design, in which patients were randomised to PTED or open microdiscectomy. Patients were aged from 18 to 70 years and had at least 6 weeks of radiating leg pain caused by lumbar disc herniation. Effect measures included leg pain and quality-adjusted life years (QALYs), as derived using the EQ-5D-5L. Costs were measured from a societal perspective. Missing data were multiply imputed, bootstrapping was used to estimate statistical uncertainty, and various sensitivity analyses were conducted to determine the robustness.

Results Of the 613 patients enrolled, 304 were randomised to PTED and 309 to open microdiscectomy. Statistically significant differences in leg pain and QALYs were found in favour of PTED at 12 months follow-up (leg pain: 6.9; 95% CI 1.3 to 12.6; QALYs: 0.040; 95% CI 0.007 to 0.074). Surgery costs were higher for PTED than for open microdiscectomy (ie, €4500/patient vs €4095/patient). All other disaggregate costs as well as total societal costs were lower for PTED than for open microdiscectomy. Cost-effectiveness acceptability curves indicated that the probability of PTED being less costly and more effective (ie, dominant) compared with open microdiscectomy was 99.4% for leg pain and 99.2% for QALYs.

Conclusions Our results suggest that PTED is more cost-effective from the societal perspective compared with open microdiscectomy for patients with sciatica.

Trial registration number NCT02602093.

INTRODUCTION

As sciatica has a lifetime prevalence of up to 43% in the general population, it has a high disease burden at the individual patient level as well as at the societal level.[1] At the individual level, patients can suffer from leg pain which can be accompanied by sensory or motor loss, possibly leading to disability and a poor health-related quality of life.[2 3] As so, sciatica can severely impact the lives of active adults, especially as sciatica mostly affects individuals aged between 30 and 50 years.[2 4] At societal level, sciatica comes with a major financial burden mainly because of sick leave and hospital costs.[5]

Fortunately, the natural course of sciatica is favourable as majority of the cases resolve with conservative treatment.[6] Due to the high prevalence of sciatica, however, surgery for lumbar disc herniation is a frequently performed procedure.[7 8] The current standard surgical procedure for the treatment of lumbar disc herniation is open microdiscectomy.[7 9 10] Percutaneous transforaminal endoscopic discectomy (PTED) was introduced as a less invasive alternative.[11 12] In contrast to open microdiscectomy, PTED is performed under local anaesthesia and is offered as outpatient surgery.[13] Furthermore, PTED is performed from a far lateral approach and requires surgeons to operate from a two-dimensional view, which makes performing PTED more challenging even for experienced surgeons. Because of this challenging learning curve, the unclear merits of PTED over conventional microdiscectomy and possible issues associated with reimbursement, PTED is offered by only a few surgeons worldwide.[7 14]

Previous research has compared various outcomes between PTED and open microdiscectomy and suggested no differences between both procedures for leg pain and functional status.[15–17] PTED, however, was found to have the advantage of less intraoperative blood loss and shorter hospital stays compared with open microdiscectomy. Some prior research has examined the direct costs of both procedures.[18 19] One study assessed the costs of the operating theatre, hospitalisation, endoscopes and sterilisation of the surgical equipment and found significantly higher costs for PTED than for open microdiscectomy.[19] Among these costs, endoscopes were identified to be the biggest cost driver and made up 66% of the costs of PTED. The other study found the cost of hospitalisation to be significantly lower for PTED by 27% compared with open microdiscectomy.[18] No studies performed a large, full trial-based economic evaluation, in which both the costs and effects of PTED and open microdiscectomy were assessed and compared with one another.

The PTED-study aimed to assess the effectiveness and cost-effectiveness (CE) of PTED compared with open microdiscectomy in patients with lumbar disc herniation.[20] Results of the effectiveness analyses suggest that PTED is non-inferior to open microdiscectomy in leg pain reduction at 12 months after surgery.[21] Furthermore, PTED had more favourable results for patient-reported leg pain and health-related quality of life as compared with open microdiscectomy. It is unknown, however, how the difference in costs between both procedures is related to the corresponding differences

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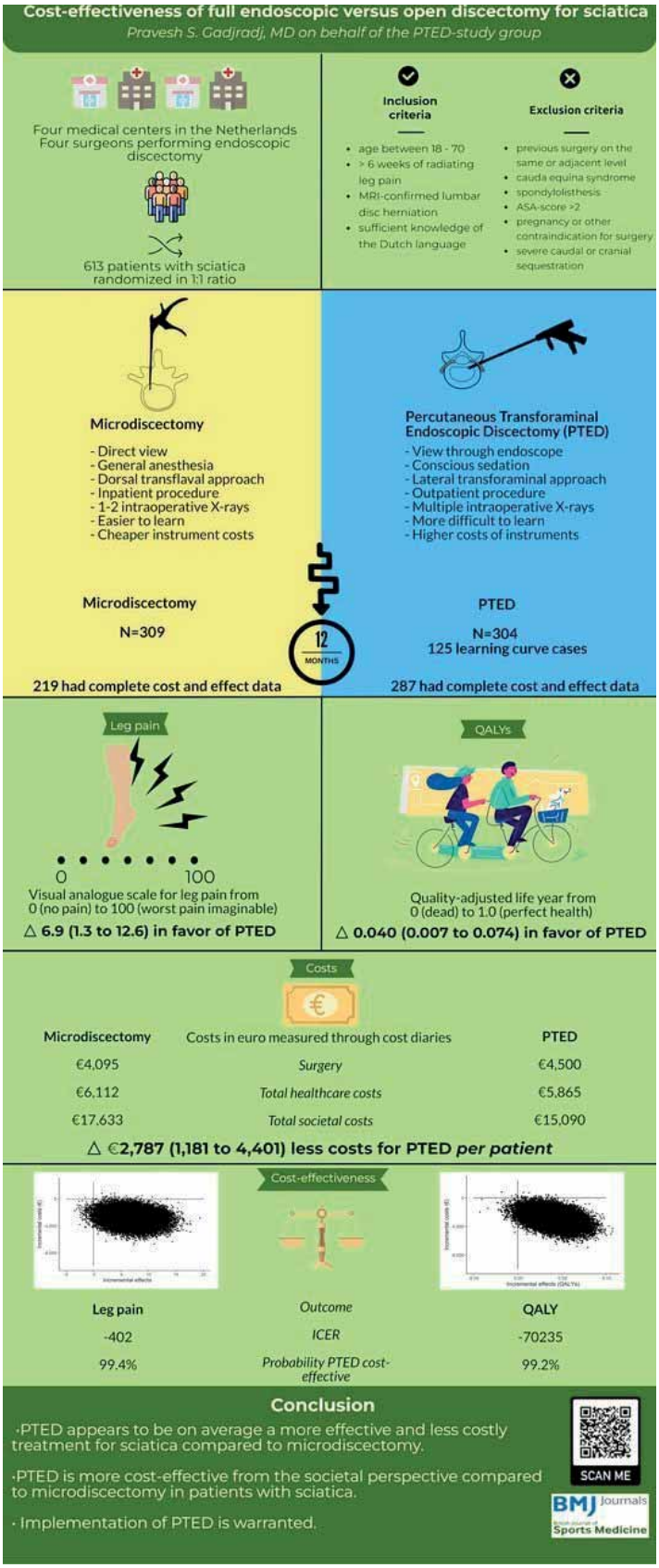
OPEN ACCESS

Cost-effectiveness of full endoscopic versus open discectomy for sciatica



EREDETI KÖZLEMÉNY

COMPARISON OF DIRECT COSTS OF PERCUTANEOUS FULL-ENDOSCOPIC INTERLAMINAR LUMBAR DISCECTOMY AND MICRODISCECTOMY: RESULTS FROM TURKEY

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Background and purpose – Microdiscectomy (MD) is a standard technique for the surgical treatment of lumbar disc herniation (LDH). Uniportal percutaneous full-endoscopic interlaminar lumbar discectomy (PELD) is another surgical option that has become popular owing to reports of shorter hospitalization and earlier functional recovery. There are very few articles analyzing the total costs of these two techniques. The purpose of this study was to compare total hospital costs among microdiscectomy (MD) and uniportal percutaneous full-endoscopic interlaminar lumbar discectomy (PELD).
Methods – Forty patients aged between 22-70 years who underwent PELD or MD with different anesthesia techniques were divided into four groups: (i) PELD-local anesthesia (PELD-Local) (n=10), (ii) PELD-general anesthesia (PELD-General) (n=10), (iii) MD-spinal anesthesia (MD-Spinal) (n=10), (iv) MD-general anesthesia (MD-General) (n=10). Health care costs were defined as the sum of direct costs. Data were then analyzed based on anesthetic modality to produce a direct cost evaluation. Direct costs were compared statistically between MD and PELD groups.
Results – The sum of total costs was $1,249.50 in the PELD-Local group, $1,741.50 in the PELD-General group, $2,015.60 in the MD-Spinal group, and $2,348.70 in the MD-General group. The sum of total costs was higher in the MD-Spinal and MD-General groups than in the PELD-Local and PELD-General groups. The costs of surgical operation, surgical equipment, anesthesia (anesthetist's costs), hospital stay, anesthetic drugs and materials, laboratory workup, nursing care, and two main groups (PELD-MD) medication differed significantly among the two main groups (PELD-MD) ($p<0.01$).
Conclusion – This study demonstrated that PELD is less costly than MD.

Keywords: *direct cost, endoscopic discectomy, microdiscectomy*

A PERCUTAN ENDOSZKÓPOS INTERLAMINÁRIS LUMBALIS DISCECTOMIA ÉS A MICRODISCECTOMIA DIREKT KÖLTSÉGEINEK ÖSSZEHASONLÍTÁSA: TÖRÖK EREDMÉNYEK

Ünsal ÜÜ, MD; Şentürk S, Assos. Prof. MD
Ideggyogy Sz 2021;74(5–6):197–205.

Háttér és cél – A microdiscectomia (MD) a lumbalis porckorongsérv műtéti kezelésének standard technikája. Az egy munkacsatornás percutan endoszkópos interlaminális lumbalis discectomia (PELD) egy másik műtéti lehetőség, ami a rövidebb kórházi ápolási idő szükségessége és a gyorsabb funkcionális gyógyulás miatt egyre népszerűbbé válik. Nagyon kevés tanulmány elemzi e két technika költségeit. Jelen tanulmány célja az MD és a PELD összes kórházi költségének összehasonlítása.
Módszerek – Negyven 22 és 70 éves kor közötti, PELD vagy MD módszerrel és különböző aneszteziológiai technikával operált beteget osztottunk négy csoportba: 1. PELD + helyi érzéstelenítés (PELD-Local) (n = 10), 2. PELD + általános érzéstelenítés (PELD-General) (n = 10), 3. MD + spinalis érzéstelenítés (MD-Spinal) (n = 10), 4. MD + általános érzéstelenítés (MD-General) (n = 10). Az egészségügyi költségeket a direkt költség összegeként definiáltuk. A költségek direkt összehasonlíthatósága érdekében az adatokat az érzéstelenítés módja szerint elemeztük. A direkt költségeket az MD- és a PELD-csoportok között hasonlítottuk össze.
Eredmények – A PELD-Local-csoportban az összes költség összege 1249,5 $, a PELD-General-csoportban 1741,5 $, az MD-Spinal-csoportban 2015,6 $, az MD-General-csoportban 2348,7 $ volt. Az összes költség összege magasabb volt az MD-Spinal- és MD-General-csoportokban, mint a PELD-Local- és PELD-General-csoportokban. A műtét, a sebészi eszközök, az anesztézia (az aneszteziológus díja), a kórházi tartózkodás, az érzéstelenítés során használt gyógyszerek és anyagok, a laboratóriumi vizsgálatok, az ápolás és a posztoperatív gyógyszerelés költsége szignifikáns mértékben eltért a négy csoport között ($p < 0,01$).
Következtetés – Vizsgálatunk igazolta, hogy a PELD kevésbé költséges, mint az MD.

Kulcsszavak: *direkt költség, endoszkópos discectomia, microdiscectomia*

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Clinical Study

Cost-effectiveness of microdiscectomy versus endoscopic discectomy for lumbar disc herniation

Kyung-Chul Choi, MD, PhD[a], Hyeong-Ki Shim, MD[a], Jin-Sung Kim, MD, PhD[b,*], Kyung Han Cha, MD[a], Dong Chan Lee, MD[a], Ea Ran Kim, RN[a], Mee Jung Kim, RN[a], Choon-Keun Park, MD, PhD[c]

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ABSTRACT

BACKGROUND CONTEXT: Microdiscectomy is a standard technique for the surgical treatment of lumbar disc herniation (LDH). Endoscopic discectomy (ED) is another surgical option that has become popular owing to reports of shorter hospitalization and earlier return to work. No study has evaluated health care costs associated with lumbar discectomy techniques and compared cost-effectiveness.

PURPOSE: To assess the cost-effectiveness of four surgical techniques for LDH: microdiscectomy (MD), transforaminal endoscopic lumbar discectomy (TELD), interlaminar endoscopic lumbar discectomy (IELD), and unilateral biportal endoscopic discectomy (UBED).

STUDY DESIGN AND SETTING: Retrospective analysis.

PATIENT SAMPLE: Patients who underwent either MD or ED for primary LDH with 1-year follow-up between the ages of 20 and 60 years old.

OUTCOME MEASURES: Incremental cost-effectiveness ratio (ICER).

METHODS: Five hundred sixty-five patients aged 20–60 years who underwent treatment using one of the four surgical techniques with at least 1-year follow-up were reviewed. Health care costs were defined as the sum of direct and indirect costs. The former included the covered and uncovered costs of the National Health Insurance from operation to 1-year follow-up; indirect costs included costs incurred by work loss. Direct and indirect costs were evaluated separately. ICER was determined using cost/quality-adjusted life year (QALY). Health care costs and ICER were compared statistically among the four surgical groups. Cost-effectiveness was compared statistically between MD and ED.

RESULTS: One hundred fifty-seven patients who underwent TELD, 132 for IELD, 140 for UBED, and 136 for MD were enrolled. The direct costs of TELD, IELD, UBED, and MD were \$3,452.2±1,211.5, \$3,907.3±895.3, \$4,049.2±1,134.6, and \$4,302.1±1,028.9, respectively ($p<.01$). The indirect costs of TELD, IELD, UBED, and MD were \$574.5±495.9, \$587.8±488.3, \$647.4±455.6, and \$759.7±491.7, respectively ($p<.01$). The 1-year QALY gains were 0.208 for TELD, 0.211 for IELD, 0.194 for UBED, and 0.186 for MD. ICER (costs/QALY) was the highest for MD (\$34,840.4±25,477.9, $p<.01$). Compared with MD, ED saved an additional net of \$8,064 per QALY ($p<.01$). There was no significant difference in the ICERs among the three endoscopic techniques.

FDA device/drug status: Not applicable.

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HEALTH SERVICES RESEARCH

A Cost-utility Analysis of Percutaneous Endoscopic Lumbar Discectomy for L5-S1 Lumbar Disc Herniation

Transforaminal versus *Interlaminar*

Dongdong Wang, MD,* Wangcheng Xie, MD,* Wenxin Cao, MD,* Shisheng He, MD,*,† Guoxin Fan, MD,*,† and Hailong Zhang, MD*,‡

Study Design. A cost-utility analysis (CUA).

Objective. The aim of this study was to evaluate the cost-effectiveness of percutaneous endoscopic transforaminal discectomy (PETD) and percutaneous endoscopic interlaminar discectomy (PEID) techniques for the treatment of L5-S1 lumbar disc herniation (LDH).

Summary of Background Data. The annual cost of treatment for lumbar disc herniation is staggering. As the two major approaches of percutaneous endoscopic lumbar discectomy (PELD): percutaneous endoscopic transforaminal discectomy (PETD) and percutaneous endoscopic interlaminar discectomy (PEID) have gained recognition for the treatment of L5-S1 lumbar disc herniation (LDH) and showed similar clinical outcome. ost-utility analysis (CUA) can help clinicians make appropriate decisions about optimal health care for L5-S1 LDH.

Methods. Fifty and 25 patients were included in the PETD and PEID groups of the study. Patients' basic characteristics, health care costs, and clinical outcome of PETD and PEID group were collected and analyzed. Quality-adjusted life-years (QALYs) were calculated and validated by EuroQol five-dimensional (EQ-5D) questionnaire. Cost-effectiveness was determined by the incremental cost per QALY gained.

Results. The mean total cost of the PETD group was $\$5275.58 \pm 292.98$ and the PEID group was $\$5494.45 \pm 749.24$. No significant differences were observed in hospitalization expenses, laboratory and radiographic evaluations expenses, surgical expenses, and drug costs. Surgical equipment and materials costs, and anesthesia expense in the PEID group were significantly higher than in the PETD group ($P < 0.001$). Clinical outcomes, including Oswestry Disability Index (ODI), Visual Analogue Scale (VAS) scores, and Japanese Orthopaedic Association (JOA), also showed no significant differences between the two groups. The cost-effectiveness ratio of PETD and PEID were $\$6816.05 \pm 717.90$/QALY and $\$7073.30 \pm 1081.44$/QALY, respectively. The incremental cost-effectiveness ratios (ICERs) of PEID over PETD was \$21887.00/QALY.

Conclusion. Observed costs per QALY gained for L5-S1 LDH with PETD or PEID were similar for patients, demonstrating that the two different approaches of PELD are equally cost-effective and valuable interventions.

Key words: cost-utility analysis, interlaminar, L5-S1 disc herniation, PELD, transforaminal.

Level of Evidence: 5

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Lumbar degenerative disorders are highly prevalent all over the world. The estimated total costs of low-back pain in the United States exceed \$100 billion per year.[1] The toll of lumbar disc disorders is enormous, which put serious pressure on the society and government finance. Lumbar disc herniation (LDH) is the most common reason for low-back pain, and the L5-S1 segment was one of the most predilection sites. In people aged 25 to 55 years, about 95% of herniated discs occur at the lower lumbar spine (L4-L5 and L5-S1 level).[2,3]

In the early decades, open lumbar microdiscectomy (OLM) has been considered the gold standard in the management of LDH for its favorable outcomes in long-term

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Efficacy of Transforaminal Endoscopic Spine System (TESSYS) Technique in Treating Lumbar Disc Herniation

Authors' Contribution:
Study Design A
Data Collection B
Statistical Analysis C
Data Interpretation D
Manuscript Preparation E
Literature Search F
Funds Collection G

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Background: To compare efficacy and safety of percutaneous transforaminal endoscopic spine system (TESSYS) and traditional fenestration discectomy (FD) in treatment of lumbar disc herniation (LDH).

Material/Methods: A total of 106 LDH patients were divided into TESSYS group (n=48) and FD group (n=58). Visual analogue scale (VAS), Oswestry disability index (ODI), Japanese Orthopedic Association (JOA), and modified MacNab criteria were used for efficacy evaluation. Post-operative responses were compared by enzyme-linked immunosorbent assay (ELISA) based on detection of serum IL-6, CRP, and CPK levels.

Results: In the TESSYS group, compared with the FD group, we observed, shorter incision length, less blood loss, shorter hospital stay, lower hospitalization cost, shorter recovery time, lower complication rate (all $P<0.001$), and lower VAS scores of lumbago and skelalgia at 3 days and 1, 3, and 6 months postoperatively (all $P<0.05$). At 24 and 48 h postoperatively, CRP level was remarkably higher in the FD group compared to the TESSYS group ($P<0.001$). Further, comparison of IL-6 levels at 6, 12, 24, and 48 h postoperatively revealed significantly higher levels in the FD group than in the FESSYS group (all $P<0.001$).

Conclusions: TESSYS had clinical advantages over FD and entails less trauma and quicker postoperative recovery, suggesting that TESSYS is well tolerated by patients and is a better approach than FD in surgical treatment of LDH.

MeSH Keywords: Dienestrol • Manipulation, Orthopedic • Osteoarthritis, Spine • Pain Measurement

Full-text PDF: http://www.medscimonit.com/abstract/index/idArt/894870

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CERVICAL SPINE

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ORIGINAL ARTICLE

Learning curve for endoscopic posterior cervical foraminotomy

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Abstract

Purpose While anterior cervical discectomy and fusion as well as cervical disk arthroplasty are gold standard treatments for the surgical treatment of cervical radiculopathy, posterior endoscopic cervical foraminotomy (PECF) as a substitute procedure is gaining popularity. To date, studies investigating the number of surgeries needed to achieve proficiency in this procedure are lacking. The purpose of the study is to examine the learning curve for PECF.

Methods The learning curve in operative time for two fellowship-trained spine surgeons at independent institutions was retrospectively assessed for 90 uniportal PECF procedures (PBD: $n=26$, CPH: $n=64$) performed from 2015 to 2022. Operative time was assessed across consecutive cases using a nonparametric monotone regression, and a plateau in operative time was used as a proxy to define the learning curve. Secondary outcomes assessing achievement of endoscopic prowess before and after the initial learning curve included number of fluoroscopy images, visual analog scale (VAS) for neck and arm, Neck Disability Index (NDI), and the need for reoperation.

Results There was no significant difference in operative time between surgeons ($p=0.420$). The start of a plateau for Surgeon 1 occurred at 9 cases and 111.6 min. The start of a plateau for Surgeon 2 occurred at 29 cases and 114.7 min. A second plateau for Surgeon 2 occurred at 49 cases and 91.8 min. Fluoroscopy use did not significantly change before and after surmounting the learning curve. The majority of patients achieved minimally clinically important differences in VAS and NDI after PECF, but postoperative VAS and NDI did not significantly differ before and after achieving the learning curve. There were no significant differences in revisions or postoperative cervical injections before and after reaching a steady state in the learning curve.

Conclusion PECF is an advanced endoscopic technique with an initial improvement in operative time that occurred after as few as 8 cases to as many as 28 cases in this series. A second learning curve may occur with additional cases. Patient-reported outcomes improve following surgery, and these outcomes are independent of the surgeon's position on the learning curve. Fluoroscopy use does not change significantly along the learning curve. PECF is a safe and effective technique that current and future spine surgeons should consider as part of their armamentarium.

Keywords Learning curve · Posterior endoscopic cervical foraminotomy · Spinal endoscopy · Spine surgery

Introduction

Cervical radiculopathy due to spondylosis or disk herniation is refractory to conservative measures in 10–25% of patients [1]. While anterior cervical discectomy and fusion (ACDF) and cervical disk arthroplasty (CDA) are gold standard surgical treatments for cervical radiculopathy, posterior cervical foraminotomy can be a substitute procedure in select cases. Posterior cervical foraminotomy (PCF) avoids the disadvantages of anterior-based surgery, including anterior approach-related morbidity, adjacent segment disease, implant-related complications, and pseudoarthrosis [2]. PCF allows for decompression of the exiting nerve root in the region of the lateral recess and intervertebral foramen, preserves the mobility of the cervical segment, and requires no implants. Posterior endoscopic cervical foraminotomy (PECF) is the latest iteration of the PCF technique. However, concerns

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OPEN

Microscopic Anterior Cervical Discectomy and Fusion Versus Posterior Percutaneous Endoscopic Cervical Keyhole Foraminotomy for Single-level Unilateral Cervical Radiculopathy

A Systematic Review and Meta-analysis

Linlin Guo, MD, Jiajing Wang, MD,† Zhen Zhao, MD,† Jing Li, MD,‡ Hongyang Zhao, MD,† Yong Gao, MD,§ and Chao Chen, MD§‖*

Study Design: A systematic review and meta-analysis.

Objective: The objective of this study was to compare the safety of microscopic anterior cervical discectomy and fusion (MI-ACDF) and posterior percutaneous endoscopic keyhole foraminotomy (PPEKF) in patients diagnosed with single-level unilateral cervical radiculopathy.

Summary of Background Data: After conservative treatment, the symptoms will be relieved in about 90% of cervical radiculopathy patients. For the other one tenth of patients, surgical treatment is needed. The overall complication rate of MI-ACDF and PPEKF ranges from 0% to 25%, and the reoperation rate ranges from 0% to 20%.

Materials and Methods: Electronic retrieval of studies from PubMed, Embase, and Cochrane Library was performed to identify comparative or single-arm studies on MI-ACDF and PPEKF. A total of 24 studies were included in our meta-analysis by screening according to the inclusion and exclusion criteria. After data extraction and quality assessment of the included studies, a meta-analysis was performed by using the R software. The pooled incidences of efficient rate, total complication rate, and reoperation rate were calculated.

Results: A total of 24 studies with 1345 patients (MI-ACDF: 644, PPEKF: 701) were identified. There was no significantly statistical difference in pooled patient effective rate (MI-ACDF: 94.3% vs. PPEKF: 93.3%, $P=0.625$), total complication rate (MI-ACDF: 7.1% vs. PPEKF: 4.7%, $P=0.198$), and reoperation rate (MI-ACDF: 1.8% vs. PPEKF: 1.1%, $P=0.312$). However, the common complications of the 2 procedures were different. The most common complications of MI-ACDF were dysphagia and vertebral body sinking, whereas the most common complication of PPEKF was nerve root palsy.

Conclusions: Both MI-ACDF and PPEKF can provide a relatively safe and reliable treatment for single-level unilateral cervical radiculopathy. The 2 techniques are not significantly different in terms of effective rate, total complication rate, and reoperation rate.

Key Words: meta-analysis, cervical radiculopathy, anterior cervical discectomy and fusion, keyhole, microscopic, endoscopic

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L.G., J.W., and Z.Z. have contributed equally to this work and share first authorship.

C.C. and Y.G. have contributed equally to this work and share last authorship.

C.C. and Y.G. conceived and designed the experiments. Z.Z. and J.J.W. screened the studies and collected the data. L.L.G. and J.L. analyzed the data. L.L.G., Z.Z., and J.J.W. wrote the paper. H.Y.Z., Y.G., and C.C. were responsible for the critical reading of the manuscript.

The study received full approval from the ethics committee of Union Hospital, Tongji Medical College, Huazhong University of Science and Technology and informed consent was waived due to the retrospective nature of the study.

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The authors declare no conflict of interest.

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Cervical radiculopathy is characterized by cervical spine degenerative changes such as disk herniation and/or foraminal stenosis compressing the nerve roots.[1–4] The typical clinical manifestations are pain in neck and one or both of the upper extremities, secondary to compression or irritation of nerve roots in the cervical spine. It can be accompanied by motor, sensory, or reflex deficits and is most common in persons 45–60 years of age, which

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The first experience with fully endoscopic posterior cervical foraminotomy and discectomy for radiculopathy performed in Viet Duc University Hospital

Son Ngoc Dinh[1,2] & Hung The Dinh[1,2]✉

The aim of the article is to present the first experience of applying a full-endoscopic posterior cervical foraminotomy and discectomy performed at Viet Duc University Hospital in Hanoi and describe the outcomes of such surgical intervention. This surgical series includes 20 patients underwent surgery through full-endoscopic posterior cervical foraminotomy and discectomy. The definitive diagnosis of the patients and the evidence for surgical treatment was radiculopathy due to lateral or intraforaminal disk herniation, foraminal stenosis, and lateral recess stenosis. Patients with discogenic cervical radiculopathy but with a contraindication to endoscopic posterior cervical foraminotomy and discectomy were not subject to surgical intervention. All patients underwent a CT and MRT examination of the cervical spine before and after surgery as complementary diagnostic methods. Besides radiological diagnostic methods, electroneuromyography and spondylography were performed with functional samples, i.e., with head tilts in the front and back, to eliminate segmental instability. The timing and degree of the root pain syndrome regression were assessed using a VAS scale (visual and analog scale) with a subsequent comparison of preoperative and postoperative performance. Immediately after the operation, all patients noted a complete or nearly complete regression of the pain syndrome.

The prevalence of discogenic compression syndromes at the cervical level is extremely high among people of working age and has a significant impact on their quality of life[1,2]. According to Lawrence[3], among the total number of degenerative-dystrophic lesions of the spine, about 10% of the population suffer periodic compression pain in the cervical spine or the hand. A significant proportion of patients eventually need surgery[4]. The most common surgical methods in treating this pathology are anterior cervical discectomy and fusion (ACDF) and posterior cervical foraminotomy and discectomy (PCFD)[5,6]. At that, a posterior cervical foraminotomy is believed to be an effective technique that does not limit the range of motion in the cervical spine and minimizes the impact on degenerative changes in adjacent motor segments[7]. PCFD allows achieving adequate decompression and visualization of the outgoing nerve root in the region of the lateral recess and intervertebral aperture. In contrast to anterior discectomy, PCFD does not require stabilization[8,9]. Choosing the most optimal surgical treatment tactics for these pathologies is an urgent problem, which requires discussion. Minimal invasive PCFD has been used in clinical practice since the early 2000s[10,11]. The desire of specialists to minimize surgical aggression has influenced the evolution of endoscopic equipment, tools for effective bone resection and decompression, which predetermined the development of tube micro-endoscopy[12–14] and percutaneous video endoscopy (full-endoscopic)[15–18] in spine surgery. To date, a full-endoscopic method is the least invasive in spine surgery. Such operations on the lumbar spine have been proven to be safe and are performed routinely[19]. At the same time, the use of endoscopic methods in operations on the cervical spine is not so frequent. In 2007, Ruetten and co-authors[20] reported on the experience of treating 87 patients with lateral hernias of the intervertebral discs of the cervical spine using a method of a full endoscopic PCFD with a 6.9 mm endoscope through a working cannula

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Observational Study

Medicine

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Clinical efficacy and learning curve of posterior percutaneous endoscopic cervical laminoforaminotomy for patients with cervical spondylotic radiculopathy

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Abstract

In this study, we aimed to investigate the clinical efficacy and learning curve of posterior percutaneous endoscopic cervical laminoforaminotomy (PPECLF) in patients with cervical spondylotic radiculopathy (CSR). A total of 64 patients with CSR received PPECLF. Clinical outcome scores included the visual analog scale, Japanese Orthopedic Association score, neck disability index, and modified Macnab criteria. Radiological outcomes included the disc height, C2 to C7 Cobb angle, and range of motion. The learning curve was evaluated using cumulative sum analysis. Patients were divided into accumulation phase and mastery phase groups (A and B), and general data and surgical efficacy were compared between the 2 groups. Follow-up ranged from 12 to 24 months. Clinical outcome scores improved significantly at the final follow-up, and there were no differences in radiological outcomes. Surgical efficacy was excellent and good in 82.8% of patients. The operative time showed a decreasing trend with the accumulation of cases. Patients were divided and the 26th case was the cutoff point according to the learning curve. No significant differences were found in the clinical outcomes between the 2 groups. Decompression with PPECLF was safe and effective in the treatment of CSR. With the accumulation of cases, the operative time was gradually shortened, and the clinical efficacy was significant. The PPECLF procedure can be performed efficiently and safely to treat CSR.

Abbreviations: ACDF = anterior cervical discectomy and fusion, ASD = adjacent segment disease, CSR = cervical spondylotic radiculopathy, CUSUM = cumulative sum, FU = follow-up, JOA = Japanese orthopedic association, NDI = neck disability index, PPECLF = posterior percutaneous endoscopic cervical laminoforaminotomy, ROM = range of motion, VAS = visual analog scale.

Keywords: cervical spondylotic radiculopathy, cumulative sum analysis, learning curve, minimally invasive, posterior percutaneous endoscopic cervical laminoforaminotomy, surgical procedures

1. Introduction

Cervical spondylotic radiculopathy (CSR), specified by Ando in 1952, has been described as the most common type of cervical spondylosis.[1] Decompression surgery is often a necessary intervention in patients with poor efficacy after conservative treatment or worsening symptoms.[2–4] Anterior cervical discectomy and fusion (ACDF) was once the mainstream surgery for the treatment of cervical degenerative diseases and was regarded as the standard operation for CSR.[5] However, ACDF is suspected to cause postoperative loss of disc height, adjacent segment disease (ASD), pseudarthrosis, and approach-related complications.[6] The traditional posterior cervical open surgical approach causes muscle dissection, substantial trauma, high blood loss, reduced postoperative effects, and reduced patient satisfaction.[7,8]

Since 2019, we have performed posterior percutaneous endoscopic cervical laminoforaminotomy (PPECLF) based on the anatomy and operating path of traditional open approach surgery. A minimally invasive working channel is used to replace the long incision exposure, and proprietary endoscopic tools are used for accurate decompression. It has the same therapeutic effect as open approach surgery and maintains a high level of security.[9,10] However, there are few reports on laminae decompression and nerve root canal under percutaneous endoscopic procedures.[11–13] The presence of technical barriers, potential replication, and the ability to judge the proficiency of this new technology are crucial for

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All data generated or analyzed during this study are included in this published article [and its supplementary information files]

This study was approved by the local institutional review board of Beijing Rehabilitation Hospital Affiliated to Capital Medical University.

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ORIGINAL RESEARCH

Comparison of Percutaneous Endoscopic Cervical Keyhole Foraminotomy versus Microscopic Anterior Cervical Discectomy and Fusion for Single Level Unilateral Cervical Radiculopathy

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Objective: To compare the clinical and radiological outcomes between microscopic anterior cervical discectomy and fusion (ACDF) and percutaneous endoscopic cervical keyhole foraminotomy (PECF) for single level unilateral cervical radiculopathy.

Methods: A total of 127 patients (59 in PECF VS 68 in ACDF) were enrolled in this study from April 2016 to May 2018 with a minimum follow-up of 2 years. Clinical data including baseline data, Neck Disability Index (NDI), and Visual Analogue Scale for neck and arm (VAS-n, VAS-a) were collected and compared. Radiological evaluation such as disc height, ROM of cervical, Cobb's angle of cervical and Cobb's angle of operated segment was measured by two experienced radiologists in twice.

Results: There was no significant difference between the two groups in the baseline data, and hospital stay was significantly decreased in PECF group than ACDF group ($P < 0.001$). PECF group did not yield superior better outcomes in NDI, VAS-a and VAS-n than ACDF group except at 1-month follow-up. As for radiological outcomes, PECF group has significantly better cervical motion, cervical angle and segmental angle than ADCF group at 12- and 24-month follow-up visit ($P < 0.05$); however, ACDF had shown better disc height restoration and maintenance than PECF ($P < 0.05$). More complications including surface hematoma and swallowing difficulty were occurred in ADCF group.

Conclusion: Percutaneous endoscopic cervical keyhole foraminotomy could be the alternative method for anterior cervical discectomy and fusion in selective cases. However, the indication should be fulfilled, more studies need to be conducted to further testify the efficacy of PECF.

Keywords: unilateral cervical radiculopathy, percutaneous endoscope cervical keyhole foraminotomy, microscopic anterior cervical discectomy and fusion

Introduction

Cervical radiculopathy has become a common clinical scenario and it increases the burden on healthcare centers.[1] Intervertebral foramen stenosis caused by cervical degenerative changes such as lateral disc herniation and osteophyte will incur neurothlipsis. As a consequence, the sensory and motion function and muscle reflection will degrade in the upper extremity. Surgical treatments are needed to reduce the neurothlipsis and relieve the pain. Conservative treatments including pharmacotherapy (nonsteroidal anti-inflammatory drugs, muscle relaxants and steroid injections), traction therapy, physical therapy and manipulative therapy are useful for pain relief but may not impede degenerative changes. Surgical treatments can achieve complete decompression and maintain cervical alignment and are superior to conservative treatments. Anterior cervical discectomy and fusion (ACDF) was firstly proposed by Smith and Robinson in 1958 and was regarded as an effective operation by many researchers.[2–4]

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CLINICAL ARTICLE

Clinical Efficacy of Posterior Percutaneous Endoscopic Unilateral Laminotomy with Bilateral Decompression for Symptomatic Cervical Spondylotic Myelopathy

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Objective: To compare the clinical efficacy of posterior percutaneous endoscopic unilateral laminotomy (PPEUL) and anterior cervical decompression and fusion (ACDF) in the treatment of single-segment spondylotic myelopathy (CSM).

Methods: This is a retrospective research, from January 2017 to December 2019, 30 cases were included in the PPEUL group and 32 cases were included in the ACDF group. The operative duration, blood loss, length of stay, complications, Japanese Orthopaedic Association (JOA) score, visual analogue scale (VAS) score, MacNab classification and imaging data were collected preoperatively, postoperative 1-week, final follow-up and statistically analyzed.

Results: The surgery was completed successfully on all patients, and there were no serious complications, such as nerve or spinal cord injury or infection. In the PPEUL and ACDF groups, the operative duration were 56.63 ± 1.40 and 65.21 ± 2.45 min, the intraoperative blood loss were 51.69 ± 3.23 and 50.51 ± 5.48 mL, and the hospitalization duration was 5.75 ± 1.43 and 6.38 ± 2.16 days. The follow-up period in the PPEUL and ACDF groups was 24.96 ± 1.12 months and 25.65 ± 1.45 months, respectively. There was no significant difference in intraoperative blood loss between the two groups, but the hospitalization and operative durations in the PPEUL group were significantly shorter than those in the ACDF group ($P < 0.05$). The VAS scores at postoperative 1 week and final follow-up were significantly improved compared with those before surgery. The JOA scores at postoperative 1 week and final follow-up were significantly improved compared with those before surgery, but there was no significant difference between the two groups at the last follow-up. The intervertebral disc height of the adjacent segment at the last follow-up was significantly lower in the ACDF group than in the PPEUL group ($P < 0.05$), but there was no significant difference between the two groups in the intervertebral disc height of the surgical segment ($P > 0.05$). The rate of excellent and good results was 90.0% and 87.5%, respectively. Postoperative cervical CT and MRI showed that the spinal canal was fully decompressed and spinal cord compression was relieved.

Conclusion: PPEUL has the advantages of reduced trauma, rapid recovery and remarkable curative efficacy, so it is a new choice for the treatment of CSM.

Key words: Cervical spondylotic myelopathy; Delta system; Unilateral approach bilateral decompression

Introduction

Cervical spondylotic myelopathy (CSM)[1] is a disease based on spinal cord compression due to cervical degeneration, which leads to disturbances in the spinal cord blood supply and finally spinal cord dysfunction. Severe CSM can cause neck and shoulder pain, numbness and weakness of limbs,

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Systematic Review

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Outcome of Anterior and Posterior Endoscopic Procedures for Cervical Radiculopathy Due to Degenerative Disk Disease: A Systematic Review and Meta-Analysis

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Abstract

Study design: Systematic review and meta-analysis.

Objectives: Cervical spine endoscopic discectomy and decompression have gained popularity in the last decade. This review aimed to shed light on the current outcomes of cervical spine endoscopic procedures for degenerative disc disease (DDD) and to calculate a pooled estimate of various outcome measures.

Methods: We retrieved articles published in English related to endoscopic cervical spine procedures from 3 central databases from inception until September 2020. A subgroup analysis based on the anterior versus the posterior approach was performed.

Results: Thirty-one articles fulfilled the eligibility criteria and included 1,410 patients. A successful outcome was observed in 91.3% (88.6-93.4%, $P = 0.000$). This percentage was lower for the anterior approach (89.6% [85.8-92.5%], $P = 0.000$) than for the posterior approach (94.2% [90.4-96.5%], $P = 0.000$). A higher percentage of poor outcomes was reported for the anterior approach (5.7% [3.2-10.1%], $P = 0.000$ vs. 2.3% [1-5.5%], $P = 0.000$ for the posterior approach). The overall complication rate was 7.2% (5.2-9.8%, $P = 0.000$). There was a slightly higher complication rate for the anterior approach (7.9% [4.5-13.3%], $P = 0.000$) than for the posterior approach (6.7% [4.4-10%], $P = 0.000$). The revision rate was 4.2% (2.6-6.8%, $P = 0.000$); and 4.2% (1.8-9.7%, $P = 0.000$) for the anterior approach and 4.00% (2.2-7.4%, $P = 0.000$) for the posterior approach.

Conclusions: There is a higher success rate and lower complication rate with the posterior approach than with the anterior approach. However, high-quality randomized controlled trials are vital to evaluate the efficacy of these procedures.

Keywords
cervical discectomy, evidence-based, endoscopic, minimally invasive, percutaneous

Abbreviations
ACDF, anterior cervical decompression and fusion; **DDD**, degenerative disk disease; **EBL**, estimated blood loss; **MIS**, minimally invasive surgery; **NDI**, neck disability index; **PECF ± D**, Posterior endoscopic cervical foraminotomy with or without discectomy; **VAS**, visual analog score.

Introduction

Degenerative disc disease (DDD) includes isolated neck pain, radiculopathy, myelopathy, or a combination of these conditions.[1] Neck pain due to DDD can affect up to 67% of people aged 50 years or older.[2] However, radiculopathy has a lower incidence than isolated neck pain.[1] It has been reported that the

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BMC Musculoskeletal Disorders

RESEARCH ARTICLE Open Access

Comparative evaluation of posterior percutaneous endoscopy cervical discectomy using a 3.7 mm endoscope and a 6.9 mm endoscope for cervical disc herniation: a retrospective comparative cohort study

Tong Yu, Jiu-Ping Wu, Jun Zhang, Hai-Chi Yu and Qin-Yi Liu*

Abstract

Background: Posterior percutaneous endoscopy cervical discectomy (p-PECD) is an effective strategy for the treatment of cervical diseases, with a working cannula ranging from 3.7 mm to 6.9 mm in diameter. However, to date, no studies have been performed to compare the clinical outcomes of the use of endoscopes with different diameters in cervical disc herniation (CDH) patients. The purpose of this study was to compare the clinical outcomes of patients with unilateral CDH treated with p-PECD using a 3.7 mm endoscope and a 6.9 mm endoscope.

Methods: From January 2016 to June 2018, a total of 28 consecutive patients with single-level CDH who received p-PECD using either the 3.7 mm or the 6.9 mm endoscope were enrolled. The clinical results, including the surgical duration, hospitalization, visual analog scale (VAS) score and modified MacNab criteria, were evaluated. Cervical fluoroscopy, CT, and MRI were also performed during follow-up.

Results: Tthere was a significant difference in regard to the average identification time of the "V" point (18.608 ± 3.7607 min vs. 11.256 ± 2.7161 min, $p < 0.001$) and the mean removal time of the overlying tissue (16.650 ± 4.1730 min vs. 12.712 ± 3.3079 min, $p < 0.05$) for the use of the 3.7 mm endoscope and the 6.9 mm endoscope, respectively. The postoperative VAS and MacNab scores of the two endoscopes were significantly improved compared with those the preoperative scores ($p < 0.05$).

(Continued on next page)

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Original Study on Full-endoscopic Spine Surgery

Full endoscopic cervical spine surgery

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Contributions: (I) Conception and design: All authors; (II) Administrative support: All authors; (III) Provision of study materials or patients: All authors; (IV) Collection and assembly of data: All authors; (V) Data analysis and interpretation: All authors; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

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Background: The authors present 4 techniques for fully-endoscopic cervical spine surgery with accompanying case series: (I) posterior cervical unilateral laminectomy and bilateral decompression, (II) posterior cervical foraminotomy (PCF), (III) anterior cervical discectomy, and (IV) anterior transcorporeal discectomy.

Methods: We retrospectively reviewed fully endoscopic cervical spine surgery cases at one high-volume endoscopic center in the United States and present clinical data extracted from endoscopic spine surgery performed over a 6-year period with a minimum clinical follow up of 1 year.

Results: A series of 114 patients who underwent fully endoscopic cervical spine surgery between 2012 and 2018 is presented. Clinical results and technical data are presented.

Conclusions: Fully endoscopic cervical spine surgery is an emerging surgical technique for addressing cervical radiculopathy and myelopathy through a minimally invasive approach.

Keywords: Endoscopic spine surgery; minimally-invasive; cervical radiculopathy; myelopathy

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Introduction

Cervical disc herniation is common and can affect patients of different ages (1). It can present as a radiculopathy or myelopathy, depending on the pattern of herniation. Cervical radiculopathy commonly presents with pain, paresthesia, and motor weakness (2). Cervical myelopathy can typically present with gait disturbance, motor weakness, loss of hand dexterity, bowel or bladder dysfunction, and paresthesia (3). Traditional surgical management includes anterior cervical discectomy and fusion (ACDF) and posterior cervical foraminotomy (PCF). These approaches have been exhaustively studied and validated (4-7). ACDF has long been considered the gold standard of cervical disc replacement techniques, but does pose some disadvantages, mainly the need for fusion and the risk of developed adjacent disc disease requiring future additional surgical intervention (8). With advances in endoscopic techniques and technologies, opportunities for development of minimally invasive and less disruptive surgical approaches presented itself.

Fully-endoscopic cervical spine surgery is different from micro-endoscopic cervical spine surgery in the sense that the tubular retractor is so small that even with loupes or microscope the operative field is not visible. Fully-endoscopic spine surgery is typically cervical spine surgery performed through a working-channel endoscope. Bi-portal fully endoscopic spine surgery, as the name implies, utilizes 2 ports: a port for surgical instruments and a port for an endoscopic camera. Endoscopic approaches to the cervical spine have been reported and found to be safe and effective in the literature (9).

Here we present 4 distinct fully endoscopic cervical spine surgery approaches for the treatment of cervical

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Original Study on Full-endoscopic Spine Surgery

Full endoscopic unilateral laminotomy for bilateral decompression of the cervical spine: surgical technique and early experience

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Contributions: (I) Conception and design: CP Hofstetter; (II) Administrative support: IJ Abecassis, CP Hofstetter; (III) Provision of study materials or patients: CP Hofstetter; (IV) Collection and assembly of data: All authors; (V) Data analysis and interpretation: All authors; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

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Background: Full-endoscopic decompression surgery has been shown to be safe and efficacious in the lumbar spine, while its role remains to be determined in the cervical spine. We describe the utility of cervical endoscopic unilateral laminotomy for bilateral decompression (CE-ULBD) in a series of elderly patients with severe central stenosis, significant medical comorbidity, and existing cervical deformity.

Methods: A prospectively collected spine surgery registry at the University of Washington was retrospectively queried for patients with cervical spondylotic myelopathy receiving CE-ULBD. Demographic data, operative details, imaging, and patient reported outcomes, including visual analogue scale (VAS) for neck and upper extremity pain, Nurick grade, and the modified Japanese Orthopedic Association (mJOA) score, were reviewed. Description of the surgical technique is provided. Descriptive statistics were calculated.

Results: From 2014 through 2018, 10 patients with an average age of 70.2±5.0 years underwent CE-ULBD for symptomatic upper cervical stenosis due to ligamentum flavum buckling. Half of these patients had one stenotic segment, the other half had two stenotic segments. The most commonly affected segment was C3/4 (5/10 patients). Average length of surgery was 128±18.4 minutes. Average length of stay was 1.2±0.2 days. Average clinical follow-up time was 22.0±4.7 months; clinical outcomes at most recent follow-up were improved via both the Nurick grade (1.2±0.4, P<0.01) and modified Japanese Orthopedic Association (14.6±1.0, P<0.001) compared with pre-operative values. One patient experienced a transient loss of motor evoked potentials intraoperatively, but there were no cases of permanent neurological deficit.

Conclusions: Severe central cervical stenosis is a safe and viable target for full-endoscopic decompression via an interlaminar approach.

Keywords: Interlaminar endoscopic; cervical stenosis; cervical myelopathy; cervical laminotomy; bilateral decompression

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Introduction

Degenerative cervical spinal stenosis is common in individuals aged 60 years or older with an incidence of approximately 90%, and an expected dramatic rise in prevalence in the near-future (1). Patients with degenerative cervical spinal stenosis are at risk for cervical spondylotic myelopathy (CSM), defined as spinal cord dysfunction due to gradual loss of neurons and myelin from manual compression and spinal cord ischemia (2,3). One of the first symptoms of CSM includes hand dysfunction. As a result, patients can have difficulties feeding and grooming

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REVIEW ARTICLE

Full-endoscopic discectomy for thoracic disc herniations: a single-arm meta-analysis of safety and efficacy outcomes

Jackson Daniel Sousa Silva[1,5] · Luis E. Carelli[2] · José A. A. de Oliveira[3] · Ricardo M. L. de Araújo[4]

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Abstract

Introduction Surgical intervention is the treatment of choice in patients with thoracic disc herniation with refractory symptoms and progressive myelopathy. Due to high occurrence of complications from open surgery, minimally invasive approaches are desirable. Nowadays, endoscopic techniques have become increasingly popular and full-endoscopic surgery can be performed in the thoracic spine with low complication rates.

Methods Cochrane Central, PubMed, and Embase databases were systematically searched for studies that evaluated patients who underwent full-endoscopic spine thoracic surgery. The outcomes of interest were dural tear, myelopathy, epidural hematoma, recurrent disc herniation, and dysesthesia. In the absence of comparative studies, a single-arm meta-analysis was performed.

Results We included 13 studies with a total of 285 patients. Follow-up ranged from 6 to 89 months, age from 17 to 82 years, with 56.5% male. The procedure was performed under local anesthesia with sedation in 222 patients (77.9%). A transforaminal approach was used in 88.1% of the cases. There were no cases of infection or death reported. The data showed a pooled incidence of outcomes as follows, with their respective 95% confidence intervals (CI)—dural tear (1.3%; 95% CI 0–2.6%); dysesthesia (4.7%; 95% CI 2.0–7.3%); recurrent disc herniation (2.9%; 95% CI 0.6–5.2%); myelopathy (2.1%; 95% CI 0.4–3.8%); epidural hematoma (1.1%; 95% CI 0.2–2.5%); and reoperation (1.7%; 95% CI 0.1–3.4%).

Conclusion Full-endoscopic discectomy has a low incidence of adverse outcomes in patients with thoracic disc herniations. Controlled studies, ideally randomized, are warranted to establish the comparative efficacy and safety of the endoscopic approach relative to open surgery.

Keywords Endoscopic · Disc herniation · Thoracic

Abbreviations

CI	Confidence intervals
CSF	Cerebrospinal fluid
FC	Facet cyst
IntTL	Interlaminar
JBI	The Joanna Briggs Institute
NA	Not available
OFL	Ossification flavum ligament
OLLP	Ossification ligament longitudinal posterior
PS	Posterior stenosis
SSI	Surgical site infection
TDH	Thoracic disc herniation
TEP	Transthoracic retropleural
TrSF	Transforaminal

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ORIGINAL ARTICLE

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Comparison of the Short-Term Efficacy of Percutaneous Endoscopic Thoracic Decompression and Laminectomy in the Treatment of Thoracic Ossification of the Ligamentum Flavum

FuCheng Bian[1,4], Jian Zhang[2], GuangYu Bian[3], DaYong Wang[2], Bin Chen[4], YongSheng An[4]

OBJECTIVE: **This study aimed to investigate the short-term efficacy of percutaneous endoscopic thoracic decompression (PETD) under local anesthesia and traditional posterior thoracic laminectomy (PTL) in treating single-segment thoracic ossification of the ligamentum flavum (T-OLF).**

METHODS: **This was a retrospective review of the clinical information of 52 patients with T-OLF between September 2017 and September 2021. Based on the inclusion criteria, a total of 52 patients were included in the present research, 26 in the PETD group and 26 in the PTL group. The general preoperative data, intraoperative surgical conditions, preoperative and postoperative clinical information, and complications were collected. The modified Japanese Orthopedic Association score and recovery rate were evaluated preoperatively and at 3, 6, and 12 months postoperatively.**

RESULTS: **There was no statistically significant difference in the baseline parameters in either group ($P > 0.05$). There were statistically significant differences in operation time (94.62 vs. 144.62 minute) and blood loss (22.12 vs. 287.69 mL) between the PETD group and the PTL group. The modified Japanese Orthopedic Association score in the 2 groups improved from (5.46 $\pm$ 1.10) and (5.69 $\pm$ 1.01) preoperatively to (9.08 $\pm$ 0.90) and (8.88 $\pm$ 1.07) at 12 months postoperatively. The recovery rate was 84.6% in the PETD group and 76.9% in the PTL group. In addition, the complications in the PETD group were fewer than those in the PTL group.**

CONCLUSIONS: **The PETD under local anesthesia for T-OLF has many advantages, such as high patient acceptance, good short-term clinical outcomes, and few complications; therefore, this procedure should be promoted as a viable treatment option for T-OLF.**

BACKGROUND

Thoracic ossification of the ligamentum flavum (T-OLF) is highly common in Asian countries, especially in Japan, South Korea and China.[1,2] T-OLF is more often affected in the lower thoracic spine than in the upper thoracic spine. There are 2 hypotheses for the cause of the development of OLF as follows: intrinsic factors (e.g., genetic and dietary factors)[3] and extrinsic factors with altered biomechanics.[4] Since the thoracic spine has a lower range of motion than the cervical and lumbar spine, the thoracic spine's pathogenesis of OLF is different from that of the other areas. Yayama et al.[5] suggested that increasing tension on the ligamentum flavum promotes ossification within the ligamentum flavum. However, the current research on the pathogenesis of T-OLF is not clear.[6]

T-OLF mainly occurs in middle-aged and older individuals, and the initial symptoms are not obvious. Compression of the spinal

Key words
- Ossification of the ligamentum
- Percutaneous endoscopic decompression
- Posterior thoracic laminectomy
- Thoracic myelopathy

Abbreviations and Acronyms
CT: Computed tomography
mJOA: The modified Japanese Orthopaedic Association
MRI: Magnetic resonance imaging
OLF: Ossification of the ligamentum flavum
PETD: Percutaneous endoscopic thoracic decompression
PTL: Posterior thoracic laminectomy
TSS: Thoracic Spinal Stenosis

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Original Article

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Comparative Analysis of Transforaminal Endoscopic Thoracic Discectomy and Microscopic Discectomy for Symptomatic Thoracic Disc Herniation

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Objective: To evaluate the clinical outcomes of transforaminal endoscopic thoracic discectomy (TETD) and microscopic discectomy (MD) for the treatment of symptomatic thoracic disc herniation (TDH).
Methods: Seventy-seven patients (mean, 55.9 years; follow-up, 11.2 months) with symptomatic TDH were retrospectively reviewed (39 TETD and 38 MD). Radiological factors and perioperative outcomes were reviewed. Visual analogue scale (VAS), Oswestry Disability Index (ODI), and American Spinal Injury Association impairment scale were used to evaluate clinical and functional outcomes. Patient satisfaction was evaluated using modified MacNab criteria.
Results: The levels of surgery and the location of hernia were evenly distributed in the both groups. The operative time (70.6 minutes vs. 175.7 minutes), estimated blood loss (3.8 mL vs. 357.4 mL), and length of hospital stay (7.0 days vs. 13.0 days) were significantly different between the TETD and MD groups ($p < 0.05$). VAS scores for dorsal back pain and ODI scores were significantly improved in both groups ($p < 0.05$). Patients who underwent TETD tended to be more satisfied with the outcome in terms of the modified MacNab criteria (89.7% vs. 73.0%, $p = 0.059$). Two patients in the MD group underwent revision surgery, whereas one patient in the TETD group underwent MD because of incomplete decompression.
Conclusion: TETD for the symptomatic TDH is a feasible and safe procedure that could be used for a wider range of surgical levels with a shorter operative time and hospital stay and less blood loss. While achieving similar outcomes, TETD achieved better patient satisfaction because of the use of local anesthesia and its minimal invasiveness.

Keywords: Thoracic disc herniation, Transforaminal endoscopic thoracic discectomy, Microscopic discectomy

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INTRODUCTION

Symptomatic thoracic disc herniation (TDH) is a relatively uncommon condition, accounting for less than 1% of all disc herniations.[1,2] If appropriate conservative treatment, such as epidural steroid injection, physical therapy, and medication, fails to improve patients' symptoms, surgical treatment is indicated. Progressive myelopathy with a significant neurologic deficit is an absolute surgical indication for TDH. Surgical treatment for TDH has been widely applied according to the location and characteristic of the hernia, clinical presentation, and surgeon's experience with approaches ranging from the posteri-

ORIGINAL ARTICLE

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Treatment of Refractory Multilevel Thoracic Spondylodiscitis Using Ultra-Minimally Invasive Endoscopic Approach for Debridement and Drainage: A Technical Note, Intraoperative Video, and Literature Review

Sean M. Barber[1], Nelson Sofoluke[2], Taylor Reardon[3], Albert Telfeian[4], Sanjay Konakondla[2]

■ OBJECTIVE/BACKGROUND: **Spondylodiscitis is an infection of the spinal column which can result in pain, deformity, instability, and/or neurologic deficits. When surgical treatment is required for thoracic spondylodiscitis, invasive open approaches are often utilized due to the ventral location of the pathology.**

■ METHODS: **We describe the use of a spinal endoscope to perform drainage and debridement of infected tissue through a transforaminal/intradiscal approach in a patient with multilevel thoracic spondylodiscitis refractory to antibiotic therapy. Illustrative videos are provided, as well as a review of the relevant literature.**

■ RESULTS: **A total of 188 patients were included in the systematic review. The mean positive reported culture rate was 76% (117/154 patients). The mean preoperative visual analog scale score was 6.8 (n = 114), and the mean postoperative visual analog scale score was 1.8 at 1 week postoperatively (n = 56) and 1.01 at the final follow-up (n = 114). The most common surgical approach was transforaminal/intradiscal (103/188 patients, 54.8%). The mean reoperation rate was 9.1%. The mean complication rate was 5.25%, with complications including increased transient radicular pain, infection, hardware failure, and new unspecified neurological deficits.**

■ CONCLUSION: **This case and those highlighted in our literature review demonstrate that endoscopic treatment for thoracic spondylodiscitis is a viable alternative to traditional open surgery in many cases.**

INTRODUCTION

Spondylodiscitis is a relatively rare infection of the spinal column which can manifest in the form of osteomyelitis, discitis, and/or epidural abscesses.[1] Infectious organisms typically reach the spine via hematogenous spread from other bodily sources of infection[2] and often inoculate the disc space before spreading to the adjacent vertebral bodies, paraspinal tissues, and epidural space.[3] The lumbar spine is the most frequently involved site (58%), followed by the thoracic (30%) and cervical spine (11%).[4]

Patients presenting with spondylodiscitis in the absence of neurological deficits or instability may often be treated successfully with antibiotics once a pathogen is established,[5] but in cases of spondylodiscitis that do not respond to antibiotic treatment, surgical debridement may be required. Patients with spondylodiscitis often have other comorbid conditions (e.g., cardiovascular disease, diabetes mellitus, immunosuppression, end-stage renal disease)[6] that can limit a patient's candidacy for a lengthy or invasive surgical procedure. Surgical approaches to thoracic pathology in particular—with surgical targets ventral to the thoracic spinal cord—may require extensive musculoskeletal collateral damage (transpedicular approach or costotransversectomy or lateral extracavitary

Key words
- Discitis
- Minimally invasive surgery
- Osteomyelitis
- Spinal endoscopy
- Spondylodiscitis

Abbreviations and Acronyms
CT: Computed tomography
FES: Full endoscopic spine surgery
MSSA: Methicillin-sensitive *Staphylococcus aureus*
PRISMA: Preferred Reporting Items for Systematic Review and Meta-Analysis
VAS: Visual analog scale

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Research Article

Full Endoscopic Surgery for Thoracic Pathology: Next Step after Mastering Lumbar and Cervical Endoscopic Spine Surgery?

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Thoracic disc herniation and stenosis are relatively rare, and various symptoms make them difficult to diagnose. Due to the complexity of neural and vascular structure, surgical treatment of thoracic pathology is challenging. Endoscopic spine surgery is an emerging minimally invasive surgical option. Based on wide experience on the cervical and lumbar spine, an endoscopic approach for the thoracic pathology can be performed beyond the learning curve. Transforaminal approach for thoracic disc herniation, endoscopic unilateral approach, and bilateral decompression for thoracic stenosis have been reported as favorable and safe surgical options. In the present study, the authors described the detailed surgical procedure as well as tips and tricks.

1. Introduction

Thoracic disc herniation or thoracic stenosis is not common but causes axial back pain, radiculopathy, and myelopathy [1–6]. Traditional surgical approaches vary from laminectomy, transpedicular, transfacetal approach, lateral extracavitary approach, costotransversectomy, or transthoracic. These approaches have been performed successfully, but approach-related complications are inevitable. Especially, it is very important to identify the entry level of the magna radicular artery and avoid ligating it to prevent paraplegia caused by spinal cord infarction [7]. Overall, complications from open surgery are reported to occur in over 25% of patients [3].

Full endoscopic spine surgery is performed through a working-channel endoscope. The basic concept for the transforaminal or interlaminar approach is similar to the lumbar spine [8–10]. Endoscopic approaches to the thoracic spine have been reported and found to be safe and effective as well as avoiding approach-related complications with injury to the visceral and vascular structure [1, 2, 11–13].

In the present report, we review transforaminal endoscopic thoracic discectomy (TETD) and thoracic endoscopic unilateral laminectomy and bilateral decompression (TE-ULBD).

2. Material and Methods

2.1. Transforaminal Endoscopic Thoracic Discectomy

2.1.1. Indication. Symptomatic soft disc herniation of paramedian, foraminal, or central disc space, not responding to the conservative treatment, is indicated for TETD. Symptoms can be varied from axial pain, radiculopathy, or myelopathy. Indications are important for beginners. Paramedian soft herniation with pain is the best indication for them. With experienced hands, challenging cases like myelopathy or calcified disc can be safely performed [1, 2, 11–13]. Concomitant ossification of the posterior longitudinal ligament or spinal infection is excluded.

2.1.2. Surgical Instrument. Although the basic mechanics of instruments for the thoracic transforaminal endoscopy sys-

OPEN

Comparative Clinical and Radiographic Cohort Study: Uniportal Thoracic Endoscopic Laminotomy With Bilateral Decompression by Using the 1-Block Resection Technique and Thoracic Open Laminotomy With Bilateral Decompression for Thoracic Ossified Ligamentum Flavum

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Presented in Virtual World Spine Congress from August 29 to 30, 2020 and won the best oral presentation second prize.

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BACKGROUND: Symptomatic thoracic myelopathy secondary to thoracic ossified ligamentum flavum (OLF) often requires decompression spinal surgery.
OBJECTIVE: To compare clinical and radiological outcomes in uniportal endoscopic vs open thoracic decompression for thoracic OLF.
METHODS: Retrospective evaluation of patients who underwent uniportal thoracic endoscopic unilateral laminotomy with bilateral decompression (TE-ULBD) by using the one-block resection technique compared with thoracic open laminotomy (TOL) with bilateral decompression. Radiological outcomes in MRI scan and clinical charts were evaluated.
RESULTS: Thirty-five levels of TE-ULBD were compared with 24 levels of TOL. The overall complication rate of TOL was 15% while TE-ULBD was 6.5%. Both TOL and TE-ULBD cohort had significantly improved their visual analog scale (VAS), Oswestry Disability Index, and Japanese Orthopaedic Association (JOA) myelopathy score after operation. Comparative analysis of TE-ULBD performed statistically and significantly better than TOL in improvement of final VAS and JOA scores. The mean difference ± standard deviation of VAS and JOA improvement in final follow-up when compared with preoperative state of TE-ULBD and TOL was 0.717 ± 0.131 and 1.03 ± 0.2, respectively, $P < .05$. The mean Hirabayashi recovery rates were 94.5% (TE-ULBD) and 56.8% (TOL). There was no statistical difference in change in preoperative and final Oswestry Disability Index and MRI volume at upper endplate, middisk, and lower endplate canal cross-sectional area.
CONCLUSION: Uniportal TE-ULBD achieved significantly improved pain and neurological recovery with sufficient spinal canal decompression, as compared with thoracic open laminectomy for patients with myelopathy secondary to OLF in our cohort.

KEY WORDS: Thoracic myelopathy, Ossified ligamentum flavum, Thoracic endoscopic spine surgery, Endoscopic decompression, Open spinal decompression

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Traditional surgical option for patients with thoracic ossified ligamentum flavum (OLF) is open laminectomy. Compared with open decompression, minimally invasive approaches and endoscopic spine surgery reduce perioperative morbidity.[1,2] Endoscopic spine surgery application has evolved from earlier era of lumbar diskectomy to current treatment for wide range of degenerative conditions.[3–8] Ruetten et al[9] described a uniportal full endoscopic thoracic decompression technique for stenosis, which had good clinical results. There are reported success in other literature on a transforaminal approach to perform endoscopic decompression on thoracic spinal stenosis and

ABBREVIATIONS: CSA, cross-sectional area; **JOA,** Japanese Orthopaedic Association; **ODI,** Oswestry Disability Index; **OLF,** ossified ligamentum flavum; **TE-ULBD,** thoracic endoscopic unilateral laminotomy with bilateral decompression; **TOL,** thoracic open laminotomy.

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BMC Surgery

RESEARCH Open Access

Comparison of percutaneous endoscopic thoracic decompression and posterior thoracic laminectomy for treating thoracic ossification of the ligamentum flavum: a retrospective study

Feng-Kai Yang, Peng-Fei Li, Chen-Tao Dou, Rong-Bo Yu and Bin Chen*

Abstract

Background: Thoracic spinal stenosis (TSS) caused by ossification of the ligamentum flavum (OLF) is generally treated by surgical decompression. In this study, we compared the efficacy and safety of percutaneous endoscopic thoracic decompression (PETD) and posterior thoracic laminectomy (PTL) for treating thoracic ossification of the ligamentum flavum (TOLF).

Methods: Twenty consecutive patients with TSS caused by TOLF who were treated between April 2016 and May 2020 were included in this retrospective study. They were divided into the PETD (n = 11) and PTL (n = 9) groups. The mean follow-up period was 19.6 months. The visual analogue scale (VAS) score, the modified Japanese Orthopedic Association (mJOA) score and the recovery rate (RR) were used to evaluate the clinical outcomes.

Results: There were significant differences between PETD group and PTL group in operative time (min) (95.0 ± 18.8 vs 131.1 ± 19.0), postoperative drainage (mL) (20.2 ± 7.9 vs 586.1 ± 284.2), hospital stay (days) (4.4 ± 1.2 vs 10.4 ± 2.6) ($P < 0.05$ for all). However, both groups had similar and significant improvement in VAS and mJOA scores. The RR of two groups achieved the same improvement (81.8% VS 77.8%, $P > 0.05$).

Conclusions: The use of PETD and PTL for treating TOLF both achieved favorable outcomes. PETD is both minimally invasive and achieves similar postoperative symptom relief to PTL. Therefore, PETD could be considered as an effective alternative to traditional open surgery for TOLF in single-segment lower thoracic spine.

Keywords: Ossification of the ligamentum flavum, Thoracic myelopathy, Thoracic spinal stenosis, Percutaneous endoscopic thoracic decompression, Posterior thoracic laminectomy

Background

Thoracic myelopathy is mainly caused by ossification of the ligamentum flavum (OLF) compressing the spinal cord. This causes lower limb numbness and weakness and bladder and bowel dysfunction, which seriously impacts patients' quality of life [1]. Thoracic ossification of the ligamentum flavum (TOLF) is particularly common in East Asian countries such as China, Japan, and Korea, and it is the leading cause of thoracic spinal stenosis (TSS) [2, 3]

Once neurological symptoms occur in patients, conservative treatment is generally ineffective, and spinal stenosis and cord compression can be progressive. The longer the time from symptom onset to surgical treatment, the worse the prognosis [4]. Therefore, surgical treatment should be initiated as early as possible once

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EFORT open reviews

Full endoscopic surgery for thoracic pathology: an assessment of supportive evidence

Rory D. S. Gibson[1]
Ralf Wagner[2]
J. N. Alastair Gibson[3]

- In the last five years, surgeons have applied endoscopic transforaminal surgical techniques mastered in the lumbar spine to the treatment of thoracic pathology.
- The aim of this systematic review was to collate the available literature to determine the place and efficacy of full endoscopic approaches used in the treatment of thoracic disc prolapse and stenosis.
- An electronic literature search of PubMed, Embase, the Cochrane database and Google Scholar was performed as suggested by the Preferred Reporting Items for Systematic Review and Meta-analysis statements. Included were any full-text articles referring to full endoscopic thoracic surgical procedures in any language.
- We identified 17 patient series, one cohort study and 13 case reports with single or of up to three patients.
- Although the majority included disc pathology, 11 papers related cord compression in a proportion of cases to ossification of the ligamentum flavum or posterior longitudinal ligament. Two studies described the treatment of discitis and one reported the use of endoscopy for tumour resection.
- Where reported, excellent or good outcomes were achieved for full endoscopic procedures in a mean of 81% of patients (range 46–100%) with a complication rate of 8% (range 0–15%), comparing favourably with rates reported after open discectomy (anterior, posterolateral and thoracoscopic) or by endoscopic tubular assisted approaches. Twenty-one of the 31 author groups reported use of local anaesthesia plus sedation rather than general anaesthesia, providing 'self-neuromonitoring' by allowing patients to respond to cord and/or nerve stimuli.

Keywords: full endoscopic; thoracic discectomy; transforaminal surgery

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Introduction

It is well recognized by surgeons that interventional treatments at the thoracic level are liable to be technically difficult and demanding. Not only is surgical access to the thoracic spinal canal limited by the anatomical constraints of the rib attachments but the spinal cord at the thoracic level is particularly vulnerable to surgical intervention. The natural thoracic kyphosis flattens the dural sheath against the posterior margin of the disc and the spinal cord's mobility is limited within the canal by the denticulate ligaments. In addition, the ratio of cord diameter to that of the canal leaves little space around the cord and, at some levels, the medullary vascularization is limited.[1]

In the majority of world centres, thoracic disc pathology is still approached using direct open anterior or posterior approaches.[2] Direct access via a transthoracic approach[3] entails opening the chest cavity and, in the case of a disc prolapse, excision of significant healthy tissue before reaching the protruding fragment. Advocated for central calcified discs, the quantity of bone and disc resection will generally require vertebral fusion to prevent postoperative pain at the affected level. Even with a more minimal approach using video-assisted thoracoscopic techniques (VATS),[4,5] or mini-thoracotomy (mini TTA),[6] there remains a significant risk of complications including paralysis, paresis, pleural tear and pneumothorax.[7,8] The alternative direct posterior approaches with laminotomy and durotomy are similarly disliked by most surgeons as segmental nerve root resection may be required and the risk of cord injury is significant.[9] This leaves one of the posterolateral approaches as probably the most commonly performed choice of access to the spine, including costotransversectomy, transpedicular and lateral extracavitary techniques.[10–12] Unfortunately, in each approach, rib head or pedicular resections are required, leading potentially to intraoperative entry to the chest and postoperative pain. Access to the central areas of the disc is also limited. Overall, complications from open surgery are reported to

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Endoscopic Spine Surgery of the Cervicothoracic Spine: A Review of Current Applications

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ABSTRACT

Background: Endoscopic spine surgery in the cervicothoracic spine is generating continued interest in a rapidly evolving field. The authors present 4 techniques for fully endoscopic cervical spine surgery: (1) posterior cervical unilateral laminectomy and bilateral decompression, (2) posterior cervical foraminotomy, (3) anterior cervical discectomy, and (4) anterior transcorporal discectomy. Two techniques for fully endoscopic thoracic spine surgery are also presented: (1) posterior thoracic unilateral laminectomy and bilateral decompression and (2) transforaminal thoracic endoscopic discectomy and foraminotomy.

Methods: We describe 6 different surgical approaches and review the relevant literature about each technique.

Results: The clinical application of endoscopic spine surgery techniques has evolved over the past 40 years. Recent data suggest comparable outcomes to other procedures and perhaps fewer complications and quicker recovery when these techniques are used in the cervical and thoracic spine. Significant variability exists in these approaches depending on the goal of canal decompression, root decompression, and the site of the pathology.

Conclusions: Each endoscopic approach in the cervicothoracic spine has its technical nuances, outcomes, advantages, and disadvantages, making fully endoscopic cervicothoracic spine surgery an exciting and growing field.

Special Issue

Keywords: endoscopic discectomy, transforaminal, TESSYS, radiculopathy, cervical, thoracic

INTRODUCTION

Cervical disc herniation and cervical stenosis are common and can present as radiculopathy or myelopathy.[1] Traditional surgical approaches include anterior cervical discectomy and fusion, posterior cervical foraminotomy, and posterior laminectomy with or without fusion. These approaches have been exhaustively studied and validated.[2–6] Thoracic disc herniations represent a host of surgical challenges, as each access corridor presents anatomical hazards. Open surgical approaches for the treatment of thoracic disc herniations and thoracic stenosis, from medial to lateral, include laminectomy, transpedicular, costotransversectomy, and transthoracic. The goal of each of these approaches is to achieve adequate decompression with little to no manipulation of the spinal cord.

Fully endoscopic cervicothoracic spine surgery is typically cervicothoracic spine surgery performed through a working-channel endoscope. Unlike open or microendoscopic cervicothoracic spine surgery, the tubular retractor is so small that the operative field is not visible even with loupes or microscope. Biportal fully endoscopic spine surgery, as the name implies, utilizes 2 ports: a port for surgical instruments and a port for an endoscopic camera. Endoscopic approaches to the cervicothoracic spine have been reported in the literature and found to be safe and effective.[7,8]

Here, we review 4 techniques for fully endoscopic cervical spine surgery: (1) posterior cervical unilateral laminectomy and bilateral decompression, (2) posterior cervical foraminotomy, (3) anterior cervical discectomy, and (4) anterior transcorporal discectomy. We also review 2 techniques for fully endoscopic thoracic spine surgery: (1) posterior thoracic unilateral laminectomy and bilateral decompression and (2) transforaminal thoracic endoscopic discectomy and foraminotomy.

METHODS

Surgical Procedures: Cervical

Posterior Cervical Unilateral Laminectomy and Bilateral Decompression

This technique is indicated for the treatment of cervical stenosis. The patient is positioned prone in a Mayfield head holder on hip and chest bolsters. The procedure is performed under general anesthesia, and somatosensory-evoked potential monitoring is typically used. Figure 1 depicts a case example. The joimax

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Five-Year Outcomes After Transforaminal Endoscopic Foraminotomy and Discectomy for Soft and Calcified Thoracic Disc Herniations

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ABSTRACT

Background: The aim of this study was to evaluate the safety and long-term clinical outcomes of transforaminal full endoscopic discectomy and foraminotomy performed with manual reamers under local anesthesia on soft and calcified herniated discs in the mid and lower thoracic spine.

Methods: Postoperative pain relief was self-evaluated by 16 patients using a visual analog scale (VAS) and Oswestry Disability Index (ODI). Patients were scored at 6, 12, 24, and 60 months after surgery.

Results: Significant pain reduction of more than 50% in the VAS score was achieved in 15 out of 16 patients at all review points throughout this study. Similarly, a decrease of more than 50% in ODI scores was achieved in 15 out of 16 patients in all 4 review points. There were no surgical complications. Good postoperative results were achieved in patients regardless of the consistency of the disc herniation.

Conclusions: Transforaminal full endoscopic discectomy and foraminotomy with manual reamers performed under local anesthesia produces sustained reduction in pain and improves functionality in patients with mid and lower thoracic spine soft and calcified disc herniations. The surgery is safe and straightforward to perform with the correct training.

Level of Evidence: 4.

Clinical Relevance: Thoracic transforaminal endoscopic discectomy and foraminotomy, performed in TIVA, may be a useful adjunct for treatment of patients with soft and calcified disc herniations in thoracic spine.

Minimally Invasive Surgery

Keywords: thoracic spine, transforaminal endoscopy, hand reamers, disc herniation

INTRODUCTION

Anterior and nonanterior approaches have been used to access herniated discs in the thoracic spine.[1–3] Nonanterior approaches are preferred because of reduced in-hospital morbidity and mortality rates.[4,5] Recently, a minimally invasive transforaminal full endoscopic technique for the treatment of thoracic disc herniations is slowly being adopted. During endoscopy, manipulation of an already compromised thoracic spinal cord is kept to a minimum, potentially reducing postoperative morbidity and enhancing postoperative recovery.

There are few papers in the medical literature describing the removal of thoracic herniated discs using an entirely endoscopic transforaminal procedure.[4,6–13] Most reports address removal of soft thoracic disc herniations, and only 2 describe endoscopic removal of calcified thoracic disc protrusions endoscopically.[6,10] Ten out of 16 patients (62.5%) in our study had partially or totally calcified disc herniations, and 6 out of 16 patients (37.5%) had soft herniated discs. Similar findings of calcified thoracic disc herniations were reported by Ruetten et al.[6] In 2 patients with 2-disc herniations, both herniations were calcified. Final clinical outcomes after surgery were the same for all patients regardless of the consistency of the disc herniation. The only difference was slightly longer time to successfully complete the surgery when operating on calcified herniated discs since they were more adherent to the dura mater.

METHODS

Patients

From January 2008 to January 2015, 16 consecutive patients who had failed conservative medical

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Thoracic Endoscopic Spine Surgery: A Comprehensive Review

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ABSTRACT

Background: From the 1990s, there has been growth in the literature demonstrating the feasibility of minimally invasive approaches for treating diverse spinal disorders. There is still much work to be done in circumnavigating the technical challenges and elucidating relative advantages of endoscopic techniques in spine surgery. In this comprehensive literature review, we discuss the history, advantages, disadvantages, approaches, and technology of, and critically examine peer-reviewed studies specifically addressing, endoscopic thoracic spinal surgery.

Methods: Literature review was conducted with the key words "endoscopic," "minimally invasive," and "thoracic spinal surgery," using PubMed, Web of Science, and Google Scholar.

Results: Review of 241 thorascopic procedures showed a success rate of 98% to 100%, low morbidity, and favorable complication profile. Review of 115 thoracic fixation procedures demonstrated high success rate, and 87% of screw positions were rated "good." Review of 55 full endoscopic uniportal decompressions showed sufficient decompression in most patients. Match pair analysis of 34 patients comparing video-assisted thoracoscopy surgery (VATS) or posterior spinal fusion reported the VATS group had increased operative duration but reduced blood loss.

Conclusions: Based on our literature review, there is a high rate of positive outcomes with endoscopic thoracic spine surgery, which reduces tissue dissection, intraoperative blood loss, and epidural fibrosis. However, the technical challenge highlights the importance of further training and innovation in this rapidly evolving field.

Level of Evidence: 3.

Clinical Relevance: There is growing evidence demonstrating the success of endoscopic thoracic spinal surgery. Populations that could be helped include the elderly and immunocompromised, who would benefit from decreased hospital stay and enhanced recovery time.

Endoscopic

Keywords: endoscopic, minimally invasive, thoracic spine

INTRODUCTION

Thoracic endoscopic spine surgery is a form of minimally invasive spine surgery (MISS) primarily used to treat thoracic spinal disc herniations and stenosis via endoscopic discectomies and decompression techniques, respectively.[1] Because of the lengthy recovery time and associated complications of open procedures, this minimally invasive approach primarily aims to reduce tissue trauma while retaining therapeutic efficacy.[1]

Historically, endoscopic spine surgery is a relatively new field that has been developing for the last 40 years. Although the technique was initially used to treat lumbar disc herniations, developments in camera, drill, and endoscope technology have opened up new horizons. The first endoscopic spine surgeries used the percutaneous nucleotomy technique, which only enabled the use of small needle-like instruments. A breakthrough was made in 1990 when Parvis Kambin delineated a triangular safe zone, later known as Kambin's triangle. This triangular zone is bordered by the exiting root anteriorly, the traversing root medially, and the superior end plate of the lower lumbar vertebra inferiorly. Kambin's triangle not only enabled the introduction of larger surgical instruments into the field, but also facilitated access to foraminal pathology. As technology progressed, Parvis Kam-

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Original Study on Full-endoscopic Spine Surgery

Transforaminal endoscopic thoracic discectomy with foraminoplasty for the treatment of thoracic disc herniation

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Contributions: (I) Conception and design: J Bae, SH Lee; (II) Administrative support: SH Shin; (III) Provision of study materials or patients: J Bae; (IV) Collection and assembly of data: J Bae; (V) Data analysis and interpretation: J Bae; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

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Background: Symptomatic thoracic disc herniation (TDH) is a rare clinical entity and surgical intervention for it is even more uncommon. Despite several surgical techniques being described for thoracic discectomy, considering the unique surgical challenges, none of them have been accepted universally. Minimally invasive techniques have brought in a paradigm shift in the management of cervical/lumbar spinal disorders and similar techniques have been extrapolated to the thoracic region too. The purpose of this paper is to describe our technique, surgical experience, and the clinical results of transforaminal endoscopic thoracic discectomy (TETD).

Methods: Consecutive patients who underwent TETD (2001–2018) were reviewed. Patients who had a minimum of 6 months of follow-up, and without cervical and lumbar spine surgery or trauma during the follow-up period were included in the study. TETD was performed in patients who presented with symptomatic disc herniation of the thoracic spine and did not respond to conservative treatments. Patients with calcified disc herniation or concomitant ossification of the posterior longitudinal ligament (OPLL) were excluded. Under local anesthesia and intravenous sedation, a 4.7-mm endoscope (TESSYS, Joimax GmbH, Germany) was introduced via transforaminal approach with foraminoplasty using reamer. Patient outcome was evaluated using visual analogue scale (VAS) and Oswestry disability index (ODI) scores. Patient satisfaction was measured using Macnab's criteria.

Results: Ninety-two consecutive patients (mean age was 48.9 years, 57 males) who underwent TETD from 2001 to 2018 met the inclusion criteria. Patients underwent surgery at different levels: 16 patients for T2–3 to T5–6 level, 41 cases for T6–7 to T8–9, and 35 patients for T9–10 to T12–L1. During follow-up for an average of 38.4 months, all patients showed a significant improvement of pain (7.6 to 1.6 in VAS and 68.2 *vs.* 13.2 for ODI, $P<0.05$ for both). There was one patient who had transient motor weakness.

Conclusions: TETD for soft, paramedian or lateral symptomatic TDH is a feasible and effective minimally invasive treatment option with favorable clinical results.

Keywords: Thoracic disc herniation (TDH); transforaminal endoscopic thoracic discectomy (TETD); foraminoplasty

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Retrospective Case Review

Fully Endoscopic 360° Decompression Surgery for Thoracic Spinal Stenosis: Technical Note and Report of 8 Cases

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Background: Surgical options for treating thoracic spinal cord compression that results from circumferential stenosis typically involve instrumented fusion procedures. The authors present here an outpatient, awake, endoscopic surgical option for treating thoracic stenosis that avoids fusion.

Objectives: To evaluate the outcome and safety of combining fully endoscopic transforaminal and posterior approaches for ventral and dorsal decompression of thoracic spinal stenosis.

Study Design: Retrospective case review.

Setting: Single-center acute-care hospital.

Methods: Eight patients with single-level, significant stenosis of the thoracic spinal canal were treated with fully endoscopic transforaminal and posterior approaches to achieve 360° ventral and dorsal decompression. Patients were followed up to 30 months postoperatively. Axial back pain was measured by the Visual Analog Scale (VAS) score, and paired Student t-test was used for statistical analysis.

Results: Successful decompression was achieved in all 8 patients. All surgeries were performed as outpatient procedures under local anesthesia with intravenous (IV) sedation. There were no intraoperative dura tears, spinal cord or nerve root injury, postoperative infections, or cases of iatrogenic-induced segmental instability. All patients had significant improvement with VAS scores significantly lower postoperatively.

Limitations: Small case series evaluated retrospectively with 15-month average follow-up.

Conclusions: Combining fully endoscopic transforaminal and posterior approaches for both ventral and dorsal decompression under local anesthesia with IV sedation is an effective and safe minimally invasive surgical treatment for thoracic spinal stenosis.

Key words: Thoracic spinal stenosis, fully endoscopic, transforaminal, myelopathy, bilateral laminotomy/unilateral approach

Pain Physician 2020: 23:E659-E663

Thoracic spinal stenosis is a relatively rare spinal disorder that is the result, typically, of degenerative processes that include disc herniation, endplate osteophyte formation, ossification of the posterior longitudinal ligament, and hypertrophy of the facet joints and/or ligamentum flavum (1,2). Surgery to treat thoracic spinal stenosis is often challenging. The goal is to achieve adequate decompression without manipulating the spinal cord. Individual planning is required, and various surgical techniques and approaches have been used (3-5). However, the traditional surgical intervention has a high incidence of complications (6-9). Although fully endoscopic technique via the transthoracic retro-pleural

TECHNICAL NOTE

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Percutaneous Endoscopic Thoracic Decompression for Thoracic Spinal Stenosis Under Local Anesthesia

Xiao-Kang Cheng and Bin Chen

BACKGROUND: **Thoracic spinal stenosis (TSS), a common vertebral degenerative disease, is generally treated via surgical decompression. Percutaneous endoscopic thoracic decompression (PETD) under local anesthesia is considered a relatively safe, minimally invasive procedure. Few reports detail the success of endoscopic decompression for treatment of TSS caused by ossification of ligamentum flavum, the most common cause of TSS. This study investigated application of PETD for treatment of TSS caused by ossification of ligamentum flavum, ossification of posterior longitudinal ligament, or thoracic disc herniation.**

METHODS: **From January 2017 to January 2019, 12 consecutive patients (6 men and 6 women) underwent PETD. TSS was caused by ossification of ligamentum flavum in 5 patients, thoracic disc herniation in 5 patients, and ossification of posterior longitudinal ligament in 2 patients. All cases were followed up for 1 year postoperatively. Preoperative and postoperative neurologic status was evaluated using the modified Japanese Orthopaedic Association score, and complications were documented.**

RESULTS: **Average modified Japanese Orthopaedic Association score improved significantly from 6.25 $\pm$ 1.60 preoperatively to 9.75 $\pm$ 1.21 at final follow-up. Dural tear was observed in 1 case during the intervention, and 1 case had transient worsening of preoperative paralysis. Recovery at final follow-up was classified as excellent in 5 cases, good in 6 cases, and poor in 1 case.**

CONCLUSIONS: **This retrospective analysis showed that PETD under local anesthesia may be a feasible alternative to treat TSS in elderly patients with other underlying complications for whom general anesthesia or major surgical trauma would be harmful.**

INTRODUCTION

Thoracic spinal stenosis (TSS) is a reduction in the capacity of the thoracic spinal canal with associated compression of the spinal cord and/or nerve roots. It is usually caused by ossification of ligamentum flavum (OLF), ossification of posterior longitudinal ligament (OPLL), osteophytes, intervertebral disc herniation, and hypertrophy of the intervertebral joint.[1] This vertebral degenerative disease gives rise to various clinical symptoms, decreasing quality of life of patients, and most commonly affects elderly adults. The clinical symptoms of TSS include local pain, lower extremity numbness with or without weakness, difficulty walking, and sphincter dysfunction.[2]

Treating TSS is challenging. Traditional open surgical spinal decompression, involving paraspinal muscle and spinous process dissection, lamina osteotomy, and removal of the hyperplastic ligament, is the prevailing treatment choice.[3] Although this is an established approach with satisfactory long-term results, there are some associated risks of transient neurologic deterioration or permanent paraplegia. Owing to improvements in equipment and optical technology, several minimally invasive spinal procedures for the cervical and lumbar spine have been reported in recent years.[4] It has been demonstrated that percutaneous endoscopic lumbar decompression (PELD) under local anesthesia is a

Key words
- Local anesthesia
- Ossification of ligamentum flavum
- Ossification of posterior longitudinal ligament
- Percutaneous endoscopic thoracic decompression
- Thoracic disc herniation
- Thoracic spinal stenosis

Abbreviations and Acronyms
mJOA: Modified Japanese Orthopaedic Association
OLF: Ossification of ligamentum flavum
OPLL: Ossification of posterior longitudinal ligament
PELD: Percutaneous endoscopic lumbar decompression
PETD: Percutaneous endoscopic thoracic decompression
TDH: Thoracic disc herniation
TSS: Thoracic spinal stenosis

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Technical Note

Percutaneous Endoscopic Thoracic Discectomy in the Upper and Midthoracic Spine: A Technical Note

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Despite the successful application of percutaneous endoscopic thoracic discectomy (PETD) its technical feasibility and outcomes for symptomatic upper and midthoracic disc herniation have not been reported yet. The purpose of this article was to evaluate the feasibility of the percutaneous transforaminal endoscopic approach to remove disc herniations in the upper and midthoracic spine. Fourteen consecutive patients (mean age, 42.4 years; 12 males, 2 females) who underwent PETD were included in the analysis. The procedure was performed under local anesthesia and intravenous sedation using the standard endoscopy instrument set. The transforaminal approach combined with foraminoplasty was used to access the herniated areas. Treatment outcomes were evaluated using visual analogue scale (VAS) scores, Oswestry Disability Index (ODI) scores, and the modified MacNab criteria. Four discectomies were performed at T2–3, 5 at T3–4, and 5 at T5–6. The mean follow-up period was 43.4 months, and all patients showed statistically significant postoperative improvement (VAS: 7.3 to 2.3, ODI: 53.5 to 16.9, $p < 0.05$ for all). No serious complications were reported during follow-up. PETD for upper and midthoracic disc herniation is a feasible and effective minimally invasive treatment option with favorable clinical results.

Keywords: Endoscopic discectomy, Upper and mid thoracic disc herniation, Transforaminal thoracic discectomy

INTRODUCTION

Thoracic disc herniation (THD) is relatively uncommon.[1-4] The incidence has been reported to be 0.25%–0.5% of spinal disc disease.[1-4] However, the diagnosis of TDH is increasing with the development of magnetic resonance image (MRI).[2-4]

Considering the complexity of neural and vascular structures, surgical treatment of upper and mid thoracic disc herniation (UMTDH) is technically challenging.[3,4] Open surgical approach for THD include laminectomy, transpedicular approach, costotransversectomy, and transthoracic approach.[5-7] For upper thoracic levels, axillary approach or transsternal approach is possible trajectory for transthoracic approach.[3,4] Although percutaneous endoscopic thoracic discectomy (PETD) has been introduced, technical feasibility and outcomes for UMTDH have not been reported. The purpose of this report is to describe percutaneous endoscopic approach to remove disc herniation on upper and mid thoracic spine via transforaminal approach.

MATERIALS AND METHODS

1. Patient Population

After approval of the Institutional Review Board by the Wooridul Hospital (WRDIRB-018-002) and receiving informed consent from patients, patients with symptomatic UMTDH who underwent PETD, were retrospectively analyzed. Cases of calcified disc herniations, concomitant ossification of the posterior longitudinal ligament or ossification of the ligamentum flavum, history of trauma and worker's compensation claim were excluded (Table 1). Total of fourteen consecutive patients (mean age, 42.4 years; 12 males, 2 females), who underwent PETD from 2001 to 2017, were included in the analysis. Four, 5, and

LUMBAR SPINE

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LITERATURE REVIEW

Full-Endoscopic Lumbar Discectomy Approach Selection

A Systematic Review and Proposed Algorithm

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Study Design. A systematic review of the literature to develop an algorithm formulated by key opinion leaders.

Objective. This study aimed to analyze currently available data and propose a decision-making algorithm for full-endoscopic lumbar discectomy for treating lumbar disc herniation (LDH) to help surgeons choose the most appropriate approach [transforaminal endoscopic lumbar discectomy (TELD) or interlaminar endoscopic lumbar discectomy (IELD)] for patients.

Summary of Background Data. Full-endoscopic discectomy has gained popularity in recent decades. To our knowledge, an algorithm for choosing the proper surgical approach has never been proposed.

Materials and Methods. A systematic review of the literature using PubMed and MeSH terms was performed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines. Patient samples included patients with LDH treated with full-endoscopic discectomy. The inclusion criteria were interventional research (randomized and nonrandomized trials) and observation research (cohort, case-control, case series). Exclusion criteria were case series and technical reports. The criteria used for selecting patients were grouped and analyzed. Then, an algorithm was generated based on these findings with support and reconfirmation from key expert opinions. Data on overall complications were collected. Outcome measures included zone of herniation, level of herniation, and approach (TELD or IELD).

Results. In total, 474 articles met the initial screening criteria. The detailed analysis identified the 80 best-matching articles; after applying the inclusion and exclusion criteria, 53 articles remained for this review.

Conclusions. The proposed algorithm suggests a TELD for LDH located in the foraminal or extraforaminal zones at upper and lower levels and for central and subarticular discs at the upper levels considering the anatomic foraminal features and the craniocaudal pathology location. An IELD is preferred for LDH in the central or subarticular zones at L4/L5 and L5/S1, especially if a high iliac crest or high-grade migration is found.

Key words: approach, disc herniation, full-endoscopic lumbar discectomy, high iliac crest, interlaminar endoscopic lumbar discectomy, lumbar disc herniation, lumbar spine, systematic review, transforaminal endoscopic lumbar discectomy

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Review Article

Impact of the learning curve of percutaneous endoscopic lumbar discectomy on clinical outcomes: a systematic review

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Clinical outcome, spine

ABSTRACT

Although it is well-recognized within the endoscopic spine community that a learning curve exists for percutaneous endoscopic lumbar discectomy (PELD), it is less well understood how the learning curve impacts PELD clinical outcomes. This systematic literature review serves as the most comprehensive and up-to-date resource on this topic. Following a focused literature search, 21 articles on the learning curve for PELD were found, and from those articles, 21 unique clinical outcome metrics were identified. Operative time was the most commonly reported clinical outcome metric in this cohort, appearing in 17 studies. There were unanimous findings among the relevant studies that the following clinical outcomes are not affected by the learning curve for PELD: Oswestry Disability Index and herniation rate. Additionally, there were unanimous findings that the following clinical results are affected by the learning curve for PELD: cannula placement time, postoperative dural sac cross-sectional area; fluoroscopy time; and operative time. The purpose of this collection of findings in this systematic review is to positively inform current and future surgeons and trainees embarking on the learning curve for PELD.

1. Introduction

Endoscopic spine surgery, is a rapidly evolving field within minimally invasive spine surgery (MISS). Endoscopic spine surgery aims to reduce collateral tissue damage, attenuate blood loss, and expedite recovery times.[1–3] This technique is made possible by the use of an endoscope which allows for direct visualization of the pathology through the use of a high-definition camera.[2,4] There is a variety of endoscopic technologies available to surgeons.

There is a widely held notion within the field of endoscopic spine surgery that a learning curve exists for novice providers. Indeed, newcomers to endoscopic spine surgery will often be dealing with mastering a procedure they have rarely (if ever) encountered in prior training. The process of picking up unfamiliar instruments and absorbing a new anatomic lens can be daunting. Because of these reasons, it is recognized that along with different points of the learning curve. Clinical outcomes will evolve. However, what is less clear is these clinical outcomes and how exactly the endoscopic spine surgery learning curve will impact them.

This article will systematically review the literature to evaluate the

Abbreviations: PELD, percutaneous endoscopic lumbar discectomy; VAS, Visual Analog Scale; ODI, Oswetry Disability Scale; NASS, North American Spine Society; LOS, length of stay; SF, short form; JOA, Japanese Orthopaedic Association; mJOA, modified Japanese Orthopaedic Association; MISS, minimally invasive spine surgery.

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ORIGINAL ARTICLE

Initial learning curve after switching to uniportal endoscopic discectomy for lumbar disc herniations

Catherine Olinger[1] · Alex Coffman[1] · Chad Campion[2] · Kirk Thompson[2] · Raymond Gardocki[3]

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Abstract

Purpose The purpose was to investigate the learning curve for elective endoscopic discectomy performed by a single surgeon who made a complete switch to uniportal endoscopic surgery for lumbar disc herniations in an ambulatory surgery center and determine the minimum case number required to safely overcome the initial learning curve.

Methods Electronic medical records (EMR) of the first 90 patients receiving endoscopic discectomy by the senior author in an ambulatory surgery center were reviewed. Cases were divided by approach, transforaminal (46) versus interlaminar (44). Patient-reported outcome measures (visual-analog-score (VAS) and the Oswestry disability index (ODI)) were recorded preoperatively and at 2-week, 6-week, 3-month, and 6-month appointments. Operative times, complications, time to discharge from PACU, postoperative narcotic use, return to work, and reoperations were compiled.

Results Median operative time decreased approximately 50% for the first 50 patients then plateaued for both approaches (mean: 65 min). No difference in reoperation rate observed during the learning curve. Mean time to reoperation was 10 weeks, with 7(7.8%) reoperations. The interlaminar and transforaminal median operative times were 52 versus 73 min, respectively ($p = 0.03$). Median time to discharge from PACU was 80 min for interlaminar approaches and 60 min for transforaminal ($p < 0.001$). Mean VAS and ODI scores 6 weeks and 6 months postoperatively were statistically and clinically improved from preoperatively. The duration of postoperative narcotic use and narcotics need significantly decreased during the learning curve as the senior author realized that narcotics were not needed. No differences were apparent between groups in other metrics.

Conclusions Endoscopic discectomy was shown to be safe and effective for symptomatic disc herniations in an ambulatory setting. Median operative time decreases by half over the first 50 patients in our learning curve, while reoperation rates remained similar without the need for hospital transfer or conversion to an open procedure in an ambulatory setting.

Level of evidence Level III, prospective cohort.

Keywords Endoscopic · Discectomy · Patient-reported outcomes · Spinal surgery · Learning curve · Uniportal · Lumbar disc · Reoperation · Ambulatory · Outpatient

Introduction

Endoscopic lumbar discectomy has been shown to be a safe alternative to microscopic lumbar discectomy with increasing popularity [8, 13]. However, new technology can pose increased risk with new procedures and the surgeon learning curve. The purpose of this study is to evaluate the learning curve for elective endoscopic discectomy performed by a single surgeon who made a complete switch to uniportal endoscopic surgery for elective lumbar disc herniations in

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Clinical efficacy of transforaminal endoscopic lumbar discectomy for lumbar degenerative diseases: A minimum 6-year follow-up

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Background: Transforaminal Endoscopic Lumbar Discectomy (TELD) is widely applied for lumbar degenerative disease (LDDs) and satisfactory short-term outcomes have been achieved. However, the mid-term and long-term follow-up of this technique is still lacking.
Objective: To retrospectively analyze the mid-term clinical efficacy of TELD for single-level LDD and its effect on intervertebral disc degeneration with a minimum of 6-year follow-up.
Methods: 64 patients with single-level LDDs (lumbar disc herniation, lumbar spinal stenosis) who underwent TELD under local anesthesia in our department from December 2014 to December 2015 were observed. Visual analog scale (VAS), Japanese Orthopaedic Association evaluation treatment (JOA) score and Oswestry Disability Index (ODI) were calculated and compared before operation, 3 months after operation, 6 months after operation, 1 year after operation and at the last follow-up. Disc Height (DH), disc range of motion (ROM) and disc degeneration on standard lumbar lateral radiographs before operation and at the last follow-up were determined. Recurrence rate and operation-related complications during follow-up were recorded.
Results: 64 cases were followed up for 6.4 ± 0.1 years. There were no complications such as infection, epidural hematoma and nerve root injury. 1 patient (1.67%) was found to have dural rupture and cauda equina hernia during the operation. There were significant differences in VAS, JOA, ODI between preoperative and postoperative 3 months, 6 months, 1 year and last follow-up ($P < 0$ 01), VAS, JOA, ODI at 3 months after operation were different from 6 months after operation ($P < 0$ 05), and there were significant differences compared with preoperative, 1 year after operation and last follow up ($P < 0$ 01). VAS, JOA and ODI at 6 months after operation were significantly different from those before operation ($P < 0.01$), but not significantly different from those at 1 year after operation and the last follow-up ($P > 0.05$). There was no significant difference in DH, ROM and the Pfirrmann grade of intervertebral disc preoperative and the last follow-up. During the follow-up period, 3 patients (4.69%) were recurrent, 13 patients (20.31%) had various degrees of postoperative dysesthesia (POD), and 3 patients (4.69%) had various degrees of muscle weakness.

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RESEARCH Open Access

A comparative study of percutaneous endoscopic interlaminar discectomy and transforaminal discectomy for L5-S1 calcified lumbar disc herniation

Yuan-Pei Cheng[1], Xiao-Kang Cheng[2] and Han Wu[1*]

Abstract

Background: Percutaneous endoscopic lumbar discectomy (PELD) is a relatively safe and effective minimally invasive surgery in the treatment of calcified lumbar disc herniation (CLDH). However, studies on percutaneous endoscopic interlaminar discectomy (PEID) and percutaneous endoscopic transforaminal discectomy (PETD) for CLDH have rarely been reported. This research aimed to compare the clinical efficacy of PEID and PETD for L5-S1 CLDH.

Methods: We retrospectively analyzed 54 consecutive patients with L5-S1 CLDH treated with PELD at our institution from August 2016 to August 2020. Patients were divided into PEID group ($n=28$) and PETD ($n=26$) group according to the surgical methods. The demographic characteristics and surgical results of the two groups were compared. Clinical outcomes were estimated by the visual analog scale (VAS) for leg pain, Oswestry disability index (ODI) and modified MacNab criteria.

Results: All patients were successfully operated on by PEID or PETD. No significant differences in the demographic characteristics, intraoperative blood loss, postoperative hospital stay and complication rate were noted between the PEID and PETD groups. The excellent and good rates in the PEID group were similar to those in the PETD group (89.29% vs 88.46%, $P=1.000$), whereas the PEID group exhibited superior results for operative time (min) (64.61 ± 5.60 vs 85.58 ± 8.52, $P<0.001$) and fluoroscopy times (n) (2.93 ± 0.90 vs 13.35 ± 2.30, $P<0.001$) compared with the PETD group.

Conclusions: PEID has achieved good clinical efficacy as PETD for L5-S1 CLDH. Compared with PETD, PEID has the advantages of shorter operative time and a reduced number of fluoroscopy times in the treatment of CLDH.

Keywords: Calcified lumbar disc herniation, Percutaneous endoscopic lumbar discectomy, Percutaneous endoscopic interlaminar discectomy, Percutaneous endoscopic transforaminal discectomy

Background

Calcified lumbar disc herniation (CLDH), with a low incidence rate, is a special type of lumbar disc herniation (LDH). Calcified disc herniation, with hard structure, usually adheres extensively to surrounding tissues such as nerve roots and the dural sac. Most patients with CLDH have severe low back and leg pain symptoms and even severe neurological symptoms in the acute stage [1]. However, conservative treatments fail to effectively relieve symptoms.

Patients with CLDH are typically treated by traditional open surgery. Traditional open surgery completely

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ENDOSCOPIC SPINE SURGERY SPECIAL SECTION

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Indications and Contraindications of Full-Endoscopic Interlaminar Lumbar Decompression

***Ralf Wagner*[1] *and Monika Haefner*[2]**

BACKGROUND: **Spinal stenosis is a common disease with an increasing incidence. Narrowing of the spinal canal is caused by bone and soft tissue degeneration, such as osteophyte formation, facet and ligamentum flavum hypertrophy, and disc herniation. Various surgical techniques have been used to treat spinal canal stenosis, including open, tubular, microsurgical decompression, and fusion surgery. This article presents the technique for full-endoscopic interlaminar bilateral decompression of the lumbar spine.**

METHODS: **Surgical approach, anatomy, pathology, indications, contraindications, and surgical equipment are described.**

RESULTS: **With well-chosen endoscopic equipment, surgical time can be reduced with minimal collateral damage. Clear advantages of full-endoscopic decompression over open or other minimally invasive surgery methods are demonstrated in many clinical studies. The endoscopic technique has been shown to be effective in spinal canal decompression with good to excellent clinical results. The interlaminar endoscopic approach minimizes iatrogenic injury to the stabilizing anatomic structures while achieving full unilateral and bilateral decompression. A significant improvement in pain and functional outcome scores with low complication rates has been demonstrated.**

CONCLUSIONS: **This technique is safe for lumbar spinal decompression and more minimally invasive than a micro-endoscopic approach. However, this technique should be performed by surgeons with advanced skills. Endoscopy could become the gold standard for treatment of canal stenosis in the near future.**

INTRODUCTION

Lumbar spinal stenosis is a common disease with an increasing incidence. Narrowing of the spinal canal leads to neurogenic claudication as the main symptom. Mainly middle-aged and older adults have lumbar leg and back pain with a negative impact on activity level and quality of life requiring spinal surgery.[1] According to a meta-analysis by Jensen et al.,[2] the mean prevalence estimates for lumbar spinal stenosis based on clinical diagnoses vary between 11% and 39%. Tomkins-Lane et al.[1] reported that the prevalence of lumbar spinal stenosis is estimated to be 9% in the general population and up to 47% in people >60 years of age.

Spinal stenosis is divided into 3 different entities, central spinal canal stenosis, lateral recess stenosis, and foraminal stenosis, according to the anatomic location of the compression. The onset of pain associated with spinal stenosis includes mechanical/biomechanical, neural, vascular, and inflammatory causes. Hypertrophy of the articular process and yellow ligament and disc herniation are the main reasons for worsening of the clinical symptoms of lumbar stenosis. The extent of stenosis observed in imaging procedures does not have to correlate with the clinical symptoms.[3-5]

Various surgical techniques have been used for the treatment of spinal canal stenosis, including tubular and microsurgical

Key words
- Contralateral
- Disc herniation
- Full-endoscopic
- Interlaminar
- Ipsilateral
- Lateral recess
- Ligamentum flavum
- Lumbar decompression
- Spinal stenosis

Abbreviations and Acronyms
LDH: Lumbar disc herniation
PELD: Percutaneous endoscopic lumbar discectomy

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CLINICAL ARTICLE

Comparison of Interlaminar and Transforaminal Approaches for Treatment of L_5/S_1 Disc Herniation by Percutaneous Endoscopic Discectomy

Aiguo Gao, MD, PhD[1], Huilin Yang, MD, PhD[2], Liyan Zhu, BSc[1], Zhangjie Hu, MSc[1], Binbin Lu, MSc[1], Qi Jin, MSc[1], Ye Wang, MSc[1], Xiaofeng Gu, MD, PhD[1]

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Objective: The aim of this study was to compare the clinical efficacy of percutaneous endoscopic interlaminar discectomy (PEID) and percutaneous endoscopic transforaminal discectomy (PETD) in treating L_5/S_1 disc herniation.

Methods: A retrospective analysis of 76 patients with L_5/S_1 intervertebral disc herniation was performed. There were two surgical treatment groups: one with patients receiving PEID and the other with patients receiving PETD. The two groups were compared by length of surgery, times of intraoperative X-ray exposure, postoperative time in bed, length of hospital stay, operative complications, patient's assessment of pain using a visual analogue scale (VAS), and disability using the Oswestry disability index (ODI) before and after surgery.

Results: Subjects in the PEID group were in surgery for 60.90 ± 13.11 min and needed intraoperative X-ray exposure 4.10 ± 1.09 times. Patients in this group were ambulatory by 7.52 ± 1.08 h after surgery and were hospitalized for 5.05 ± 0.92 days. In contrast, patients in the PETD group were in surgery for 84.06 ± 15.58 min and needed intraoperative X ray exposure 12.81 ± 8.46 times. These patients were ambulatory by 7.06 ± 0.91 h after surgery and remained in the hospital for 4.94 ± 0.80 days. Based on these data, operation time and fluoroscopy time were significantly less ($P < 0.002$ and $P < 0.001$, respectively) for subjects in the PEID group. However, ambulatory time and hospitalization were similar for both in terms of pain relief and decreased disability, and subjects in both groups responded well to the surgery and showed a significant decrease in both VAS and ODI scores at their 1-year follow-up ($P < 0.01$). Furthermore, there were no statistically significant differences between the two surgeries in terms of pain relief and decrease in disability.

Conclusion: For L_5/S_1 disc herniation, PEID and PETD provide similar results for patients. However, PEID has the advantage over PETD in that it is a shorter procedure and exposes the patient to less radiation.

Keywords

Key words: Clinical efficacy; Lumbar disc herniation; Minimally invasive spine surgery; PEID; PETD

Introduction

Lumbar disc herniation (LDH) is a common disease in spine surgery. It has the characteristics of obvious hyperplasia of local tissue, heavy degeneration of intervertebral discs, and long course of disease. The cause of LDH is related to the degenerative changes of different degrees caused by external forces on various parts of the lumbar disc, finally pressing or stimulating the adjacent spinal nerve roots[1,2]. Lumbocrural pain is a common clinical symptom of this disease. Early application of traditional open surgery for LDH has a good curative effect, but the surgical trauma is considerable, postoperative complications are significant, and the

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Technical Considerations of Interlaminar Approach for Lumbar Disc Herniation

Kuo-Tai Chen[1], Chun Tseng[2], Li-Wei Sun[3,4], Kai-Sheng Chang[3], Chien-Min Chen[3,5,6]

With the evolution of endoscopic instruments and techniques, full-endoscopic spine surgery has attracted more attention worldwide in recent years. At the initial stage, surgeons conducted endoscopic lumbar discectomy using the transforaminal approach. Next, interlaminar endoscopic lumbar discectomy was developed to treat a herniation disc at the L5-S1 level. The progression in interlaminar endoscopic techniques has further broadened the indications for full-endoscopic spine surgery. However, the steep learning curve of endoscopic procedures has remained challenging. The use of interlaminar endoscopic lumbar discectomy entails many essential skills to manage the different anatomical structures of the spine. From the perspective of successful and safe interlaminar endoscopic lumbar discectomy, we have discussed the technical considerations for endoscopic procedures.

INTRODUCTION

Full-endoscopic spine surgery (FESS) has evolved continuously, with the progression of instruments and techniques for the past three decades. Recently, increasing evidence has drawn attention to the advancement and benefits of FESS.[1] The early randomized trial from Germany showed that the clinical outcomes of patients who had undergone full-endoscopic lumbar discectomy (FELD) were comparable with the outcomes after conventional microdiscectomy.[2] In addition, FELD has been shown to be superior to microdiscectomy in enhancing postoperative recovery and decreasing complication rates. With the advancement of FESS in Asia, the progression of the endoscopic techniques and instruments has improved the clinical results and applications of FELD. The 2018 comparative meta-analysis in Korea also showed advantages for both clinical outcomes and postoperative recovery.[3] Although the systemic review was mainly retrospective and nonrandomized with small sample size, it suggested that FELD has been well-developed and is a reliable treatment at the current stage.

FELD was initially developed for use with a posterolateral or transforaminal approach.[4,5] However, some limitations exist at the L5-S1 level for the posterolateral corridor, including a high iliac crest, the smallest intertransverse space, and a narrow foramen compared with the other levels cranially.[6,7] Therefore, interlaminar endoscopic lumbar discectomy (IELD) was introduced as an alternative for the challenging situation disc herniation at the L5-S1 level.[8,9] The use of IELD will usually result in one encountering a neural structure before the herniated disc. In contrast, the transforaminal approach will often reach the nerve after removal of the herniation. Thus, IELD demands meticulous techniques to avoid neural complications and recurrence. The learning curve for IELD is flat, and the technique is difficult to master.[10] In the present review, we have elaborated on the technical considerations for IELD at the corresponding anatomical structures.

TECHNICAL CONSIDERATIONS FOR IELD

Local or General Anesthesia

The anesthesia for patients undergoing IELD can be local, regional (epidural), or general.[11] The choice of anesthesia depends on the complexity of the surgery, extent of the root manipulation, and surgeon experience. General anesthesia can allow one to secure the airway when the patient is in the prone position. A complicated procedure such as extensive bone work or

Key words
- Full endoscopic
- Interlaminar
- Lumbar disc herniation
- Lumbar discectomy

Abbreviations and Acronyms
CT: Computed tomography
FELD: Full-endoscopic lumbar discectomy
FESS: Full-endoscopic spine surgery
IELD: Interlaminar endoscopic lumbar discectomy
LF: Ligamentum flavum

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Technical Considerations of the Transforaminal Approach for Lumbar Disk Herniation

Chang Il Ju

Transforaminal full endoscopic lumbar diskectomy (TELD) is a typical minimally invasive surgery, with the associated benefit of decreased possibility of anatomic structural injury, and is an effective alternative to open diskectomy. Among the various endoscopic spinal surgical techniques currently available, TELD is the most basic and traditional surgery that can be performed through the transforaminal route; it has been used for >30 years. Recently, with the advancements in surgical techniques, TELD has been successfully performed for patients with lumbar disk herniation of different types. However, beginner surgeons are unfamiliar with the anatomy of transforaminal endoscopic surgery and this surgery has a steep learning curve to date. If not well prepared, operators may experience complications that require reoperation in the early stages. These complications may include symptomatic incomplete decompression, exiting nerve root injury, dural tearing, and rarely, hematoma, infection, and visceral injury.

Here, we propose several technical guidelines for TELD to increase the possibility of successful lumbar diskectomy and to reduce the incidence of complications. The first step is the accurate anatomic understanding of Kambin triangle and determining the appropriate endoscopic access angle, depending on the type of disk herniation. The second step is to determine a safe and easily accessible entry point and then landing and docking the working sleeve as close to the target as possible without causing exiting nerve root injury. The third step is complete decompression of the symptomatic nerve with free mobilization of the neural tissue. The final step involves performing foraminoplasty using an advanced technique to overcome the limitations associated with TELD in difficult cases.

INTRODUCTION

Transforaminal full endoscopic lumbar diskectomy (TELD) is regarded as a minimally invasive and effective surgical procedure for treating soft disk herniation. The advantage of this surgery is that it preserves most of the anatomic posterior structure while achieving an effect similar to that of conventional open diskectomy.[1-4] Recently, TELD has become more popular due to the rapid evolution in the equipment and techniques used in the procedure.

When this procedure was initially introduced, its basic concept was a method of indirect neural decompression by removal of the central nucleus pulposus. Since then, the focus of decompression has shifted to annular protruding intervertebral disks. As the procedure progressed, the working area, which was limited to the internal disk space, extended into the epidural space and reached the region where the disk material migrated in various directions. In recent years, advancements in this technique have aided in the achievement of nerve decompression by reducing damage to the nucleus pulposus.[5,6]

Many studies have reported the surgical effectiveness of TELD. Various advanced techniques have been introduced that report successful surgical results, even in difficult cases wherein TELD was previously contraindicated.[2,7-9] However, as the use of TELD has become popular, various side effects of, and complications from, this procedure have been reported.[10-13]

This study aimed to provide an understanding of the surgical concept of TELD to minimize the incidence of the associated complications and to provide tips for basic and advanced techniques.

First Step: Anatomy of Kambin Triangle and the Endoscopic Approach Angle

Kambin Triangle (Safety Zone). The Kambin triangle was first described by Dr. Parviz Kambin in 1973; it is an anatomic pathway used to access the endoscopic transforaminal route in various spinal procedures. Described as a right-angled triangular region,

Key words
- Minimal invasive surgery
- Percutaneous endoscopic lumbar diskectomy
- Transforaminal approach

Abbreviations and Acronyms
AP: Anterior posterior
PLL: Posterior longitudinal ligament
SAP: Superior articular process
TELD: Transforaminal full endoscopic lumbar diskectomy

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ORIGINAL RESEARCH

Endoscopic and Microscopic Interlaminar Discectomy for the Treatment of Far-Migrated Lumbar Disc Herniation: A Retrospective Study with a 24-Month Follow-Up

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Purpose: Percutaneous endoscopic lumbar discectomy for the treatment of far-migrated lumbar disc herniation (LDH) is clinically challenging. The aim of this study was to compare the efficacy and safety of interlaminar endoscopic lumbar discectomy (IELD) and interlaminar microscopic lumbar discectomy (IMLD) for the treatment of far-migrated LDH.

Materials and Methods: We retrospectively analyzed 50 consecutive cases of far-migrated LDH treated by IELD or IMLD. Clinical data and outcomes were assessed before the operation and 1 day and 3, 12, and 24 months after the surgery using the visual analog scale (VAS) and Oswestry disability index (ODI). Modified MacNab criteria were used to evaluate patient satisfaction at the 24-month follow-up.

Results: A significant reduction in leg pain and improvement in ODI ($P<0.01$) were observed in both groups after surgery. Lower back pain (LBP) was reduced at 24 months postsurgery in the IELD group ($P<0.05$) but not in the IMLD group ($P>0.05$). There were significant intergroup differences in VAS LBP score at 1 day and 24 months postsurgery ($p=0.01$ and 0.02, respectively) and in ODI at 24 months ($p=0.03$). The rate of excellent or good outcome was 90.32% with IELD and 78.95% with IMLD ($p=0.55$). Hospital stay and time to ambulation were shorter in the IELD group than in the IMLD group, but the former had a longer operative time ($p<0.01$). Low and comparable complication rates were reported in the IELD (16.13%) and IMLD (10.53%) groups ($p=0.70$).

Conclusion: Both IELD and IMLD achieve favorable clinical results in the treatment of far-migrated LDH, with only minor complications. Compared to IMLD, LBP was significantly reduced with IELD presumably because it involved less trauma.

Keywords: minimally invasive spinal surgery, highly migrated lumbar disc herniation, interlaminar approach, downward migration, upward migration

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Introduction

Lumbar disc herniation (LDH) is one of the most common disorders of the lumbar spine,[1] with disc fragment migration occurring in 35%–72% of cases.[2,3] Far-migrated disc herniation (DH) is accompanied by back pain and severe sciatica and can lead to sensory changes and motor weakness.[4] Such cases often respond poorly to conservative treatment and require surgical intervention.[5]

Interlaminar microscopic lumbar discectomy (IMLD), which is considered as the gold standard procedure for the treatment of LDH, involves removal of part of

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ORIGINAL RESEARCH

Clinical Efficacy Study of the Quadrant Channel and Delta Large Channel Technique in the Treatment of Lumbar Degenerative Diseases

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Objective: To compare the therapeutic effect of the quadrant channel and delta large channel techniques in lumbar degenerative diseases.

Methods: According to the inclusion criteria, 62 patients suffering from lumbar degenerative disease were selected for the present study, which was conducted from September 2018 to June 2020. Patients were divided into Group A (quadrant channel technology) and Group B (delta large channel technology), which comprised 28 and 34 patients, respectively. The factors compared between the two groups were operation time, length of incision, blood loss, ambulation time, length of hospitalization, visual analogue scale (VAS) preoperatively, 7 days postoperatively, and 30 days postoperatively, and Oswestry dysfunction score (ODI).

Results: The length of incision, blood loss, ambulation time, and length of hospitalization stay in Group A were significantly higher compared with Group B ($P < 0.05$). There was no significant difference between the two groups in operation time, preoperative ODI index, preoperative VAS scores, and thirty-day postoperative VAS scores ($P > 0.05$). The seven-day postoperative VAS score, seven-day postoperative ODI index, and thirty-day postoperative ODI index of Group A were significantly higher than those of Group B ($P < 0.05$). The preoperative VAS score and ODI index in both groups were significantly higher compared with after operation ($P < 0.05$).

Conclusion: Both surgical methods achieved a good clinical outcome in the treatment of lumbar degenerative diseases. The delta large channel technique may offer some advantages over quadrant channel technology, such as less trauma and bleeding and faster recovery time.

Keywords: quadrant channel, delta large channel technique, lumbar degenerative diseases

Introduction

Lumbar degenerative diseases (LDDs) include lumbar disc herniation, lumbar spinal stenosis, lumbar spondylolisthesis, lumbar scoliosis, and spinal instability. According to the literature, around half the elderly population suffers from LDDs.[1] The method of surgery for treating LDD has gradually changed from traditional open surgery to minimally invasive surgery. In recent years, minimally invasive technology has become a research hotspot in various clinical fields. Percutaneous transforaminal endoscopic discectomy (PTED) was originally conducted as a treatment for lumbar disc herniation. However, given increasing expectations for minimally invasive surgery, PTED is not appropriate for treating all types of lumbar disc herniation and lumbar spinal stenosis. The Interlaminar Endoscopic Surgical System (iLESSYS) has

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Observational Study

Comparison of the Outcomes of Percutaneous Endoscopic Interlaminar Lumbar Discectomy and Open Lumbar Microdiscectomy at the L5-S1 Level

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Background: Although many studies have compared full endoscopic spine surgery and open spine surgery, few have compared the outcomes of percutaneous endoscopic interlaminar lumbar discectomy (PEILD) and open lumbar microdiscectomy (OLM) at the L5-S1 level.

Objectives: We compared the clinical, surgical, and radiological outcomes of patients with disc herniation at the L5-S1 level who underwent either PEILD, or OLM, performed by a single surgeon with novice-level proficiency.

Study Design: Observational, retrospective matched cohort design.

Setting: An analysis of clinical data was performed at a single center, collected from September 2012 to August 2016.

Methods: The study enrolled 56 patients who underwent discectomy at the L5-S1 level, with a minimum one-year follow-up. Patients were allocated to 2 groups: a PEILD group (n = 27; September 2014 to August 2016), or an OLM group (n = 29; September 2012 to August 2014). Clinical, surgical, and radiological outcomes were retrospectively evaluated.

Results: Baseline characteristics including age, gender, past medical history, body mass index, preoperative symptom, and preoperative radiological findings did not differ significantly between the groups. Further, overall clinical outcomes including back and leg pain; surgical outcomes including blood loss, complication rate, and recurrence rate; and radiological outcomes including degree of decompression, disc height, and sagittal alignment were not different significantly between the 2 groups.

However, the PEILD group showed significant advantages including lower immediate postoperative back pain (mean 1.44 [95% confidence interval (CI), 1.16-1.72] versus 2.41 [95% CI, 2.14-2.69], $P < 0.001$), favorable immediate postoperative Odom's criteria (excellent 57.14% versus 24.14%, $P = 0.025$), shorter operation time (mean 63.89 ±17.99 minutes versus 109.66 ±31.42 minutes, $P < 0.001$), shorter hospital stay (3.15 [95% CI, 2.21-4.09] days versus 5.72 [95% CI, 3.29-8.16] days, $P < 0.001$), and rapid return to work (15.67 [95% CI, 12.64-18.69] days versus 24.31 [95% CI ,19.97-28.65] days, $P = 0.001$).

Limitation: Due to its retrospective nature, it was not possible to control for all variations. Moreover, the number of patients in the final cohort was relatively small.

Conclusions: Our findings indicate that the PEILD group achieved better perioperative outcomes despite no significant intergroup difference in mid-term clinical and radiological outcomes.

Key words: Complication, discectomy, full endoscopic surgery, lumbar disc herniation, lumbar spine, microscopic surgery, outcome, recurrence

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ORIGINAL RESEARCH

Clinical Comparison of Full-Endoscopic and Microscopic Unilateral Laminotomy for Bilateral Decompression in the Treatment of Elderly Lumbar Spinal stenosis: A Retrospective Study with 12-Month Follow-Up

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Purpose: Although lumbar spinal stenosis (LSS) is the most common spinal disease in the elderly, there is still a confusion about the appropriate surgical treatment strategy. The aim of this study was to compare the safety and efficacy of full-endoscopic and microscopic unilateral laminotomy for bilateral decompression (ULBD) for LSS in elderly patients.

Patients and Methods: A retrospective analysis of 61 consecutive elderly patients with LSS who underwent either full-endoscopic (FE group) or microscopic (Micro group) unilateral laminotomy for bilateral decompression was performed. Clinical data were assessed before 2 weeks, 3 months, 6 months and 12 months after surgery using the Visual Analog Scale (VAS), the Oswestry Disability Index (ODI) and the modified MacNab criteria.

Results: There are no significant differences in VAS (back and leg) and ODI between the two groups. However, the VAS back pain in the FE group was significantly improved compared to the Micro group at 2 weeks. The rate of excellent or good outcomes was 87.88% and 85.71% in the FE and Micro group, respectively (P>0.05). The hospital stay and early ambulation in FE group were shorter than those in Micro group, but the operation time was longer (P<0.05). The complications between the FE group (18.18%) and the Micro group (17.86%) were minor (P>0.05).

Conclusion: Both full-endoscopic and microscopic decompression have achieved favorable clinical results in treating elderly lumbar spinal stenosis, and the complications are minor. Full-endoscopic decompression has the advantages of small incision and rapid recovery, which can be used as an alternative for the treatment of lumbar spinal stenosis, especially the elderly with comorbidities.

Keywords: central stenosis, minimally invasive spinal surgery, MISS, comorbidity, complication

Introduction

With the increase of the elderly population and the prolongation of life expectancy, the prevalence of lumbar degenerative diseases, especially lumbar spinal stenosis, has increased significantly.[1] Lumbar spinal stenosis usually begins with degeneration of the intervertebral disc and surrounding tissues, resulting in spinal canal narrowing and nerve compression, which is a common cause of low back and leg

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Minimum 2-Year Efficacy of Percutaneous Endoscopic Lumbar Discectomy versus Microendoscopic Discectomy: A Meta-Analysis

Jietao Xu, Yawei Li, Bing Wang, Guohua Lv, Lei Li, Yuliang Dai, Bin Jiang, Zhenzhong Zheng

Key words
- Lumbar disc herniation
- Meta-analysis
- Microendoscopic discectomy
- Percutaneous endoscopic lumbar discectomy

Abbreviations and Acronyms
CI: Confidence interval
LBP: Low back pain
LDH: Lumbar disc herniation
MED: Microendoscopic discectomy
NOS: Newcastle-Ottawa Scale
ODI: Oswestry Disability Index
OR: Odds ratio
PELD: Percutaneous endoscopic lumbar discectomy
VAS: Visual analog scale

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BACKGROUND: **Minimally invasive surgery in the treatment of lumbar disc herniation has gained popularity in recent years, as 2 dominant techniques, percutaneous endoscopic lumbar discectomy (PELD) and microendoscopic discectomy (MED) obtained comparable short-term clinical outcomes. However, midterm and long-term efficacy and reoperative rate are still debated.**

METHODS: **Electronic databases Web of Science, PubMed, Scopus, Cochrane Library, EMBASE, Ovid, and EBSCO were searched. STATA 14.0 was used for statistical analysis. Odds ratio (OR) and 95% confidence interval (CI) were pooled to quantify the strength of the statistical differences.**

RESULTS: **Nine studies (468 patients in the PELD group and 516 patients in the MED group) with high methodologic quality met the selection criteria. No differences were found in leg pain visual analog scale score before surgery or at any follow-up time after surgery. PELD obtained better outcomes in low back pain visual analog scale score, Oswestry Disability Index score, and excellent and good ratio after 24 months postoperatively (OR = −0.856, 95% CI −1.488 to −0.224, $P = 0.008$; OR = −0.425, 95% CI −0.724 to −0.127, $P = 0.005$; OR = 3.034; 95% CI 1.254 to 7.343; $P = 0.014$) compared with MED. No difference was found within 24 months postoperatively. No significant differences were found in complication, recurrence, and reoperation rates within and after 2 years postoperatively.**

CONCLUSIONS: **Both PELD and MED can offer relatively effective and safe treatment for low back pain and radiculopathy associated with a herniated disc. PELD could obtain better midterm and long-term clinical outcomes compared with MED.**

INTRODUCTION

Lumbar disc herniation (LDH) is one of the most common causes of low back pain (LBP) with or without pain and numbness of lower extremities. The previously reported incidence rate of LDH was 20%–35% among adults >50 years old.[1-3] Although most patients with LDH achieved pain relief with conservative treatment such as physical therapy and pharmaceutical treatment, nearly 40%–60% of patients still need surgical intervention.[4]

With the concept of broad operative view, less trauma, and rapid recovery, microendoscopic discectomy (MED) was first described in 1997 by Smith and Foley[5] and subsequently became widely used for the treatment of LDH via endoscopy and minimally invasive transmuscular approach.[6,7] In recent years, percutaneous endoscopic lumbar discectomy (PELD) has become increasingly popular for the treatment of LDH. Previous studies have reported short-term clinical outcomes of PELD comparable to conventional surgical technique and MED, indicating this is an alternative technique for LBP and radicular pain based on its advantages of minimal invasiveness, local anesthesia, and rapid recovery.[8-12] However, midterm and long-term efficacy and reoperative rate are still debated because of the relatively higher rate of early recurrence and steep learning curve of PELD.[13-21] Moreover, no meta-analysis to our knowledge has evaluated the minimum 2-year efficacy of PELD and MED.[17-19,22,23] Therefore, the aim of this study was to evaluate the midterm and long-term efficacy of PELD versus MED systematically and update the included studies to avoid being confounded by the different follow-up times to determine the superiority of PELD versus MED in the treatment of LDH.

MATERIALS AND METHODS

Search Strategy

Nine articles were extracted by searching the electronic databases Web of Science, PubMed, Scopus, Cochrane Library, EMBASE, Ovid, and EBSCO. The search terms and commonly used synonyms and abbreviations were "percutaneous endoscopic lumbar discectomy/PELD" or "percutaneous transforaminal endoscopic

Clinical outcomes of MED and iLESSYS® Delta for the treatment of lumbar central spinal stenosis and lateral recess stenosis: A comparison study

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Abstract. Microendoscopic discectomy (MED) is an established procedure used to treat lumbar central spinal stenosis (LCSS) and lateral recess stenosis (LRS). The Interlaminar Endoscopic Surgical System iLESSYS® Delta approach has been developed from the traditional interlaminar endoscopic technique for the treatment of LCSS and LRS. In the present study, MED was used as a reference to evaluate this newly developed approach. A total of 82 and 52 patients with radicular leg pain and/or neurogenic claudication symptoms were treated by spinal canal decompression using the MED or iLESSYS® Delta approach, respectively. The clinical outcomes of the patients were analyzed using the Modified MacNab's criteria, visual analogue scale (VAS) leg pain score, VAS back pain score and the Oswestry Disability Index (ODI) score. Finally, the effectiveness of the decompression was evaluated on a cross-sectional area of the dural sac (CSAD) at the disc level. The incision length in the iLESSYS® Delta group was significantly decreased compared with the MED group ($P<0.05$); however, the duration of the operation in the iLESSYS® Delta group was significantly longer compared with the MED group ($P<0.05$). The VAS score of the back and ODI score in the iLESSYS® Delta group were significantly decreased compared with the MED group at the 1-week follow-up ($P<0.0125$). The postoperative CSAD was also significantly increased in both groups compared with before the operation ($P<0.05$); however, there were no significant differences in the postoperative CSAD between the two groups. The good-to-excellent rates of the MED and iLESSYS® Delta approach were 89.0 and 90.4%, respectively, whereas the complication rates of the MED and iLESSYS® Delta system were 3.66 and 3.85% in the two groups, respectively. In conclusion, the iLESSYS® Delta approach was identified to be comparable with the MED approach for treating LCSS and LRS, demonstrating both precise and limited decompression. In addition, the iLESSYS® Delta approach may reduce the short-term back pain and promote faster recovery compared with the MED.

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Key words: microendoscopic discectomy, interlaminar endoscopic surgical system, lumbar central spinal stenosis, lumbar lateral recess stenosis

Introduction

Lumbar spinal stenosis (LSS) is a common degenerative disease that is prevalent among the elderly population. LSS can be divided into lumbar central spinal stenosis (LCSS), lateral recess stenosis (LRS) and foraminal stenosis; LCSS is commonly combined with LRS (1). The pathogenesis behind LCSS and LRS was discovered to be responsible for compression of the dural sac and nerve roots, which are directly caused by disc herniation (DH), hypertrophic ligamentum flavum (LF) and hypertrophic facet joint (2,3). The main aim of surgical treatment in LCSS and LRS is to decompress the nerve roots and relieve the symptoms (4). As a consequence, the majority of patients who suffer from LCSS and LRS will undergo surgery if traditional treatment regimens fail to relieve the neurological symptoms (5).

Traditional open surgery encompasses fenestration, semi-laminectomy and total laminectomy; however, although these traditional surgical methods can improve the neurological symptoms, surgery is often associated with postoperative complications, especially in elderly populations with comorbidities (6,7). Compared with traditional surgical procedures, minimally invasive spinal surgery (MISS) has been observed to minimize iatrogenic traumatization, promote recovery and preserve the segmental stability (8,9). Notably, following the development of medical instruments, complicated degenerative neurological disorders such as LSS have also been successfully treated using MISS (6). Microendoscopic discectomy (MED) is one of the MISS procedures that is used to treat LSS (10-12).

The Endoscopic Trans-Superior Articular Process Approach: A Novel Minimally Invasive Surgical Corridor to the Lateral Recess

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BACKGROUND: Transforaminal approaches to the lumbar spine are typically performed utilizing Kambin's triangle as approach corridor; however, degenerative changes can distort anatomy and expose the exiting nerve root to inadvertent injury.

OBJECTIVE: To describe the surgical technique of a novel full-endoscopic approach to access the lateral recess and report clinical outcomes.

METHODS: The trans-superior articular process (SAP) approach involves partial resection of the SAP, allowing access to the lateral recess both ventral and dorsal to the traversing nerve root. A retrospective review of 40 patients who had undergone a trans-SAP approach for decompression of lateral recess pathology was conducted. Outcomes were measured using visual analog scores (VAS) and Oswestry Disability Index (ODI) at 2 wk, 3 mo, and at last follow-up.

RESULTS: At a mean follow-up of 24 mo, patients experienced statistically significant improvement of the VAS for ipsilateral leg pain, VAS for back pain, and ODI when comparing preoperative values to all postoperative time points. The percentage of patients reaching a minimally clinically important difference for VAS leg pain and ODI was approximately 90% and 88%, respectively. The complication profile was favorable with no dural tears and no postoperative motor or sensory deficits. One patient required revision, with a total reoperation rate of 3%.

CONCLUSION: The trans-SAP approach is a novel approach that utilizes a safe surgical corridor via the SAP to access lateral recess pathology. Our initial clinical experience suggests that the trans-SAP approach allows for treatment of lateral recess and foraminal pathology with low complication rates.

KEY WORDS: Endoscopic, Spine, Surgery, Transforaminal approach, Minimally invasive, Superior articular process

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Working-channel endoscopes have propelled the evolution of minimally invasive surgical access to the spinal column. Advances in optics, illumination, and high-definition camera technique of full-endoscopic spine surgery have contributed to the steady increase in popularity, particularly in Europe and Asia. There is mounting evidence[1-7] that endoscopic lumbar decompression results in functional outcome equivalent to microsurgical or tubular techniques with shorter duration of hospitalization,[8] less collateral tissue damage,[9,10] and reduced systemic inflammatory stress.[11,12] With the development of reliable and safe anatomy-based surgical technique, innovations in surgical tools and focus on training programs indications for full-endoscopic spine surgery have been expanded to the cervical[11,13] and thoracic spine.[14] The primary barriers to wider adoption of this technology are the technological learning curve associated with precise targeting of pathology, lack of standardization in surgical technique, and the 2-dimensional distortion of magnified spinal anatomy.[15-17]

ABBREVIATIONS: AP, anteroposterior; **CT,** computed tomography; **MCID,** minimally clinically important difference; **MRI,** magnetic resonance imaging; **ODI,** Oswestry Disability Index; **SAP,** superior articular process; **SEM,** standard error of the mean; **VAS,** visual analog score

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JNS SPINE

CLINICAL ARTICLE

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Comparison of clinical outcomes following minimally invasive or lumbar endoscopic unilateral laminotomy for bilateral decompression

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OBJECTIVE Minimally invasive lumbar unilateral tubular laminotomy for bilateral decompression has gradually gained acceptance as a less destabilizing but efficacious and safe alternative to traditional open decompression techniques. The authors have further advanced the principles of minimally invasive surgery (MIS) by utilizing working-channel endoscope–based techniques. Full-endoscopic technique allows for high-resolution off-axis visualization of neural structures within the lateral recess, thereby minimizing the need for facet joint resection. The relative efficacy and safety of MIS and full-endoscopic techniques have not been directly compared.

METHODS A retrospective analysis of 95 consecutive patients undergoing either MIS (n = 45) or endoscopic (n = 50) unilateral laminotomies for bilateral decompression in cases of lumbar spinal stenosis was performed. Patient demographics, operative details, clinical outcomes, and complications were reviewed.

RESULTS The patient cohort consisted of 41 female and 54 male patients whose average age was 62 years. Half of the patients had single-level, one-third had 2-level, and the remaining patients had 3- or 4-level procedures. The surgical time for endoscopic technique was significantly longer per level compared to MIS (161.8 ± 6.8 minutes vs 99.3 ± 4.6 minutes; $p < 0.001$). Hospital stay for MIS patients was on average 2.4 ± 0.5 days compared to 0.7 ± 0.1 days for endoscopic patients ($p = 0.001$). At the 1-year follow-up, endoscopic patients had a significantly lower visual analog scale score for leg pain than MIS patients (1.3 ± 0.3 vs 3.0 ± 0.5; $p < 0.01$). Moreover, the back pain disability index score was significantly lower in the endoscopic cohort than in the MIS cohort (20.7 ± 3.4 vs 35.9 ± 4.1; $p < 0.01$). Two patients in the MIS group (epidural hematoma) and one patient in the endoscopic group (disc herniation) required a return to the operating room acutely after surgery (< 14 days).

CONCLUSIONS Lumbar endoscopic unilateral laminotomy for bilateral decompression is a safe and effective surgical procedure with favorable complication profile and patient outcomes.

https://thejns.org/doi/abs/10.3171/2018.9.SPINE18689

KEYWORDS full-endoscopic spine surgery; stenosis; radiculopathy; minimally invasive spine surgery; MIS; unilateral laminotomy for bilateral decompression; lumbar

Lumbar spinal stenosis is characterized by narrowing of the spinal canal from hypertrophic degenerative changes of surrounding soft and bony tissues.[1,9,10,25,27] Given the degenerative nature of these changes, it follows that they are seen at a high rate in older patients, and indeed the LAIDBACK study found that patients 65 years and older had a 100% rate of disc degeneration, 38% rate of facet arthropathy, and 21% rate of moderate to severe central stenosis.[22,35] These degenerative changes and the concomitant compression of neural elements may manifest as axial low-back and/or radicular leg pain; symptoms are exacerbated by standing and walking and are commonly referred to as neurogenic claudication. Lumbar spinal stenosis represents the primary indication for spine surgery in patients older than 65 years, with over 37,000 patients in this population undergoing operative intervention in 2007.[9,10,36]

Open laminectomy for spinal stenosis has been shown to be a safe and cost-effective procedure, with superior outcomes compared to nonsurgical management.[3,4,28,31,32]

ABBREVIATIONS AP = anteroposterior; BMI = body mass index; MCID = minimally clinically important difference; MIS = minimally invasive surgery; ODI = Oswestry Disability Index; SAP = superior articular process; ULBD = unilateral laminotomy for bilateral decompression; VAS = visual analog scale.

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NEUROSURGICAL FOCUS

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Comparison of full-endoscopic and minimally invasive decompression for lumbar spinal stenosis in the setting of degenerative scoliosis and spondylolisthesis

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OBJECTIVE The management of lumbar spinal stenosis (LSS) with concurrent scoliosis and/or spondylolisthesis remains controversial. Full-endoscopic unilateral laminotomy for bilateral decompression (ULBD) facilitates neural decompression while preserving stabilizing osseoligamentous structures and may be uniquely suited for the treatment of LSS with concurrent mild to moderate degenerative deformity. The safety and efficacy of full-endoscopic versus minimally invasive surgery (MIS) ULBD in this patient population is studied here for the first time.

METHODS A retrospective analysis of prospectively collected data was conducted on 45 consecutive LSS patients with concurrent scoliosis (≥ 10° coronal Cobb angle) and/or spondylolisthesis (≥ 3 mm). Patient demographics, operative details, complications, and imaging characteristics were reviewed. Outcomes were quantified using back and leg visual analog scale (VAS) scores and the Oswestry Disability Index (ODI) at 2 weeks, 3 months, and 1 year.

RESULTS A total of 26 patients underwent full-endoscopic and 19 underwent MIS-ULBD with an average follow-up period of 12 months. The endoscopic cohort experienced a significantly shorter hospital length of stay ($p = 0.014$) and fewer adverse events ($p = 0.010$). Both cohorts experienced significant improvements in VAS and ODI scores at all time points ($p < 0.001$), but the endoscopic cohort demonstrated significantly better early ODI scores ($p = 0.024$).

CONCLUSIONS Endoscopic and MIS-ULBD result in similar functional outcomes for LSS with mild to moderate deformity, while the endoscopic approach demonstrates a favorable rate of complications. Further studies are required to better delineate the characteristics of spinal deformities amenable to this approach and the durability of functional results.

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KEYWORDS endoscopic spine surgery; stenosis; radiculopathy; minimally invasive spine surgery; MIS; scoliosis; unilateral laminotomy for bilateral decompression; ULBD

Lumbar spinal stenosis (LSS) represents the most common indication for spine surgery in patients older than 65 years, with its prevalence expected to rise 59% to 64 million elderly adults by the year 2025.[13,15,16,50] While the treatment of patients with LSS without existing deformity or instability is primarily a decompressive procedure, there is a large subset of patients who have coexisting spondylolisthesis and/or degenerative deformity; the optimal treatment for these patients remains controversial.

The incidence and prevalence of degenerative scoliosis affecting adults has been reported variably, with curves greater than 10° present in more than 50% of elderly females with back pain and osteoporosis and a new onset of deformity observed in over 30% of elderly patients.[7,32,43] A population-based study using the National (Nationwide) Inpatient Sample database found that 82.7% of patients with LSS with coexisting spondylolisthesis and 67.6% of patients with coexisting scoliosis underwent a fusion procedure, while only 26.2% of patients with LSS without instability underwent a fusion procedure.[4]

Treatment options depend largely on patient factors and clinical presentation; patients with severe back pain and disability from significant sagittal or coronal imbalance are unlikely to benefit from a minimalist decompressive approach given the underlying structural problem. Patients whose symptoms are predominantly radiculopathy may be

ABBREVIATIONS ASA = American Society of Anesthesiologists; LE = lumbar endoscopic; LSS = lumbar spinal stenosis; MCID = minimally clinically important difference; MIS = minimally invasive surgery; ODI = Oswestry Disability Index; PI-LL = pelvic incidence–lumbar lordosis; ULBD = unilateral laminotomy for bilateral decompression; VAS = visual analog scale.

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Case Report

Contralateral facet-sparing sublaminar endoscopic foraminotomy for the treatment of lumbar lateral recess stenosis: technical note

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Lumbar lateral recess stenosis that results from a degenerative bulging of the disc and overgrowth of the facet is a very common cause for lumbar radiculopathy in the elderly. The standard surgical treatment for symptomatic lumbar lateral recess stenosis often requires a laminectomy or hemi-laminectomy and medial facetectomy which can further destabilize a pathological motion segment. The authors present here a novel technique for contralateral endoscopic access to the lateral recess pathology that is truly minimally invasive and spares most of the facet joint complex: 6 patient cases are described where lateral recess stenosis pathology was accessed from a contralateral sublaminar endoscopic approach.

Keywords: Endoscopic spine surgery; minimally-invasive; transforaminal; contralateral sublaminar decompression; spinal stenosis

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Introduction

Traditional open and minimally invasive posterior approaches to surgically treating lateral recess stenosis entail performing a modest laminotomy or laminectomy with removal of a portion of the medal facet joint in order to decompress the traversing, and sometime exiting nerve root. The risk with this approach is in further destabilizing the already degenerative facet joint complex. Transforaminal endoscopic decompression of lateral recess stenosis attempts to avoid destabilizing the facet complex, but the procedure can be a challenge even for the most experienced of endoscopic spine surgeons. Accessing the medial lateral recess pathology, hypertrophied ligamentum flavum and hypertrophied facet bone, from an ipsilateral transforaminal approach will often require tedious and time-consuming endoscopic drilling to adequately remove the compressive pathology. A posterior endoscopic approach is a more minimally invasive version of the microscopic or microendoscopic approach which involves a direct posterior decompression of the medial portion of the top of the IAP-SAP complex down to the bottom of the IAP-SAP complex until the traversing nerve root is decompressed. Here the authors describe a more direct percutaneous targeting of the lateral recess pathology from a contralateral interspinous, sublaminar approach that directly targets that compressive lateral recess pathology and spares most of the facet joint complex.

Clinical series (***Figures 1-3***)

In this small clinical series, patients treated were symptomatic from lumbar lateral recess stenosis as evidenced by their MR studies (*Figure 1A,B* and *Figure 2A,B*), clinical presentation and physical exam. Each patient had previously undergone physical therapy and interventional pain management prior to considering surgery. Contralateral sublaminar endoscopic decompressions were performed in 4 male and 2 female patients. *Table 1* lists the patient demographics and outcomes. Patient ages were between

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Technical Note

Foraminoplastic Superior Vertebral Notch Approach with Reamers in Percutaneous Endoscopic Lumbar Discectomy : Technical Note and Clinical Outcome in Limited Indications of Percutaneous Endoscopic Lumbar Discectomy

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To describe the details of the foraminoplastic superior vertebral notch approach (FSVNA) with reamers in percutaneous endoscopic lumbar discectomy (PELD) and to demonstrate the clinical outcomes in limited indications of PELD. Retrospective data were collected from 64 patients who underwent PELD with FSVNA from August 2012 to April 2014. Inclusion criteria were high grade migrated disc, high canal compromised disc, and disc protrusion combined with foraminal stenosis. The clinical outcomes were assessed using by the visual analogue scale (VAS), Oswestry Disability Index (ODI) and modified MacNab criteria. Complications related to the surgery were reviewed. The procedure used a unique approach, using the superior vertebral notch as the target and performing foraminoplasty with only reamers under C-arm control. The mean age of the 55 female and 32 male patients was 52.73 years. The mean F/U period was 12.2±4.2 months. Preoperative VAS (8.24±1.25) and ODI (67.8±15.4) score improved significantly at the last follow-up (VAS, 1.93±1.78; ODI, 17.14±15.7). Based on the modified MacNab criteria, excellent or good results were obtained in 95.3% of the patients. Postoperative transient dysthesia (n=2) and reoperation (n=1) due to recurred disc were reported. PELD with FSVNA could be a good method for treating lumbar disc herniation. This procedure may offer safe and efficacious results, especially in the relatively limited indications for PELD.

Key Words : Percutaneous endoscopic · Foraminoplasty · Superior vertebral notch.

INTRODUCTION

Percutaneous endoscopic lumbar discectomy (PELD) is one option to treat herniated lumbar disc disease. Regardless of many merits, such as less tissue trauma and shorter hospital stay, some cases like high migrated disc protrusion, high canal compromised disc, or foraminal stenosis have not been considered optimal indications for the endoscopic procedure[16,18]. Approach-related complications, like postoperative dysthesia and motor weakness due to upper root injury are of concern to performing PELD. To overcome these limitations and prevent unfavorable complications in PELD, various other approaches and techniques have been developed[4,8,19,22]. Some authors have described the endoscopic foraminoplasty technique by using a drill, reamer, or laser in performing PELD[2,5,7,11,12,19,24,29]. But, there are few reports extensively detailing the method of foraminoplasty. We describe the details of a unique percutaneous endoscopic superior vertebral notch approach performed with the foraminoplastic technique using reamers under C-arm control, and demonstrate the clinical results and efficacy in limited indications of PELD.

MATERIALS AND METHODS

Patients population and outcome evaluation

A retrospective review was performed on 589 patients who had undergone percutaneous endoscopic lumbar discectomy with foraminoplasty using the superior vertebral notch approach between August 2012 and April 2014 at single center. Among those patients, 64 patients were selected for this study. Inclusion criteria were patients who were preoperatively diagnosed with high

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Efficacy of Transforaminal Endoscopic Spine System (TESSYS) Technique in Treating Lumbar Disc Herniation

Authors' Contribution:
Study Design A
Data Collection B
Statistical Analysis C
Data Interpretation D
Manuscript Preparation E
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Background: To compare efficacy and safety of percutaneous transforaminal endoscopic spine system (TESSYS) and traditional fenestration discectomy (FD) in treatment of lumbar disc herniation (LDH).

Material/Methods: A total of 106 LDH patients were divided into TESSYS group (n=48) and FD group (n=58). Visual analogue scale (VAS), Oswestry disability index (ODI), Japanese Orthopedic Association (JOA), and modified MacNab criteria were used for efficacy evaluation. Post-operative responses were compared by enzyme-linked immunosorbent assay (ELISA) based on detection of serum IL-6, CRP, and CPK levels.

Results: In the TESSYS group, compared with the FD group, we observed, shorter incision length, less blood loss, shorter hospital stay, lower hospitalization cost, shorter recovery time, lower complication rate (all $P<0.001$), and lower VAS scores of lumbago and skelalgia at 3 days and 1, 3, and 6 months postoperatively (all $P<0.05$). At 24 and 48 h postoperatively, CRP level was remarkably higher in the FD group compared to the TESSYS group ($P<0.001$). Further, comparison of IL-6 levels at 6, 12, 24, and 48 h postoperatively revealed significantly higher levels in the FD group than in the FESSYS group (all $P<0.001$).

Conclusions: TESSYS had clinical advantages over FD and entails less trauma and quicker postoperative recovery, suggesting that TESSYS is well tolerated by patients and is a better approach than FD in surgical treatment of LDH.

MeSH Keywords: Dienestrol • Manipulation, Orthopedic • Osteoarthritis, Spine • Pain Measurement

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ENDOSCOPIC ONCOLOGICAL SURGERY

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The Role of the Endoscope in Spinal Oncology: A Systematic Review of Applications and Systematic Analysis of Patient Outcomes

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Key words
- Endoscopic spine surgery
- Spinal oncology
- Transforaminal approach

Abbreviations and Acronyms
EBL: Estimated blood loss
FES: Full-endoscopic spinal surgery
FESS: Full-endoscopic separation surgery
LOS: Length of stay
MIS: Minimally invasive surgical
VAS: Visual analog scale

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INTRODUCTION: **Surgical techniques to treat tumors of the spine often require extensive tissue dissection and bony removal, predisposing patients to elevated risk for perioperative morbidity and mortality. When indicated, minimally invasive surgical techniques may be preferred as they result in less collateral damage and quicker recovery times. Full endoscopic spine surgery (FES) represents an ultra-minimally invasive approach that further minimizes tissue damage. The advantages to the application of FES to treat spinal tumors remain unclear.**

METHODS: **Electronic databases were systematically searched for published literature on the application of FES in spinal oncology to assess its utility, safety, and outcomes via Nurick, McCormick, and Frankel grades, visual analog scale, complication rate, duration of surgery, estimated blood loss, length of stay, and mean follow-up.**

RESULTS: **Fifteen articles describing 72 patients met inclusion criteria. The most common approach was the interlaminar approach (40.98%). The most common spinal level was lumbar (38.89%). The most common goal of surgery was gross total resection (82.11%). The average Nurick grade decreased from 2.96 to 0.67. All patients showed an improvement from Frankel grade C or D to grade E except for one. The average visual analog scale score decreased from 9.3 to 1.3. The complication rate was 6.56%. The average length of stay was 55.2 hours. The average estimated blood loss was 49 mL. The average duration of surgery was 121.26 minutes. The mean follow-up was 10.58 months.**

CONCLUSION: **The utility of FES in spinal oncology is not well understood. Literature results of this technique show promise. Further study is needed to draw definitive conclusions on FES efficacy and safety in spinal oncology.**

INTRODUCTION

Tumors of the spinal cord and spinal column often require surgical intervention with several goals in mind: to preserve neurologic function, facilitate local tumor control, treat pain, and/or treat mechanical instability. Primary spinal tumors are relatively rare, making up only 2%–4% of all central nervous system neoplasms.[1] Metastatic spinal tumors are seen in 20% of patients with cancer, and approximately 20% of these patients will require surgical intervention (approximately 150,000/year in the United States). Current surgical techniques may require extensive tissue dissection, bony removal, and staged procedures with multiple surgical incisions and the involvement of various surgical disciplines. These approaches can lead to high blood loss,[2] prolonged operative times, and elevated risk for perioperative morbidity and mortality, particularly in patients with multiple comorbidities and high presurgical risk.

Minimally invasive surgical (MIS) techniques can be considered in patients with poor surgical candidacy who require surgical intervention. The literature suggests that MIS approaches can result in less collateral damage, leading to faster recovery times, shorter hospitalizations, lower blood loss, and fewer wound complications.[3-6] Full endoscopic spinal surgery (FES) represents an ultra-minimally invasive approach that further minimizes tissue damage and has the potential to accelerate recovery when compared with traditional minimally invasive techniques.[7,8] The application of FES to spinal oncology has been described in several small reports and case series, but the safety and efficacy of FES in this application is poorly defined.

The objective of this study is to review the published literature describing the use of FES in spinal oncology to better understand the utility, safety, efficacy, and outcomes of FES in patients with spinal tumors.

METHODS

This review was conducted and subsequently reported according to the Preferred Reporting Items for Systematic

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Endoscopic Techniques for Spinal Oncology: A Systematic Literature Review

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ABSTRACT

Background: Due to its ultraminimally invasive nature, endoscopic spinal surgery is an attractive tool in spinal oncologic care. To date, there has been no comprehensive review of this topic. The authors therefore present a thorough search of the medical literature on endoscopic techniques for spinal oncology.

Methods: A systematic review using PubMed was conducted using the following keywords: endoscopic spine surgery, spinal oncology, and spinal tumors.

Results: Collectively, 19 cases described endoscopic spine surgery for spinal oncologic care. Endoscopic spine surgery has been employed for the care of patients with spinal tumors under the following 4 circumstances: (1) to obtain a reliable tissue diagnosis; (2) to serve as an adjunct during traditional open surgery; (3) to achieve targeted debulking; or (4) to perform definitive resection. These cases employing endoscopic techniques highlight the versatility of this approach and its utility when applied to the right patient and with an experienced surgeon.

Conclusions: Our systematic review suggests that, given the right patient and an experienced surgeon, endoscopic spine surgery should be considered in the armamentarium for spinal oncologic care for both staging and definitive resection.

Clinical Relevance: This systematic literature review showed that endoscopic techniques have been successfully applied across the spectrum of care in spinal oncology, from diagnosis to definitive treatment.

Endoscopic Minimally Invasive Surgery

Keywords: endoscopic decompression, metastatic lesion, oncologic spine care

INTRODUCTION

Tumors of the spinal column demand essential consideration within the broader oncologic disease landscape. First, tumors of the spinal column are prevalent among patients with cancer. It is estimated that 60% to 70% of patients with metastatic cancer have a metastatic disease burden to the spinal column.[1–4] Second, spinal column tumors can be incredibly debilitating. Roughly 64% of patients with spinal bone metastasis have motor dysfunction, and 90% have back pain.[5] Finally, although life expectancy is increasing for patients with tumors of the spinal column, these patients overall tend to have a limited prognosis.[1,6] Thus, any surgical solution that can offer practical and clinically efficacious care with a short recovery period would be desirable.

Historically, open surgery for spinal tumors has been limited by the overall frailty of this patient population and the considerable recovery period required following such surgeries. Endoscopic spine surgery can potentially circumvent these challenges due to its ultra–minimally invasive nature that allows for less intensive anesthesia, reduced operative time, minimal tissue and bony disruption, less blood loss, and shorter hospital length of stay and recovery. In this context, endoscopic spine surgery represents a promising tool in spinal oncologic care.[7–13] However, despite the promise of endoscopic spine surgery for spinal oncologic care, to our knowledge, there has been no comprehensive review on this topic. Therefore, the present article summarizes and discusses published literature on endoscopic spinal oncologic care. Points of discussion will include indications, outcomes, challenges, and the key elements of a learning curve to be considered when integrating endoscopic protocols into an ongoing oncologic spine care program.

METHODS

A PubMed search was conducted in January 2022 for articles published in the English language between 1990 and 2021 using the following keywords: endoscopic

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The History of Neurosurgical Spinal Oncology: From Inception to Modern-Day Practices

Miriam M. Shao, Sebastian Rubino, Darryl J. DiRisio, John W. German

Key words
- Endoscopy
- Minimally invasive spine surgery
- Spinal oncology
- Spinal tumors
- Stereotactic radiosurgery

Abbreviations and Acronyms
CT: Computed tomography
FDA: Food and Drug Administration
MR: Magnetic resonance
MRI: Magnetic resonance imaging
SLITT: Spinal laser interstitial thermal therapy
SRS: Stereotactic radiosurgery

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The neurosurgical management of spinal neoplasms has undergone immense development in parallel with advancements made in general spine surgery. Laminectomies were performed as the first surgical procedures used to treat spinal neoplasms. Since then, neurosurgical spinal oncology has started to incorporate techniques that have developed from recent advances in minimally invasive spine surgery. Neurosurgery has also integrated radiotherapy into the treatment of spine tumors. In this historical vignette, we present a vast timeline spanning from the Byzantine period to the current day and recount the major advancements in the management of spinal neoplasms.

INTRODUCTION

Paul of Aegina (c. 625—c. 690), of the Byzantine Empire, performed one of the earliest recorded spine surgeries and deviated from Hippocrates' previously accepted principle that surgical operation of the spine would be disastrous for the patient and should be avoided.[1] Paul of Aegina performed laminectomies for trauma and wrote that spinous process fractures could "readily be felt upon examination with the finger" and could be treated with "an incision of the skin externally" to extract the bone fragment.[2] Alban Smith was the next surgeon to successfully perform a laminectomy, in 1829. His patient had fallen from a horse 2 years earlier and had sustained a low cervical spinal cord injury. Smith removed the lamina with a saw and intraoperatively observed bone fragments compressing the spinal cord. A week after the laminectomy, the patient reported improvements in hand and thigh sensation.[3]

First Spinal Tumor Resection

The first laminectomy for spinal tumor excision was performed by Sir Victor Horsley in 1887. The patient was a 40-year-old man, who presented with extreme lower back pain that progressed to paraplegia, loss of sensation, and urinary retention over 4 months.[4,5] The patient was initially seen and diagnosed by renowned neurologist Sir William Gowers and sent to see Horsley. On physical examination, the only abnormal finding was tenderness to palpation on the left side of the spine, with no visible or palpable deformity. The operative report (Figure 1) describes the excision of an extramedullary lesion, identified as a fibromyxoma (Figure 2). The patient recovered well and was noted to have returned to standing, walking, and working a year postoperatively.[5]

Shortly thereafter, Christian Fenger made the first documented attempt at resection of an intramedullary spinal cord tumor, in 1890,[6] but it was Anton von Eiselsberg who accomplished this, in 1907.[7] In 1911, Charles Elsberg and Edwin Beer described a 2-stage process for resection of an intramedullary spinal tumor.[7,8] The first stage involved a posterior midline myelotomy overlying the tumor in which the wound was closed but the dura left open for approximately a week, allowing the tumor to partially extrude itself from the spinal cord. The second stage consisted of reopening the wound and resecting the extruded tumor.[8-10]

Diagnostic Imaging of Spinal Tumors

While the first operations for spine tumor resection were occurring, important advancements were concomittantly occurring in neuroradiology. After Wilhelm Roentgen's discovery of x-rays in 1895, Harvey Cushing used x-rays for neurosurgery as early as 1897. Cushing was able to visualize a bullet in a patient who presented with Brown-Sequard syndrome after a gunshot wound to the cervical spine.[6,11] In 1919, Walter E. Dandy first described pneumoencephalography for intracranial tumors but postulated that the same technique could be used to outline the spinal cord and that injected air could be used to localize spinal cord tumors by extending up to the level of the mass.[12,13]

In 1921, the Swedish internist Hans Christian Jacobaeus and the Norwegian surgeon Sofus Widero independently documented their use of pneumomyelography to diagnose spinal cord tumors. A year later, in 1922, French physician Jean-Athanese Sicard and his student Jacques Forestier documented that intrathecal injection of lipiodol, a type of iodized poppy seed oil, could be used to diagnose spinal masses. Sicard had previously injected lipiodol into the epidural space to visualize infections and tumors, but his student unintentionally injected the lipiodol into the thecal sac during a particular incident. On looking at the fluorescent screen, Sicard was able to visualize the spine and observe that the lipiodol had descended into the bottom of the spinal canal. Shortly thereafter, in

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ORIGINAL ARTICLE

Evaluation of open and minimally invasive spinal surgery for the treatment of thoracolumbar metastatic epidural spinal cord compression: a systematic review

Mohammed Alshareef[1,4] · Gibson Klapthor[2,4] · Ali Alawieh[3,4] · Stephen Lowe[1,4] · Bruce Frankel[1,4]

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Abstract

Background Metastatic epidural spinal cord compression (MESCC) is a debilitating sequela of cancer that results in pain, disability, and neurologic deficits. Surgical techniques have included open surgical (OS) techniques with anterior and/or posterior decompression and fusion procedures. Further technical evolution has led to minimally invasive spinal (MIS) decompression and fusion. The objective of this study is to compare MIS to OS techniques in the treatment of thoracolumbar MESCC.

Methods A review of the literature was performed using PubMed database. Inclusion criteria included patients 18 years or older, thoracolumbar MESCC, and surgeries with instrumented fusion. A total of 451 articles met the inclusion criteria and further analysis narrowed them down to 81 articles. Variables collected included blood loss, length of stay, operative time, pre- and postoperative Frankel grade, and complications.

Results A total of 5726 papers were collected, with a total of 81 papers meeting final inclusion criteria: 26 papers with MIS technique and 55 with OS. A total of 2267 patients were evaluated. They were split into three surgical subtypes of MIS and OS: posterior decompression and fusion, partial corpectomy, and complete corpectomy. Overall, MIS had lower operative time, blood loss, and complications compared to OS. A timeline analysis showed reduction of complication rates in MIS surgery between papers published over a 28-year period.

Conclusion MESCC carries significant morbidity and mortality. Surgical approaches for palliative treatment should account for this fact. We conclude that MIS techniques offer a viable alternative to traditional OS approaches with lower overall morbidity and complications.

Keywords Spine surgery · Metastatic epidural spinal cord compression · Minimally invasive spine · Corpectomy · Thoracolumbar · Metastasis

Introduction

Metastatic epidural spinal disease is a debilitating consequence of cancer that occurs in approximately 30–40% of patients with advanced disease, with the thoracolumbar spine accounting for the majority of osseous metastasis [1, 2]. Through structural collapse of the vertebral body or direct growth of the tumor, spinal metastases can lead to metastatic epidural spinal cord compression (MESCC). MESCC is a morbid condition that is often times considered a medical emergency with risk of permanent neurologic dysfunction. Multiple iterations of MESCC management have been produced based on efficacy of various treatments for MESCC, primarily steroids, radiotherapy, and surgery. Patchell et al. published a randomized controlled trial that reported significant functional benefit in patients

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A Novel Endoscopic Technique for Biopsy and Tissue Diagnosis for a Paraspinal Thoracic Tumor in a Pediatric Patient: A Case Report

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ABSTRACT

Background: Conventional approaches to the thoracic spine can require extensive tissue dissection, bony disruption, and instability that may warrant the need for instrumentation and fusion. Furthermore, anterior approaches may require the involvement of various surgeons from multiple disciplines to ensure a successful operation and mitigate complications. Currently, available minimally invasive approaches still require bony removal and usually rely heavily on computed tomography (CT)-guided imaging without direct gross visualization. Endoscopic spinal procedures have provided an ultra–minimally invasive alternative to access many areas in and around the spinal column.

Methods: We present a 12-year-old boy with a right-sided 2.0 × 3.2-cm paravertebral lesion at the level of T5. The patient successfully underwent an endoscopic approach to the lesion with minimal tissue and bony disruption for tissue diagnosis and tumor resection.

Results: At initial and 6-month follow-up, the patient remained asymptomatic and without issues.

Conclusions: We demonstrate here the feasibility and suggest the safety of a posterior ultra–minimally invasive endoscopic spinal approach to obtain a tissue biopsy of an incidentally found ventrolateral paraspinal tumor in the thoracic region in a pediatric patient. This minimal approach can prove to achieve similar results as other approaches that may otherwise necessitate more extensive or transthoracic procedures.

Minimally Invasive Surgery

Keywords: endoscopic spine surgery, thoracic tumor, paraganglioma

INTRODUCTION

Access to paraspinal tumors in the thoracic region requires thorough planning and discussion to select the most suitable approach. Generally, the available approaches can be categorized into posterior, anterior, lateral, or a combination of these approaches. Furthermore, we can subclassify these approaches into open or minimally invasive. Open posterior approaches to paraspinal tumors in the thoracic region often demand a wide exposure and significant muscle disruption and require bony removal of the posterior spinal elements with partial removal of unilateral or bilateral joints and ribs. Extensive bony removal can cause concern for iatrogenic spinal instability, which may necessitate the need for a more involved operation requiring instrumentation and fusion. Open anterior or lateral transthoracic approaches can frequently require the involvement of multiple surgeons with expertise in various disciplines for both approach and tumor resection.[1] Minimally invasive or computed tomography (CT)-guided approaches to these areas can be transpedicular posteriorly or transthoracic from an anterior or lateral approach, though these also often involve extensive bony removal, poor visualization, additional radiation, and tumor contamination, among other limitations.[2] These CT-guided needle approaches, moreover, do not allow for maximally safe tumor resection.

As advancements in endoscopic equipment and visibility progress and evolve, the indications for endoscopic techniques to treat various spinal pathologies are rapidly increasing.[3,4] The requirement of precise localization, nuanced operative techniques, and familiarization of surgical anatomy,

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Full-Endoscopic Resection of Osteoid Osteoma in the Thoracic Spine: A Case Report

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ABSTRACT

Common symptoms such as axial pain or nocturnal pain, associated with warning signs that are often worrisome in addition to nonspecific radiological findings, can characterize benign lesions in the spine, and osteoid osteoma is among them. We describe here a clinical case of a pediatric patient with an expansive bone lesion in the thoracic spine discovered after investigation for thoracic pain, mainly at night, which, despite a good response to simple analgesics, evolved in the short term with global spinal deformity. After a multidisciplinary evaluation, she underwent surgical resection using a pioneering endoscopic technique that allowed the definitive anatomopathological diagnosis of osteoid osteoma and guaranteeing very satisfactory treatment and evolution. Although there are already several therapeutic techniques described and with good results in specific cases of osteoid osteomas and other benign neoplastic lesions of the spine, full-endoscopic resection appears as an innovative and potentially promising option for diagnosis and treatment, especially since it is a safe, effective, and not too morbid intervention.

Minimally Invasive Surgery

Keywords: osteoid osteoma, minimally invasive, endoscopic surgery, bone tumor, spine

INTRODUCTION

When a patient presents with unexplained axial pain that is difficult to control and alarming symptoms, such as worsening nocturnal pain, deformities or postural changes, and suspicious radiological imaging, benign bone tumor of the spine, although rare, should be considered.[1,2] Historically, management of benign bone tumors includes surgical lesion resection and possible mechanical stabilization. Since the early 1990s, percutaneous (ablation) techniques have been increasingly advocated for resolution of this type of disease.[3]

This case is among the pioneers in the literature in the use of this technique in the resection of tumors, previously more restricted to the treatment of degenerative pathologies of the spine. Since 2012, some case reports began to appear describing full-endoscopic techniques in the initial surgical treatment of spinal tumors.[4]

We combined the resoluteness and efficiency of traditional surgical resection with technology and the noninvasiveness of percutaneous techniques to treat a patient with osteoid osteoma of the thoracic spine using a full-endoscopic surgical technique.

The endoscopic procedure proved to be just as resolute as it was noninvasive and resulted in good control of the disease without structural changes to the patient's spine.

CASE PRESENTATION

A 6-year-old female patient, previously healthy with no history of trauma, presented with nonspecific thoraco-lumbar pain (transition), which was predominantly local in tightness, without irradiation or signs of radiculopathy, and without associated neurological deficits. The pain was of a moderate intensity (visual analog scale: 6/10). There was no associated weight loss or febrile episodes, and while she could not describe the worsening pain, it kept her awake at night. She showed significant improvement with the use of acetylsalicylic acid (AAS).

Medical charts outlined responses to conservative and drug treatment, details of outpatient follow-ups, and complementary radiological investigations but did not specify determinative differential diagnoses. Computed tomography (CT) of the thoraco-lumbar spine showed absence of the right T11 pedicle, and its space was replaced by material with

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TECHNICAL NOTE

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Percutaneous Endoscopic Excision and Ablation of Osteoid Osteoma of the Lumbar Spine and Sacrum: A Technical Note and Outcomes

Tianhang Xie, Peng Xiu, Yueming Song, Jiancheng Zeng, Shishu Huang

OBJECTIVE: **This study aimed to present a new endoscopic technique for osteoid osteoma (OO) of the lumbar spine and sacrum and to evaluate its safety and effectiveness.**

METHODS: **Eleven consecutive patients with spinal OO underwent percutaneous endoscopic excision and ablation (PEEA) between March 2014 and May 2018. A cannula 0.7 cm in diameter was used for the procedure. According to the size of the nidus, whole-piece removal and piecemeal intralesional resection were used. Afterward, ablation was performed using an endoscopic radiofrequency electrode in the residual osteoma cavities. Clinical outcomes were assessed by Visual Analog Scale (VAS) scores. The efficacy of this technique was assessed using relevant clinical data and postoperative radiographs.**

RESULTS: **The niduses of the 11 patients were all located in the posterior element of the lumbar spine and sacrum (10 in the lumbar spine and 1 in the sacrum). The preoperative VAS score was 7.18 (range, 6–9), the score on postoperative day 1 was 1 (range, 0–2), and the last follow-up VAS score was 0.27 (range, 0–1). All patients were discharged within 24 hours after surgery. The mean follow-up period was 21.8 months (range, 12–36 months). No serious complications were observed during the follow-up period.**

CONCLUSIONS: **PEEA is a safe and effective technique for OO in the lumbar spine and sacrum in which the nidus is located in the posterior element. However, it has a steep learning curve. Further research with a larger and more comprehensive sample population is warranted.**

INTRODUCTION

Spinal osteoid osteoma (SOO) is a type of benign bone neoplasm that occurs in more frequently in children and teenagers than in adults. Approximately 68.4% to 100% of SOOs are located in the posterior element,[1-3] and 34% are located in the lumbar spine.[2] Severe pain is a typical symptom; a few patients experience painful scoliosis or radiculopathy.[4]

Previous large studies have shown good results with nonsteroidal anti-inflammatory drugs (NSAIDs) for osteoid osteoma (OO).[5,6] However, to avoid long-term medication regimens and drug treatment failure, surgery is recommended.[7,8] Traditional open surgery may require extensive paraspinal muscular detachment and disruption of the facet joints, which are important for spinal stability, and fusion and instrumentation may be required to restore spinal stability.[7,9] The thermoablation approach, including percutaneous radiofrequency ablation and percutaneous laser coagulation, is considered a safe and effective treatment for SOO. However, the development of this technique has been limited because of the potential theoretic danger, especially when the SOO is close to neural structures.[1,10,11] The percutaneous endoscopic technique is widely used in cervical/lumbar disc herniation and spinal stenosis.[12-14] Minimal invasion and ease of operation under direct view led us to believe that this minimally invasive technique can be applied to the treatment of a larger number of spinal diseases. Thus, the objective of the current study was to

Key words
- Ablation
- Bone tumor
- Minimally invasive
- Osteoid osteoma
- Percutaneous endoscopic
- Spine

Abbreviations and Acronyms
CT: Computed tomography
MRI: Magnetic resonance imaging
NSAIDS: nonsteroidal anti-inflammatory drugs
OO: Osteoid osteoma
PEEA: Percutaneous endoscopic excision and ablation
SOO: Spinal osteoid osteoma
VAS: Visual Analog Scale

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TECHNICAL NOTE

Transforaminal Endoscopic Approach for Large-Sample Tumor Biopsy using Beveled Working Channel for Core Technique: A Technical Note

Sanjay Konakondla[1], Nelson Sofoluke[1], Jimmy Xia[2], Ryan Grant[1], Albert E. Telfeian[3], Christoph P. Hofstetter[4], Jonathan R. Slotkin[1]

■ BACKGROUND: **Identifying the histopathological diagnosis of a spinal tumor is the necessary step prior to pursuing subsequent treatment. Both minimally invasive and open spinal procedures have been described as useful methods of obtaining tumor tissue for diagnosis but differ by their limitations. Minimally invasive techniques, such as computed tomography–guided biopsies, can expose the patient to radiation, and the tissue obtained may be nondiagnostic. Tubular and open procedures require collateral soft-tissue damage and may require bony removal leading to iatrogenic injury. Endoscopic approaches to the spine can be employed to avoid treatment delay in diagnosis, decrease length of stay, and provide adequate tissue for diagnosis.**

■ METHODS: **We describe the surgical planning, tumor localization, and transforaminal endoscopic approach for tissue diagnosis of a lumbar spinal mass in a patient with a known history of Hodgkin lymphoma and non-Hodgkin lymphoma after a nondiagnostic computed tomography–guided biopsy. Final histopathological diagnosis of the lumbar spinal mass was consistent with large B-cell non-Hodgkin lymphoma.**

■ CONCLUSIONS: **We demonstrate the application of an endoscopic transforaminal approach in spine oncology. We also describe our technique on how we use a beveled working channel to obtain a large tissue core sample for definitive diagnosis.**

INTRODUCTION

The management of a spinal tumor is largely dictated on the histopathologic diagnosis confirmed with tissue sampling. When a biopsy is required, access to the lesion requires thorough planning and discussion to determine the most appropriate approach. Generally, approaches to the spine can be classified as minimally invasive or open procedures. Minimally invasive procedures can be performed via percutaneous approaches using computed tomography (CT) guidance. CT-guided needle techniques are useful to biopsy tissue in small spaces but are limited by the amount of tissue that can be obtained. In some cases, multiple needle biopsies are needed to reach a definitive diagnosis, often requiring separate encounters and causing delay in treatment.[1] Open procedures result in larger incisions and cause increased collateral muscle and bony disruption, which may require surgical fixation and fusion. At times, this may also necessitate the involvement of surgeons from other disciplines to gain access to the lesions via other body cavities.

Endoscopic applications in spinal oncology have been described using various corridors to access tumors in the thoracic, lumbar, and sacral spine.[2-4] With endoscopic approaches, tissue diagnosis can be obtained and the tumor can be debulked to relieve mass effect with minimal to no tissue and bony disruption.[5] These qualities, among others, give endoscopic approaches a distinct advantage over minimally invasive and open procedures. Nuanced operative techniques, requiring precise localization and familiarization of surgical anatomy, make endoscopic spine procedures uniquely challenging. Here we describe a transforaminal endoscopic approach to obtain tissue diagnosis of a lumbar spinal tumor in a patient with known history of Hodgkin lymphoma (HL) and non-Hodgkin lymphoma (NHL) after inadequate percutaneous CT-guided tissue sampling. We also discuss technical notes on how to use a beveled

Key words
- Endoscopic spine surgery
- Spinal oncology
- Transforaminal approach

Abbreviations and Acronyms
CT: Computed tomography
HL: Hodgkin lymphoma
NHL: Non-Hodgkin lymphoma

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The Role of Minimal Access Surgery in the Treatment of Spinal Metastatic Tumors

Ori Barzilai, MD[1], Mark H. Bilsky, MD[1,2], and Ilya Laufer, MD[1,2]

Abstract

Study Design: Literature review.

Objective: To provide an overview of the recent advances in minimal access surgery (MAS) for spinal metastases.

Methods: Literature review.

Results: Experience gained from MAS in the trauma, degenerative and deformity settings has paved the road for MAS techniques for spinal cancer. Current MAS techniques for the treatment of spinal metastases include percutaneous instrumentation, mini-open approaches for decompression and tumor resection with or without tubular/expandable retractors and thoracoscopy/endoscopy. Cancer care requires a multidisciplinary effort and adherence to treatment algorithms facilitates decision making, ultimately improving patient outcomes. Specific algorithms exist to help guide decisions for MAS for extradural spinal metastases. One major paradigm shift has been the implementation of percutaneous stabilization for treatment of neoplastic spinal instability. Percutaneous stabilization can be enhanced with cement augmentation for increased durability and pain palliation. Unlike osteoporotic fractures, kyphoplasty and vertebroplasty are known to be effective therapies for symptomatic pathologic compression fractures as supported by high level evidence. The integration of systemic body radiation therapy for spinal metastases has eliminated the need for aggressive tumor resection allowing implementation of MAS epidural tumor decompression via tubular or expandable retractors and preliminary data exist regarding laser interstitial thermal therapy and radiofrequency ablation for tumor control. Neuronavigation and robotic systems offer increased precision, facilitating the role of MAS for spinal metastases.

Conclusions: MAS has a significant role in the treatment of spinal metastases. This review highlights the current utilization of minimally invasive surgical strategies for treatment of spinal metastases.

Keywords

spine, tumor, minimally invasive surgery, minimal access surgery, surgery

Introduction

Over the past 2 decades, we have witnessed an increase in utilization of minimal access surgery (MAS) for the treatment of spinal pathologies. The expertise gained from surgery for spinal trauma, deformity, and degenerative disease has stemmed the adoption of minimally invasive surgeries for spinal cancer. Patients with spinal tumors generally require a combination of surgical, radiation, and systemic therapies making rapid postoperative healing and return to treatment of paramount importance. Comparative data evaluating the benefit of MIS approaches versus open surgeries in spinal metastatic disease are still limited and a systematic review of surgical approaches for spinal metastases concluded that although some studies showed superiority of MAS approaches, data is low quality and strong recommendations cannot be made.[1] Nevertheless, multiple studies have demonstrated decreased blood loss, transfusion rates, and hospitalization length with MAS stabilization techniques for spinal tumors.[2-5] As an example, a retrospective study comparing outcomes of 25 MAS

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Original Study on Full-endoscopic Spine Surgery

Endoscopic surgical treatment for symptomatic spinal metastases in long-term cancer survivors

Albert E. Telfeian, Adetokunbo Oyelese, Jared Fridley, Cody Doberstein, Ziya L. Gokaslan

The Warren Alpert Medical School of Brown University, Providence, RI, USA

Contributions: (I) Conception and design: All authors; (II) Administrative support: All authors; (III) Provision of study materials or patients: All authors; (IV) Collection and assembly of data: All authors; (V) Data analysis and interpretation: All authors; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

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Background: To evaluate the feasibility of awake transforaminal endoscopic surgery in the management of symptomatic spinal metastases.

Methods: Transforaminal endoscopic spine procedures were performed by 1 surgeon in 325 patients over a period of 4 years from 2014 to 2018. Four of these patients suffered from radicular pain secondary to nerve compression from metastatic spine disease and are the basis of our analysis. Data was evaluated retrospectively in these patients with a minimum follow up of 1 year.

Results: All 4 patients treated with transforaminal endoscopic spine surgery for decompression of their metastatic spine disease had successful resolution of their symptoms without any perioperative complications and only brief recovery periods required.

Conclusions: Awake endoscopic surgery for the treatment of symptomatic metastatic spine disease is an effective outpatient surgical option for the treatment of patients suffering from radicular pain due to nerve compression from metastatic spine disease.

Keywords: Endoscopic spine surgery; minimally-invasive spine; transforaminal; metastases

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Introduction

Approximately 1.7 million people develop cancer annually (1) and 5–10% of affected patients will develop symptomatic vertebral metastases (2,3), making the spine one the most common locations of disease spread. In fact, spinal regions are the most common osseous location of metastatic lesions (4) with studies demonstrating evidence of spinal metastases in 30–90% of patients who died of cancer (5) Most lesions spread to the thoracic spine representing 70% of cases, while 20% spread to the lumbar spine and 10% to the cervical spine (3,6,7). Spinal metastases present variably (8) but symptoms of axial bone pain and back pain are present in 85–95% of cases and can be caused by periosteal stretching, mechanical instability, or nerve root compression (5,9). Nerve root compression caused by metastatic lesions can also lead to disabling radicular pain as well as sensory or motor deficits in the corresponding myotomal and dermatomal distributions. These symptoms are often debilitating and can adversely impact quality of life, physical function, and psychosocial performance in cancer patients.

Despite its severity, recent medical advances in cancer treatment have significantly lengthened life expectancies in patients with spinal metastatic disease (4). Although not curative, surgical interventions can play a vital role in the overall management of cancer patients harboring spinal lesions by significantly improving quality of life and helping maintain functional independence. Goals of surgical treatment include preserving neurologic function, pain relief, removal of tumor mass, and spinal stabilization (5,8). However, cancer-associated comorbidities may

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Percutaneous Full-Endoscopic Removal of Lumbar Intradural Extramedullary Tumor via Translaminar Approach

Salim Şentürk and Ülkün Ünlü Ünsal

Key words
- Endoscope
- Meningioma
- Translaminar approach

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BACKGROUND: **Despite the fact that technologic advances and surgical experience expand the use of endoscope in spinal surgery, there are few reports on its application in the management of spinal tumors. We present a case report of intradural extramedullary tumor excision with the percutaneous full endoscopic translaminar approach.**

CASE DESCRIPTION: **A 67-year-old male presented to our clinic with lumbar, left thigh pain and paresthesia in both thighs. Preoperative magnetic resonance imaging revealed a contrast-enhanced intradural extramedullary mass with benign characteristics on L1 with the preliminary diagnosis of meningioma. The percutaneous translaminar endoscopic approach was planned to remove the intradural extramedullary tumor from a 7-mm skin incision. Surgery was planned in 4 stages: 1) exposure of the dura by opening a window on the lamina, 2) opening and expanding of the dura, 3) exposure of all sides of the tumor, and 4) excision of the tumor and hemostasis. Closing the dura and ending the surgery.**

CONCLUSIONS: **This report supports that full endoscopic spinal intradural extramedullary mass excision may give good results in selected cases and in experienced hands.**

INTRODUCTION

The use of endoscopes has recently become quite common with degenerative spine pathologies, particularly lumbar disk hernia and lumbar spinal stenosis. Full endoscopic techniques are considered the treatment of choice for spinal epidural tumors.[1] Endoscopy-assisted spinal intradural tumor resection has also been reported.[2] Technologic advances and surgical experience have expanded the indications for endoscopic spine surgery. Here we report on a patient whose intradural extramedullary tumor was removed via the percutaneous endoscopic translaminar approach. To our knowledge, such a case has not been reported in the literature.

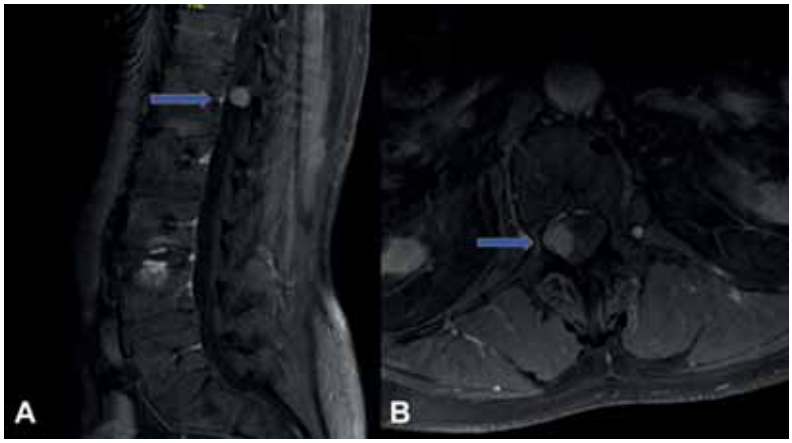

Figure 1. Magnetic resonance imaging of the lumbar spine: an extramedullary contrast enhanced mass with benign characteristics on L1 is observed (*blue arrows*). Meningioma was presumed as the preliminary diagnosis (sagittal and axial).

CASE DESCRIPTION

History and Examination

A 67-year-old male presented to our institution with lumbar pain and paresthesia in both thighs. His preoperative neurologic examination was unremarkable. He had a medical history of hypertension and panic attacks.

Imaging Studies

On magnetic resonance imaging of the lumbar spine, a contrast-enhancing intradural extramedullary mass with benign characteristics was noted at L1. A preliminary diagnosis of tumor was made (Figure 1A and B).

Surgery

Percutaneous translaminar endoscopic approach was planned to remove the tumor through a 7-mm skin incision.

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Clinical Study

"Microendoscopic" versus "pure endoscopic" surgery for spinal intradural mass lesions: a comparative study and review

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Abstract

BACKGROUND CONTEXT: Endoscopy is increasingly being used for minimal invasiveness and panoramic visualization, with unclear efficacy and safety among spinal intradural mass.

OBJECTIVE: The present study aims to compare microendoscopic and pure endoscopic surgery for spinal intradural lesions.

MATERIALS AND METHODS: Spinal intradural lesions operated using endoscopic or access ports were categorized into "microendoscopic" (predominant microscope use) or "pure endoscopic" (stand-alone endoscopy) surgery, and were studied with respect to clinico-radiological features, techniques, perioperative course, histopathology, clinical, and radiological outcome at minimum of 3 months.

RESULTS: Among 34 patients studied, the initial 15 had "microendoscopic" surgery, 16 had "pure-endoscopic" surgery, and 3 had "mixed" use. There were 18 nerve sheath tumors, 6 meningiomas, 6 cysts, 2 ependymomas, ranging in size from 1.5 to as large as 6.8 cm (21%≥4 cm), including 4 in craniovertebral junction (CVJ). Intermuscular or paraspinous approach was utilized, followed by small bony fenestration or interlaminar corridor. Even larger tumors could be excised using expandable ports or "sliding delivery" technique. Although visualization of sides and angles was better with endoscope, hemostasis and dural closure had steep learning curve, necessitating the use of microscope in the initial cases. Clinical improvement and radiological resolution could be achieved in all. There was no significant difference between the groups. The change in Nurick grade had significant correlation with only the dimension of lesion (p=.03) and preoperative grade (p=.05).

CONCLUSIONS: This is probably the first report of spinal endoscopy for intradural tumors in CVJ or as big as 7 cm. Endoscopy is effective and safe for even large tumors with better visualization of sides and angles, albeit with hemostasis and dural closure having initial learning curve. Wide heterogeneity of surgical terminologies in the literature on these procedures warrants consensus for uniform reporting. © 2018 Elsevier Inc. All rights reserved.

Keywords: Spinal endoscopy; Intradural; Microendoscopy; Minimally invasive; Spinal tumors; CVJ; IDEM; MISS

Introduction

Spinal intradural extramedullary (IDEM) lesions are one of the common causes of morbidity in the productive age group, with 80% being nerve sheath tumors and meningiomas [1,2]. The traditional approach to these lesions often involves long incision, bilateral paraspinal muscle stripping, and laminectomy with additional facetectomy in anterolateral tumors or those that extend into neural foramen. This approach may lead to protracted pain, infection, cerebrospinal fluid (CSF) leakage and instability. Spinal deformity has been reported in about 12%–16% of patients overall, and possibly higher in younger patients, after multilevel laminectomies, laminectomy with facetectomy, and laminectomies at junctional (cervicothoracic and thoracolumbar) areas [3,4,5]. This may eventually require fixation among few patients in the long term [3,4].

Open spinal approaches are gradually giving way to limited bone removal procedures such as hemilaminectomy and minimally invasive spine surgery (MISS) obviating the potentially destabilizing dissection of osseoligamentous structures and muscles [1,2,5–23]. Minimally invasive spine surgery as a

FDA device/drug status: Approved (X-tube System and Quadrant System [Medtronic]; Destandau System [Karl Storz]).

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Review Article

Endoscopic Techniques for Lumbar Interbody Fusion: Principles and Context

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Endoscopic techniques in spine surgery are rapidly evolving, with operations becoming progressively safer and less invasive. Lumbar interbody fusion (LIF) procedures comprise many spine procedures that have benefited from endoscopic assistance and minimally invasive approaches. Though considerable variation exists within endoscopic LIF, similar principles and techniques are common to all types. Nonetheless, innovations continually emerge, requiring trainees and experienced surgeons to maintain familiarity with the domain and its possibilities. We present two illustrative cases of endoscopic transforaminal lumbar interbody fusion with a comprehensive literature review of the different approaches to endoscopic LIF procedures.

1. Introduction

Endoscopic spine surgery (ESS) techniques for discectomy have been used for decades [1–3], but its first reported use for lumbar fusions was in 1996 [4]. Endoscopic lumbar interbody fusion (ELIF) procedures encompass a group of minimally invasive surgeries (MIS) for treating degenerative disc disease (DDD) of the lumbar spine. Endoscopic spine operations leave a smaller surgical footprint than the minimally invasive surgeries they build upon and further the advantages of MIS, including reduced tissue disruption, decreased intraoperative blood loss, and shorter hospital admissions [5]. Moreover, endoscopic surgeries represent a unique contribution in that they may be performed under conscious sedation instead of general anesthesia [6, 7], engendering potential improvement in patient satisfaction [8, 9]. In the next review article, the authors will discuss the different approaches to LIF and how innovation in endoscopic techniques has driven the learning requirements for these techniques.

2. Categories of Endoscopic Lumbar Interbody Fusion

Multiple options for ELIF procedures have emerged within the last half-century. Their respective applications usually parallel those of the traditional lumbar interbody fusion technique from which they were adapted. As such, ELIFs are broadly distinguished by surgical approach, which is

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Learning Curve and Initial Outcomes of Full-Endoscopic Posterior Lumbar Interbody Fusion

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Study Design: This was a retrospective cohort study.

Objective: We evaluated the feasibility, safety, and accuracy of full-endoscopic posterior lumbar interbody fusion (FE-PLIF) by assessing the learning curve and initial clinical outcomes.

Summary of Background Data: Low back pain is one of the crucial medical conditions worldwide. FE-PLIF has been reported to be a minimally invasive method to treat mechanical low back pain, but there lacks a thorough evaluation on this new technique.

Methods: The patients were divided into three groups in the order of operating date, implying that Group A consisted of the initial 12 cases, Group B the subsequent 12 cases, and Group C the last 12 cases. The data of patients were reviewed for gender, age, preoperative symptoms, satisfaction, as well as clinical outcomes demonstrated by visual analog scale (VAS). The operative time and intraoperative fluoroscopy were recorded to demonstrate the learning curve and the extent of radiographic exposure. Statistical significance was set at a $p < 0.05$ (two-sided).

Results: The patients enrolled in this study were followed up at an average of 1.41 ± 0.24 years. Overall, patients were satisfied with the surgery. The average number of intraoperative fluoroscopy was 6.97 ± 0.74. A significant improvement was observed in the VAS of both lumbar pain and leg pain. The overall fusion rate was 77.7%. Complications were reported in two patients in Group A, one in Group B, and none in Group C. The average operative time showed a trend of gradual decline. The learning curve was characterized using a cubic regression analysis as $y = -27.07x + 1.42x^2 - 0.24x^3 + 521.84$ ($R^2 = 0.617$, $p = 0.000$).

Conclusions: FE-PLIF is an effective and safe method for treating low back pain caused by short-segmental degenerative diseases. The learning curve of this technique is steep at the initial stage but acceptable and shows great potential for improvement.

Keywords: full-endoscopic, posterior approach, interbody fusion, minimally invasive surgery, learning curve

Systematic Review

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Comparison of Clinical Outcomes and Complications Between Endoscopic and Minimally Invasive Transforaminal Lumbar Interbody Fusion for Lumbar Degenerative Diseases: A Systematic Review and Meta-analysis

Haiwei Guo, MD[1,2,#], Yuke Song, MD[1,2,#], Rui Weng, MD[1,2], Han Tian, MD[1], Jiayao Yuan, MD[1], and Ying Li, PhD[3]

Abstract

Study design: Systematic review and meta-analysis.

Objective: Minimally invasive transforaminal lumbar interbody fusion (MIS-TLIF) is a classic surgical procedure for the treatment of lumbar degenerative diseases (LDD). With the development of endoscopic technology, endoscopic transforaminal lumbar interbody fusion (Endo-TLIF) can also achieve adequate decompression and interbody fusion. However, whether Endo-TLIF is superior to MIS-TLIF has not been adequately studied. In this systematic review and meta-analysis, we aimed to evaluate the treatment difference between Endo-TLIF vs MIS-TLIF.

Methods: We conducted a systematic review and meta-analysis of the studies to compare the clinical outcomes and complications associated with Endo-TLIF vs. MIS-TLIF for the treatment of LDD. A literature search was conducted using the PubMed, Embase, Cochrane Library and Scopus databases for studies published up to April 1, 2022. Both retrospective and prospective studies that compared between Endo-TLIF and MIS-TLIF were included.

Results: A total of 8 studies involving 581 patients were finally included in this meta-analysis. Endo-TLIF significantly prolonged the operation time, but reduced the blood loss amount and length of hospital stay. Moreover, Endo-TLIF was superior to MIS-TLIF on relief of back pain and functional recovery in the early postoperative period. However, there were no significantly differences in long-term clinical outcomes, fusion rate and incidence of complications between Endo-TLIF and MIS-TLIF.

Conclusions: Endo-TLIF was similar to MIS-TLIF in the long-term clinical outcomes, fusion and complication rates. Endo-TLIF prolongs the operation time, but shortens the length of hospital stay, and has the advantages of less surgical trauma, less blood loss, faster recovery, and early postoperative back pain relief.

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Endoscopic Lumbar Interbody Fusion and Minimally Invasive Transforaminal Lumbar Interbody Fusion for the Treatment of Lumbar Degenerative Diseases: A Systematic Review and Meta-Analysis

Yuanqiao Kou[1], Jianjun Chang[2], Xiaoming Guan[2], Qiang Chang[2], Haoyu Feng[2]

OBJECTIVE: **To compare clinical efficacy and safety of endoscopic lumbar interbody fusion (Endo-LIF) and minimally invasive transforaminal lumbar interbody fusion (MIS-TLIF) in treatment of lumbar degenerative diseases.**

METHODS: **A literature search was performed using PubMed, Embase, Web of Science, and Cochrane Library databases. Studies published up to November 15, 2020, that compared Endo-LIF with MIS-TLIF for treating lumbar degenerative diseases were retrieved. Data were extracted according to predefined clinical outcome measures. Primary outcomes were preoperative and postoperative visual analog scale for leg and back pain and Oswestry Disability Index scores. Secondary outcomes were operative time and intraoperative blood loss; length of hospitalization; and complication, reoperation, and fusion rates. Data analysis was conducted with statistical software.**

RESULTS: **The meta-analysis included 6 studies comprising 480 patients. Results of the merged analysis revealed similar complication, reoperation, and fusion rates and preoperative and postoperative visual analog scale for leg and back pain and Oswestry Disability Index scores ($P > 0.05$) for Endo-LIF and MIS-TLIF. Nevertheless, with the exception of longer operative time ($P < 0.05$), Endo-LIF compared favorably with MIS-TLIF, with less intraoperative blood loss, shorter hospital stay ($P < 0.05$), and better long-term functional outcome.**

CONCLUSIONS: **Based on the evidence provided by this study, there is no significant difference in clinical efficacy and safety between Endo-LIF and MIS-TLIF in the treatment of lumbar degenerative diseases. Although Endo-LIF has a longer operative time, it has the advantages of less tissue trauma and rapid recovery after operation.**

INTRODUCTION

Lumbar fusion is an effective surgical technique for various lumbar diseases, including lumbar stenosis, spondylolisthesis, and disc herniation. The objective of spinal fusion surgery is to achieve a substantial arthrodesis of spinal segments while restoring disk height, immobilizing the unstable segment, and restoring load bearing to anterior structures.[1]

Posterior lumbar interbody fusion (PLIF) was developed by Cloward[2] in 1950 and later modified by Lin[3] with satisfactory results of >85%. Transforaminal lumbar interbody fusion (TLIF) technique was first described by Harms in 1982[4]; this technique overcome the shortcomings of PLIF and became popular. The advantage of TLIF is that it reduces retraction of the dural sac and root, thus

Key words
- Endoscopy
- Lumbar degenerative diseases
- Meta-analysis
- Minimally invasive
- Transforaminal lumbar interbody fusion

Abbreviations and Acronyms
CI: Confidence interval
Endo-LIF: Endoscopic lumbar interbody fusion
ERAS: Enhanced recovery after surgery
MIS-TLIF: Minimally invasive transforaminal lumbar interbody fusion
ODI: Oswestry Disability Index
OR: Odds ratio
PLIF: Posterior lumbar interbody fusion
RCT: Randomized controlled trial
TLIF: Transforaminal lumbar interbody fusion
VAS: Visual analog scale
WMD: Weighted mean difference

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ORIGINAL RESEARCH

Full-Endoscopic Posterior Lumbar Interbody Fusion with Epidural Anesthesia: Technical Note and Initial Clinical Experience with One-Year Follow-Up

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Objective: The purpose of this study was to introduce and evaluate the early clinical outcomes of the full-endoscopic posterior lumbar interbody fusion (Endo-PLIF) technique with epidural anesthesia (EA) for single-segment lumbar degenerative diseases.

Methods: In this retrospective case series study, we explored the feasibility and effectiveness of the Endo-PLIF with EA for single-segment lumbar degenerative diseases. Between March 2018 and January 2019, a series of 24 patients with single-segment lumbar degenerative diseases underwent Endo-PLIF surgery and were followed up for a minimum of 12 months (15.21±2.27 months). Clinical outcomes including visual analog scale (VAS) scores for back and leg pain, Oswestry Disability Index (ODI) scores, and the Short Form-36 health survey questionnaire (SF-36) were evaluated preoperatively, and postoperatively at 3 days and at 3, 6, and 12-months.

Results: All patients underwent successful single-segment Endo-PLIF surgery. The mean operation time was 209.17±39.49 min, and average amount of bleeding was 43.33 ±14.87 mL. The VAS for lower extremity pain and back pain significantly improved at 3 days, and at 3, 6, 12 months compared with preoperative, respectively. The ODI scores decreased from 42.04±3.96 to 12.75±2.71 (P<0.001) at preoperative and 12 months postoperatively, respectively. The SF-36 Physical Component Scores (PCS) improved from 34.96 ±4.63 preoperatively to 52.08±6.05 (P<0.001) at 12 months postoperatively. Additionally, the SF-36 Mental Component Scores (MCS) improved from 39.38±5.70 at preoperative to 53.13±5.97 (P<0.001) at 12 months postoperatively. Two patients experienced dysesthesia, and one patient had a wound infection.

Conclusion: Endo-PLIF with EA is a feasible and valuable technique for the treatment of single-segment lumbar degenerative diseases in selected patients.

Keywords: full-endoscopic posterior lumbar interbody fusion, lumbar degenerative disease, lumbar fusion, clinical outcome

Introduction

Lumbar degenerative diseases (LDD) are common, and the age of onset has been trending downwards over the years. LDD has been considered as the main cause of chronic low back pain (LBP) and sciatica, including lumbar disc herniation, lumbar spinal stenosis, and lumbar spondylolisthesis.[1,2] Currently, while ladder-like therapy is recommended to treat with LDD, surgery is the most effective

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Technical Considerations of Uniportal Endoscopic Posterolateral Lumbar Interbody Fusion: A Review of Its Early Clinical Results in Application in Adult Degenerative Scoliosis

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■ BACKGROUND: **Uniportal endoscopic posterolateral lumbar interbody fusion (Endo-TLIF) provides one of the least invasive forms of minimally invasive surgery, allowing large size cages which are commercially available for open and tubular microscopic transforaminal lumbar interbody fusion (TLIF) to be inserted through this approach. We studied the effect of such a technique on a series of patients with low-grade degenerative scoliosis.**

■ METHODS: **Endo-TLIF was applied to patients who had 10°—40° of degenerative adult scoliosis. Pre- and postoperative 1-week, 3-month, and final follow-up clinical status of visual analog scale, Oswestry Disability Index, perioperative complications, and Macnab criteria were collected. Roentgenogram to assess changes in Cobb angles was done.**

■ RESULTS: **There was statistically significant improvement of preoperative, 1-week postoperative, 3-month postoperative, and final follow-up mean of visual analog scale scores with 7.72 (5—10), 3.68 (3—6), 2.88 (2—4), and 1.96 (1—3), respectively, and with Oswestry Disability Index mean of 70.4 (52—86), 35.12 (26—56), 27.68 (24—38), and 24 (20—28), respectively ($P < 0.05$). In terms of Macnab criteria, 100% had good to excellent result. In terms of scoliosis measured by Cobb angle, there was statistically significant improvement.**

■ CONCLUSIONS: **Endo-TLIF is a safe and effective procedure in mild to moderate degenerative scoliosis with good early clinical results and improvement in coronal Cobb angle. It can be considered as an option if a short segment(s) fusion is planned for adult degenerative scoliosis.**

INTRODUCTION

Evolution of endoscopic spine surgery has brought more types of minimally invasive techniques to lumbar spine surgery.[1] Uniportal transforaminal approaches, interlaminar approaches, and contralateral approaches provide endoscopic decompression options to treat degenerative spinal canal stenosis and prolapsed intervertebral disk with good early perioperative and long-term clinical outcomes.[2-6] One of the last frontiers of lumbar spinal endoscopic surgery is endoscopic-assisted fusion. Currently, the popular techniques for endoscopic-assisted interbody fusion are performed by uniportal transforaminal approach with or without ventral facet resection and biportal endoscopic-assisted posterolateral lumbar interbody fusion.[7-10] There is limited literature on uniportal posterolateral lumbar interbody fusion with large cage. Kim et al.[11] have described the use of uniportal full endoscopic approach to perform posterolateral transforaminal lumbar interbody fusion (Endo-TLIF) in a patient with grade 2 spondylolisthesis in a case report. We have adopted the technique described by Kim et al.[11] and expanded its indications to treat patients with symptomatic back and leg pain with radiologic evidence of mild to moderate adult degenerative scoliosis. We describe our early experience in this technical note and report early radiologic and clinical outcomes of a cohort of adult patients with degenerative scoliosis who underwent Endo-TLIF.

Key words
- Degenerative scoliosis
- Endoscopic fusion
- Endoscopic spine surgery
- Transforaminal lumbar interbody fusion
- Uniportal endoscopic posterolateral lumbar interbody fusion

Abbreviations and Acronyms
CT: Computed tomography
Endo-TLIF: Uniportal endoscopic posterolateral lumbar interbody fusion

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Technical Considerations of Endoscopic Kambin's Triangle Lumbar Interbody Fusion

Gregory W. Basil and Michael Y. Wang

The performance of transforaminal endoscopic lumbar interbody fusion through a Kambin's triangle approach requires significant modifications when compared to a traditional transforaminal discectomy. Indeed, due to the inherently limited field of view, small working corridor, and need to deploy an adequately sized interbody graft, there are several important technical adaptations which can help improve the efficacy of this approach. In this manuscript, the technical aspects of a percutaneous, endoscopic interbody fusion are discussed in detail.

INTRODUCTION

The establishment of a safe working corridor to percutaneously access the disk space by Parvis Kambin represented a landmark development for minimally invasive spine surgery.[1,2] This corridor, referred to as Kambin's triangle, is defined by the exiting nerve root anteriorly, the traversing nerve root medially, the superior endplate of the lower vertebral body inferiorly, and the superior articular process (SAP) posteriorly.[2-4] The inclusion of a 4th border (the SAP) in the description of a triangle (which has 3 borders) has led some to describe this space as a prism, rather than a triangle.[5] Nevertheless, the common nomenclature used to describe Kambin's triangle uses the exiting nerve root, the traversing nerve root, and the superior endplate of the lower vertebral body as its borders (Figure 1). Following Dr Kambin's early work, there has been a large body of literature discussing the endoscopic transforaminal discectomy and describing various technical variations and their relative merits. More recently, this same working corridor has been applied to endoscopic, transforaminal interbody fusions.[6] Although there have been previous publications describing various endoscopic approaches to lumbar interbody fusion, these approaches do not always utilize a true Kambin's triangle approach, and often involve significant bony removal.[4,5,7,8] The high rate of complications reported by some practitioners with endoscopic assisted fusion, contrasted to the high level of success achieved by others, also suggests a careful examination of technical details.[6,9,10]

Additionally, although the anatomical boundaries for a transforaminal endoscopic fusion are the same as those utilized in a traditional endoscopic discectomy, the application to an interbody fusion construct requires several notable technical adaptations. These nuances arise from a fundamental difference between the goals of an endoscopic decompression and those of an endoscopic fusion. In the case of an endoscopic decompression, the surgeon is often working to remove a foraminal or paracentral disk fragment. This has led to the popularity of the "outside in" approach, whereby the working cannula is docked on the outer edge of the disk space.[11-14] Contrastingly with an endoscopic fusion, the goal is to perform an aggressive discectomy whereby the endplates are removed of any cartilaginous material and an interbody graft can be placed across the midline. These differing goals mandate an appropriate adjustment in terms of trajectory to the disk space.[5]

The contralateral decompression mandated by an endoscopic fusion also requires a constant awareness of anatomic structures—many of which cannot be visualized. Although this is also true of an endoscopic decompression, it is especially critical during an endoscopic fusion performed using a unilateral approach, where contralateral neural elements can be easily injured if a practitioner becomes disoriented or overly aggressive with a shallow approach angle.

The surgical tools for an endoscopic approach to fusion via Kambin's triangle must also be considered. While the endoscopic working channel is unchanged for either a decompression or a fusion, the fusion surgery adds an additional layer of complexity—namely, the deployment of an interbody graft. The chosen approach will then dictate the necessary surgical instruments. At our institution we favor a single portal, and therefore utilize

Key words
- Endoscopic fusion
- Kambin's triangle
- Lumbar fusion
- Percutaneous fusion
- Transforaminal fusion

Abbreviations and Acronyms
AP: Anterior-posterior
BMP: Bone morphogenetic protein
DRG: Dorsal root ganglion
SAP: Superior articular process

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Review and Technical Note

Uniportal Endoscopic Lumbar Interbody Fusion

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The cause of radiculopathy is the compression of the nerve root which can be secondary to sliding of the vertebra and reduced disc height. In some patients, decompression alone does not resolve this problem. We describe the uniportal endoscopic transforaminal lumbar interbody fusion technique. Full-endocopic foraminotomy and discectomy are followed by cage implementation and percutaneous instrumentation. The goal of this surgical method is decompression of nerve roots, segment stabilization, disc height, and sagittal alignment restoration. Uniportal endoscopic facet sparing transforaminal transkambin lumbar interbody fusion is a good surgical option to treat degenerative disc disease, mechanical instability, and spondylolisthesis. This method shows favourable clinical outcomes in selected patients.

Keywords: Lumbar interbody fusion, Endoscopic interbody fusion, Surgical technique, Spinal stenosis, Decompression, Transforaminal endoscopy

INTRODUCTION

Transforaminal transkambin interbody fusion is a routinely used and well-accepted technique for lumbar fusion. Goals of the transforaminal lumbar interbody fusion (TLIF) are the decompression of central canal stenosis or exiting nerve roots, enlargement of the neuroforamina through disc height restoration, segment stabilization, and sagittal alignment restoration with an appropriate anterior load bearing.

Conventional TLIF has drawbacks due to long skin incision, muscle stripping, epidural fibrosis, blood loss, and possible nerve root injury. Minimally invasive tissue-sparing approaches became the standard in many areas and are preferred over traditional open surgery in both hospitals and ambulatory surgery centers. Reduced destruction of soft tissue results in reduced postoperative pain and length of hospital stay.[1-3] Despite many advantages, the learning curve especially in endoscopic procedures is a frequently discussed issue.[4-7]

The use of full-endoscopic uniportal or biportal techniques with a rigid endoscope is becoming more popular for decompression of central and lateral recess stenosis.[8-13]

The tranforaminal region (Kambin triangle) is the key for the transforaminal fusion techniques as it defines the point of entry. The endoscopic transforaminal approach can potentially reduce the risk of uncontrolled bleeding, excessive blood loss, and the need for blood transfusion. The disc height determines the cranial and caudal dimension of the neuroforamen. Length of the pedicle, facet joint arthritis, and hypertrophic yellow ligament influence the size of the Kambin triangle.

Spinal stenosis, disc protrusion, or herniations as well as osteophytes on the endplates of the motion segment can cause a change in position of the neural structures. The traversing nerve root might be shifted anteriorly in spinal stenosis. In case of herniated discs, the exiting nerve root can be pushed to posterior, medial or lateral, depending on the location of the extruded disc material.

Wang et al.[14] report on an effective and safe transforaminal approach utilizing the endoscope to implant an expandable cage.

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Surgical Outcomes After Single-Level Endoscopic Transforaminal Lumbar Interbody Fusion: A Systematic Review and Meta-Analysis

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Abstract

Background and objective

Novel surgical advancements have introduced endoscopic operative techniques for low back surgery, including transforaminal lumbar interbody fusion (TLIF), which theoretically allows for improved decompression with minimal invasiveness. In addition, endoscopically performed TLIF has allowed for the use of local anesthesia as an alternative method to general anesthesia for patients. We aimed to evaluate the clinical outcomes in patients undergoing endoscopic TLIF and also compare the outcomes in patients undergoing general versus local anesthesia.

Methods

The databases of PubMed, Medline, Embase, and the Cochrane Library were queried for all studies involving patients undergoing endoscopic TLIF. After the extraction of the data and assessment of study quality via the Newcastle-Ottawa Scale, statistical analysis was performed with the R software (The R Foundation, Vienna, Austria) metafor package. The random-effects model was used as the data was largely heterogeneous (I^2 >50%).

Results

In total, 15 studies involving a total of 441 patients were selected for the final quantitative meta-analysis. The overall mean difference between the postoperative visual analog scale (VAS) leg scores and preoperative VAS scores was 3.45 (95% CI: 4.93-1.97, p: <0.01). Postoperative VAS low back scores revealed a mean difference of 3.36 (95% CI: 5.09-1.63, p: <0.01). The overall mean difference of ODI scores was 4.58 (95% CI: 6.76-2.40, p: <0.01). Mean blood loss was 136.32 mL and the mean operative time was 149.15 minutes. The mean length of stay postoperatively was lower in the local anesthesia group compared to the general anesthesia group (1.40 vs 5.99 days respectively). There were no outcome variables of patients undergoing general anesthesia versus local anesthesia that showed statistically significant differences in this analysis due to the small amount of data published on patients undergoing endoscopic TLIF with local anesthesia. In addition, the failure of studies in reporting standard deviations as data parameters further limited the quantitative analysis.

Conclusion

Endoscopic TLIF appears to be a viable option for patients undergoing lumbar interbody fusion. Initial data reveal that endoscopic TLIF with local anesthesia may offer patients outcomes similar to those in patients undergoing endoscopic TLIF with general anesthesia, with lower operative times and length of stay.

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Categories: Neurosurgery
Keywords: general anesthesia, endoscopic, tlif, fusion, transforaminal, lumbar, interbody, eras protocols, local anesthesia, minimally-invasive spine

Introduction

Lumbar interbody fusion has been used for over a century to treat a variety of neurosurgical conditions, including disc herniation, spinal instability, spondylolisthesis, spinal stenosis, deformity, trauma, malignancy, and infection [1]. First described by Albee and Hibbs in 1911, the fusion of the lumbar spine has been improved by advances in fusion instrumentation, innovative biologics, and new bone-grafting capabilities [1,2]. These advances have expanded the clinical utility of this procedure and greatly improved postoperative outcomes.

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LITERATURE REVIEW

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Clinical Results and Complications of Endoscopic Lumbar Interbody Fusion for Lumbar Degenerative Disease: A Meta-Analysis

Dong Hwa Heo[1], Dong Chan Lee[2], Hyeun Sung Kim[3], Choon Keun Park[2], Hungtae Chung[1]

Key words
- Endoscopy
- Fusion
- Lumbar
- Lumbar degenerative disease
- Minimally invasive surgery
- Transforaminal

Abbreviations and Acronyms
CI: Confidence interval
CT: Computed tomography
MCID: Minimal clinically important difference
MIS: Minimally invasive surgery
ODI: Oswestry Disability Index
OLIF: Oblique lumbar interbody fusion
PLIF: Posterior lumbar interbody fusion
TLIF: Transforaminal lumbar interbody fusion
VAS: Visual analog scale

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BACKGROUND: **Although endoscopic transforaminal lumbar interbody fusion (TLIF) may combine the advantages of minimally invasive fusion and endoscopic spine surgery, little evidence exists on endoscopic TLIF. This meta-analysis investigated the clinical results of endoscopic TLIF.**

METHODS: **We performed a systematic search of Web-based electronic databases to identify articles on endoscopic lumbar interbody fusion. Only studies of water-based endoscopic TLIF with pedicle screw fixation were included. We analyzed preoperative and postoperative scores for the Oswestry Disability Index (ODI) and visual analog scales (VASs) for back and leg pain to evaluate clinical efficacy. The minimal clinically important difference (MCID) of VAS and ODI was analyzed. We calculated differences in means and 95% confidence intervals and investigated indications for endoscopic TLIF, surgical approaches for endoscopic TLIF, the endoscopic systems that were used, and procedure-related complications.**

RESULTS: **Thirteen articles were included in this meta-analysis. Uniportal and biportal endoscopic systems were used. Six articles used the posterolateral approach and 7 used the trans-Kambin approach. Preoperative ODI and VAS scores for leg and back pain significantly improved after endoscopic TLIF with percutaneous pedicle screw fixation ($P = 0.00$). The ODI significantly improved by twice as much as the MCID. The mean change in the VAS for back and leg pain showed significant improvements over the MCID. The perioperative complications were usually minor.**

CONCLUSIONS: **The early clinical results of endoscopic TLIF with percutaneous pedicle screw fixation are favorable. However, long-term outcomes should be investigated and randomized controlled trials should be conducted.**

INTRODUCTION

In recent years, endoscopic lumbar interbody fusion surgery has been tried for the treatment of lumbar degenerative diseases, including lumbar stenosis, lumbar instability, foraminal stenosis, spondylolysis, spondylolisthesis, and instability.[1-5] The advantages of minimally invasive surgery (MIS) lumbar fusion, including endoscopic and microendoscopic approaches, are the preservation of normal tissue and rapid recovery after fusion procedures.[6-8] Recently, endoscopic lumbar interbody fusion surgery has been attempted instead of conventional fusion surgery or MIS lumbar fusion.[1,9-12]

There are many types of endoscopic lumbar interbody fusion procedures, including microendoscopic transforaminal lumbar interbody fusion (TLIF),[8,13] microendoscopic posterior lumbar interbody fusion (PLIF),[14] endoscopy-assisted oblique lumbar interbody fusion (OLIF),[15,16] biportal endoscopic TLIF,[6,17,18] and uniportal endoscopic TLIF.[10,19,20] Water medium-based endoscopic lumbar interbody fusion procedures have been tried most recently.[3,10,17,20-23]

There are 2 kinds of water-based endoscopic lumbar interbody fusion procedures: uniportal endoscopic TLIF[3,10,19,21,23] and biportal endoscopic TLIF.[2,17,18,24] Although uniportal and biportal endoscopic TLIF may combine the advantages of MIS fusion and endoscopic spine surgery,[2,19] little evidence on endoscopic TLIF has been reported. The purpose of this study was to analyze the clinical results of water-based biportal and uniportal endoscopic TLIF through a meta-analysis of previously published articles.

METHODS

A systemic search of Web-based electronic databases was performed to identify articles on endoscopic lumbar interbody fusion using PubMed, Cochrane Library, and Web of Science (Figure 1). We searched for articles on endoscopic lumbar interbody fusion using the search

P305: Enhanced Recovery Following Interbody Fusion by Transforaminal Endoscopic Techniques

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Introduction: In the past decade, transforaminal endoscopic spine surgery (TESS) has become increasingly commonly used for disc resection and foraminotomy. The transforaminal approach minimizes damage to the paraspinal muscles and should enhance patient recovery postsurgery. We aimed to evaluate the technical and clinical success of endoscopic disc resection and interbody cage fusion via a transforaminal approach. **Materials and Methods:** Forty patients (mean age 60 ± 10 years, 75 ± 14 kg, 10 males, 30 females) presenting with stenotic symptoms secondary to single-level disc protrusion and degenerative instability (Grade 1 spondylolisthesis) were admitted for surgery. Patients with significant lateral recess in-growth producing a "trefoil" canal were excluded. Median duration of symptoms was 48 months. Surgery was performed in all patients under general anesthesia in the prone position. Transforaminal discectomy removed prolapsed and central disc back to the end-plates. Titanium (Ti6Al4 V) trabecular cages (EndoLIF Oblique cage, joimax GmbH) were then inserted obliquely without graft. The operated level was stabilized further by a percutaneous pedicle screw/rod construct (Percusys joimax, GmbH or similar). Outcomes were collated with hospital stay and re-admission rates compared to those reported on the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) database for patients after posterior lumbar fusion (2005-2010: 1861 and 2011-15: 36,610 patients respectively). **Results:** Mean surgical time was 128 ± 57minutes and radiation dose area product 1166 ± 552 cGy·cm^2. There were no intraoperative complications and median hospital stay was 12 hours (range 4-120) compared with ACS-NSQIP of 2.9 ± 1 days. Two cages were inserted at L2/3, 5 at L3/4, 26 at L4/5 and 7 at L5/S1. Most cages were 30 mm × 11 mm × 12 mm size and mean blood loss was 150 mL. Disc height increased with instrumentation from 7.6 ± 1.9 mm to 10.5 ± 1.6 mm anterior, and from 4.9 ± 1.0 to 9.8 ± 1.7 mm posterior ($P < .001$). Preoperative ODI decreased from 50 ± 17 to 27 ± 20 at 6 months, back pain VAS (0-10) from 7.3 ± 2.2 to 3.3 ± 2.5 (both $P < .001$) and pain in the most affected leg from 5.9 ± 3.5 to 3.7 ± 3.0 ($P < .01$). One readmission for cage displacement at 4 months (2.5%) compared with a rate of 5.4% within 30 days on the ACS-NSQIP. **Conclusion:** Our results indicate that endoscopic interbody fusion via a transforaminal approach is safe and effective. Mean hospital stay was significantly less than that reported for other fusion methods. Randomized studies are still required to determine whether instrumentation and fusion are required over and above transforaminal endoscopic decompression alone.

Presented at Global Spine Congress Toronto, CN, 2019

ORIGINAL ARTICLE

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Fully Endoscopic Lumbar Laminectomy and Transforaminal Lumbar Interbody Fusion Under Local Anesthesia with Conscious Sedation: A Case Series

Jian Shen

OBJECTIVE: **To evaluate clinical outcomes of a case series of 18 patients who underwent fully endoscopic foraminotomy, laminectomy, and transforaminal lumbar interbody fusion combined with percutaneous screw fixation.**

METHODS: **This was a retrospective case series of a single surgeon. Average age of patients was 66 years (range, 51–82 years). All patients had grade I or grade II spondylolisthesis and severe central canal stenosis. Patients underwent endoscopic transforaminal access through Kambin triangle for foraminotomy, discectomy, endplate preparation, and interbody fusion, which was followed by fully endoscopic unilateral laminectomy and bilateral decompression and percutaneous pedicle screw and connecting rod placement.**

RESULTS: **All procedures were successful without conversion to open surgery. Mean operative time was 168 minutes, and average estimated blood loss was 36 mL. Mean length of hospital stay was 1.2 days. There were no intraoperative or postoperative complications. Comparison of preoperative and final clinical metrics demonstrated that average Oswestry Disability Index score improved from 48 ± 14 (range, 37–61) to 13 ± 11 (range, 0–27) ($P < 0.001$). Average visual analog scale back pain score improved from 8.1 ± 2.0 (range, 6.8–10.0) to 1.8 ± 0.9 (range, 0.0–3.5) ($P < 0.001$). Oswestry Disability Index and visual analog scale back pain scores at last follow-up showed 73% and 78% improvement, respectively, from the preoperative period. There were no cases of nonunion clinically or radiographically on final follow-up of >12 months.**

CONCLUSIONS: **Fully endoscopic laminectomy and interbody fusion under conscious sedation is an effective treatment with minimal complications for patients with lumbar spondylolisthesis and severe spinal stenosis.**

INTRODUCTION

Interbody spinal fusion with cages was first described by Bagby[1] and has been performed to treat a variety of different spine conditions. The transforaminal corridor in the lumbar spine allows access to the traversing and exiting nerve roots, the thecal sac, and the intervertebral disc space. The transforaminal lumbar interbody fusion (TLIF) approach was developed by Harms and Jeszenszky.[2] In open surgery, muscle degeneration occurs secondary to prolonged muscle traction.[3] Foley et al.[4] developed TLIF using minimally invasive surgery (MIS) employing a tubular retractor, which is beneficial for preserving the back muscles[5] and has been shown to have comparable results to traditional open TLIF with the benefits of a shorter hospital stay, less blood loss, and shorter recovery time. However, long tubular retractors are still difficult to work with in a deep operative field with limited working space. Recently, with the combination of endoscopic visualization and expandable cage technology, an endoscopic lumbar interbody fusion technique was developed.[6-8] Wang and Grossman[9] reported a case series of endoscopic TLIF without general anesthesia. Complications of TLIF, including exiting nerve root injury, a high rate of cage migration, and a relatively long delay to obtain fusion, have been reported.[7] In this case series, a fully endoscopic technique was used for foraminotomy, laminectomy, discectomy, and endplate preparation combined with percutaneous screw fixation to achieve bilateral direct decompression and interbody fusion.

Key words
- Fully endoscopic
- Interbody fusion
- Lumbar laminectomy

Abbreviations and Acronyms
MIS: Minimally invasive surgery
ODI: Oswestry Disability Index
TLIF: Transforaminal lumbar interbody fusion
VAS: Visual analog scale

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Research Article

Percutaneous Endoscopic Lumbar Interbody Fusion: Technical Note and Preliminary Clinical Experience with 2-Year Follow-Up

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Objective. Endoscopic surgeries have been attempted in the field of lumbar decompression and fusion surgery in the past decade. Percutaneous endoscopic lumbar interbody fusion (PELIF) is a new-emerging technique taking advantages of an anatomical (Kambin's triangle) to achieve simultaneous decompression and fusion under endoscopic visualization. The purpose of this study is to evaluate the feasibility and safety of PELIF technique with general anesthesia and neuromonitoring. *Methods*. The authors present the details of PELIF technique with general anesthesia and neuromonitoring. The first 7 consecutive patients treated with minimum of 2 year's follow-up were included. Clinical outcomes were assessed by visual analog scale (VAS) for back and leg pain, Oswestry Disability Index (ODI) scores, and the Short Form-36 health survey questionnaire (SF-36) in the immediate preoperative period and during the follow-up period. *Results*. All patients underwent single-level PELIF surgery successfully and without conversion to open surgery. The average age was 56.0±13.0 years. All patients had Grade I degenerative/isthmic spondylolisthesis and 4 patients coexisted with disc herniation. The mean operative time was 167.5±30.9 minutes, and intraoperative blood loss was 70.0±24.5 ml. Postoperative drainage volume was 24.5±18.3 ml. The differences in the VAS scores for low back pain and leg pain between preoperative and follow-up were significant ($P<0.05$). The SF-36 Physical Component Summary (PCS) improved from 38.83±4.17 to 55.67±2.58 ($P<0.001$). The SF-36 Mental Component Summary (MCS) improved from 43.83±3.13 to 57.50±5.36 ($P=0.001$). The ODI score improvement rate was 33.7±3.7 %. All cases demonstrated radiopaque graft in the intervertebral disc space consistent with solid arthrodesis. *Conclusions*. PELIF technique seems to be a promising surgical technique for selected appropriate patients, with the minimal invasive advantages in decreased blood, shortage of ambulation time, and hospital stay, compared with MIS-TLIF. Because of limited Kambin's triangle space and the exiting nerve root nearby, PELIF is still a challenging technique. Future advancement and development in instrument and cage design are vital for application and popularization of this technique. Prospective, randomized, controlled studies with large sample size on PELIF technique are still needed to prove its safety, efficacy, and minimal invasive advantages.

1. Introduction

Conventional open posterior fusion surgery of the lumbar spine, though addressing the pathology adequately, may—depending on significant surgical destruction of posterior muscular-ligamentous complex—lead to muscular atrophy, postoperative back pain, and functional disability [1–4]. Therefore, several factors which include, but are not limited to, the desire to minimize complications and hospitalization; the desire to facilitate an early return to productive hospitalization; the desire for elderly patients to return to active premorbid status; and the desire to decrease the cost of medical care have combined to facilitate the paradigm shift from open to minimally invasive spine surgery (MIS) [5, 6].

Currently, there are many types of MIS lumbar fusion surgery, including transforaminal lumbar interbody fusion (TLIF), anterior lumbar interbody fusion (ALIF), extreme lateral lumbar interbody fusion (XLIF), and posterior lumbar interbody fusion (PLIF) [2, 7]. All these procedures, though sharing the label of MIS, have different attributes in terms of

Reduced Acute Care Costs With the ERAS® Minimally Invasive Transforaminal Lumbar Interbody Fusion Compared With Conventional Minimally Invasive Transforaminal Lumbar Interbody Fusion

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BACKGROUND: Enhancing Recovery After Surgery (ERAS®) programs have been widely adopted throughout the world, but not in spinal surgery. In this report, we review the implementation of a "fast track" surgery for lumbar fusion and its effect on acute care hospitalization costs.

OBJECTIVE: To determine if a "fast track" surgery methodology results in acute care cost savings.

METHODS: Thirty-eight consecutive ERAS patients were compared with patients undergoing conventional minimally invasive transforaminal lumbar interbody fusion. Differences between these groups included the use of endoscopic decompression, injections of liposomal bupivacaine, and performing the surgery under sedation in the ERAS® group.

RESULTS: Patients had similar medical comorbidities (2.02 vs 2 for ERAS® and comparator groups, respectively; $P = .458$). Body mass index was similar (26.5 vs 27.0; $P = .329$). ERAS® patients were older (65 vs 59 yr, $P = .031$). Both groups had excellent clinical results with an improvement of 23% and 24%, respectively. Intraoperative blood loss was less (68 ± 31 cc vs 231 ± 73, $P < 0.001$). Length of stay was also less with ERAS® surgery, at a mean of 1.23 ± 0.8 d vs 3.9 ± 1.1 d ($P = 0.009$). When comparing ERAS® surgery to standard minimally invasive transforaminal lumbar interbody fusion, the total cost for the acute care hospitalization was \$19 212 vs \$22 656, respectively ($P < 0.001$). This reflected an average of \$3444 in savings, which was a 15.2% reduction.

CONCLUSION: ERAS® programs for spinal fusion surgery have the potential to reduce the costs of acute care. This is made possible by leveraging less invasive interventions to minimize soft tissue damage.

KEY WORDS: Minimally invasive, Cost, Economic, Spine, QALY, Anesthesia, Pedicle screw, Percutaneous, ERAS, Enhancing recovery, Exparel

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The American health care system is currently undergoing a major overhaul. The changes occurring today are the result of numerous economic, political, and social forces that are largely not under the control of physicians and surgeons. Thus, it is anticipated that in the near future, major restructuring of how spinal care is bought and paid for will occur. Many of these changes have already begun to occur glacially, including reduced reimbursements for care, denials for payment of surgical procedures, demands for documentation of results, and improvement in quality, to name a few.

As stakeholders in this changing environment, surgeons should be proactive in this process. While the Affordable Care Act's call for increased access, reduced costs, and higher quality are

ABBREVIATIONS: CT, computed tomography; **ERAS,** Enhancing Recovery After Surgery; **ICU,** intensive care unit; **MIS TLIF,** minimally invasive transforaminal lumbar interbody fusion

ENDOSCOPIC PAIN THERAPY

ASIAN SPINE JOURNAL
Clinical Study
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Endoscopic Facet Joint Denervation on the Lumbar Spine: A Retrospective Analysis

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Study Design: This single-center retrospective study analyzed patients with chronic low back pain (CLBP) who underwent endoscopic facet joint denervation (EFJD) between April 2018 and May 2019.
Purpose: This study was designed to investigate the effectiveness of EFJD in treating CLBP.
Overview of Literature: CLBP is a challenging burden to healthcare systems worldwide. As up to 45% of cases originate from the lumbar facet joints, sufficient therapy strategies must be developed. EFJD offers a precise depiction of the dorsal medial ramus and the facet joint capsule.
Methods: In this study, 64 patients who underwent EFJD were included. The main outcome of interest was patients' Visual Analog Scale (VAS) pain score, which was recorded at 3-time points (i.e., before operation and 6 weeks and 12 months after surgery).
Results: EFJD effectively reduced the VAS pain scores by 58% in the short term (6 weeks) and 38% in the long term (12 months). Patients with isolated facet joint osteoarthritis benefited more (p<0.001).
Conclusions: EFJD is a good treatment alternative for CLBP originating from the facet joints, particularly in patients with isolated facet joint osteoarthritis. Moreover, this method can address not only the dorsal medial ramus but also the surrounding tissue (e.g., facet joint capsule, facet joint effusion, and osteophytes) as the origin of CLBP.

Keywords: Endoscopic facet joint denervation; Chronic low back pain; Facet joint osteoarthritis; Dorsal medial ramus; Facet joint effusion; Facet joint capsule

Introduction

Low back pain (LBP) is the most common reason for individuals to consult a practitioner in Western countries and therefore increases the burden on healthcare systems [1]. It is assumed that 15%–45% of cases of LBP originate from the lumbar facet joint (FJ) [2]. The lumbar FJ is a true synovial joint and consists of the processus articularis

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Endoscopic Rhizotomy for Facetogenic Back Pain: A Review of the History, Financial Considerations, Patient Selection Criteria, and Clinical Outcomes

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Key words
- Dorsal medial branch
- Endoscopic rhizotomy
- Facetogenic back pain
- Lumbar facet joint
- Radiofrequency ablation
- Rhizotomy

Abbreviations and Acronyms
3DNER: Three-dimensional navigated endoscopic rhizotomy
CBP: Chronic back pain
DMB: Dorsal medial branch
ER: Endoscopic rhizotomy
FJ: Facet joint
LFJP: Lumbar facet joint pain
NSAIDs: Nonsteroidal anti-inflammatory drugs
RFA: Radiofrequency ablation
VR: Virtual reality

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BACKGROUND: **Chronic back pain (CBP) is a condition that places a considerable burden on society, with several million people affected in the United States alone. Treatment options to address this problem and relieve CBP are constantly evolving, and one of the most promising treatment modalities for CBP that is refractory to conservative treatment options is endoscopic rhizotomy (ER).**

METHODS: **A thorough search of the PubMed (MEDLINE) database was conducted to assess the full progression of ER from its earliest uses to present day in a historical narrative review of ER, with treatment of facetogenic pain as a model pathology.**

RESULTS: **ER allows for direct visualization and ablation of sensory branches of the dorsal ramus to provide pain relief in up to 80% of patients faced with refractory CBP. This technique has been built upon since the early 20th century, and the novel endoscopic approach continues to gain popularity among physicians. Benefits of ER include superior postoperative median pain-free duration compared with traditional percutaneous radiofrequency ablation, as well as direct visualization of regional anatomy. Patient selection criteria for the procedure and a modest list of contraindications allow the use of ER as a viable treatment option for a significant population of patients suffering from CBP. Potential barriers to ER include high cost of the procedure, longer intraoperative time, and expensive proprietary equipment.**

CONCLUSIONS: **ER is an effective treatment for refractory CBP with notable advantages. As the technology and popularity of this procedure progress, improvements in the cost, training, and intraoperative time may make it a favorable alternative to the current standard of care.**

INTRODUCTION

Chronic back pain (CBP) is one of the most common chief complaints among the adult population. Contributing to high healthcare costs, CBP is defined as pain that lasts 12 weeks or longer.[1,2] The prevalence of CBP among those between 20 and 69 years of age is 13.1%, with one study showing patients in their fifth decade having the highest likelihood of CBP, at 27.4%.[3] Although the prevalence of CBP is high, the ability to accurately diagnose it is relatively low.[4,5] Consequentially, conservative treatment for CBP is typically broad, with the use of nonsteroidal anti-inflammatory drugs (NSAIDs), glucocorticoids,[6] and opioids.[7]

In cases of conservative therapy-refractory pain, surgical options become the standard of care.[4] Traditional measures, such as spinal fusion surgery for the treatment of chronic low back pain, lead to significant morbidity and involve a surgeon treating a symptom without a clearly defined anatomic defect.[4] Traditional percutaneous radiofrequency ablation (RFA) is a much less invasive option but does not allow direct visualization of the dorsal medial branch (DMB).[8] Moreover, the pain relief provided for these patients is often short-lived, with studies showing a considerable number of patients with pain at 1-year follow up.[9,10] For this reason, escalating therapy in the form of multiple percutaneous RFAs is necessary for some patients, such as patients with anatomic variations.[10]

Endoscopic rhizotomy (ER) is now a viable treatment option for patients with chronic low back pain lacking a radiographically defined anatomic defect.[11] Using this technique, surgeons insert an endoscope to view the DMB of the affected zygapophyseal joint and can achieve DMB denervation using RFA.

Therapeutic Advances in Musculoskeletal Disease

Original Research

Endoscopic radiofrequency facet joint treatment in patients with low back pain: technique and long-term results. A prospective cohort study

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Abstract

Aims: The aim of the study was to evaluate the efficacy of endoscopic rhizotomy (ER) for denervation of lumbar facet joints in patients with chronic low back pain (LBP) due to facet joint syndrome (FJS).

Methods: A total of 50 consecutive patients suffering from chronic LBP due to facet joints were screened to be treated with ER. The patients participating in the study had a 2-year follow up. Numeric Rating Scale (NRS) and Oswestry Disability Index (ODI) were assessed in the preoperative and postoperative period. To evaluate secondary endpoints, patients were divided into groups. One group included the patients previously treated with percutaneous radiofrequency (RF). The other group comprised patients at their first interventional treatment. We also compared patients dividing them by age and by number of joints treated, trying to elucidate if these parameters could be predictive of effectiveness of the procedure.

Results: All patients had a reduction in NRS and an improvement in ODI. NRS was reduced significantly after 1 month and remained the same until the end of the study. ODI was significantly improved from T1 (1 month after surgery) up to T7 (end of the study). The improvements did not differ whether already treated with percutaneous rhizotomy or not. Patients less than 60 years or with 1–2 joints treated had better improvement compared with the others.

Conclusion: The results obtained demonstrate that ER for denervation of the facet joint is an effective treatment in patients with chronic LBP, with consistent and stable results at 2-year follow up. The technique has a rapid learning curve and no major complications occurred. Moreover, the previous percutaneous RF treatment had no influence on the results obtained with endoscopic technique. There is evidence that best results are obtained in younger patients and/or in patients with 1–2 joints treated.

Keywords: endoscopic radiofrequency, facet joint syndrome, low back pain, medial branch radiofrequency, radiofrequency neurolesion

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Lay summary

Low-back pain has facet joints inflammation or degeneration as pain generator in 20–40% of cases. Nervous lesion of the dorsal ramus innervating the facet joints has been shown as an efficacious treatment to obtain good analgesia. Percutaneous techniques have provided short term results for several reasons. This research aimed to see whether endoscopic denervation, which guarantees a more precise approach to anatomical structure, would result in more durable results. The study conducted on 40 patients has made it clear that this approach gives significant analgesia for at least 2 years, which was the time of patient follow up.

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RESEARCH ARTICLE Open Access

Endoscopic rhizotomy for chronic lumbar zygapophysial joint pain

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Abstract

Background: Chronic lumbar zygapophysial joint pain is a common cause of chronic low back pain. Percutaneous radiofrequency ablation (RFA) is one of the effective management options; however, the results from the traditional RFA need to be improved in certain cases. The aim of this study is to investigate the effect of percutaneous radiofrequency ablation under endoscopic guidance (ERFA) for chronic low back pain secondary to facet joint arthritis.

Methods: This is a prospective study enrolled 60 patients. The cases were randomized into two groups: 30 patients in the control group underwent traditional percutaneous radiofrequency ablation, others underwent ERFA. The lumbar visual analog scale (VAS), MacNab score, and postoperative complications were used to evaluate the outcomes. All outcome assessments were performed at postoperative 1 day, 1 month, 3 months, 6 months, and 12 months.

Results: There was no difference between the two groups in preoperative VAS ($P > 0.05$). VAS scores, except the postoperative first day, in all other postoperative time points were significantly lower than preoperative values each in both groups ($P < 0.05$). There was no significant difference between the two groups in VAS at 1 day, 1 month, and 3 months after surgery ($P > 0.05$). However, the EFRA demonstrated significant benefits at the time points of 3 months and 6 months ($P > 0.05$). The MacNab scores of 1-year follow-up in the ERFA group were higher than that in the control group ($P < 0.05$). The incidence of complications in the ERFA group was significantly less than that in the control group ($P < 0.05$).

Conclusions: ERFA may achieve more accurate and definite denervation on the nerves, which leads to longer lasting pain relief.

Keywords: Endoscope, Lumbar medial branch nerves, Medial branches of the dorsal rami, Lumbar facet syndrome, Chronic low back pain

Background

The lumbar zygapophysial joint is a synovial joint between two adjacent vertebrae. The joint capsule and surrounding tissues are densely covered with nerve terminal which mainly originate from the lumbar dorsal medial branch [1].

Chronic lumbar zygapophysial joint pain refers to low back pain with a course longer than 3 months accompanied by radiating pain down to the buttocks and legs [2]. Medial branch block (MBB) is a reliable approach to confirm facet joints as the source of back pain [3].

Percutaneous radiofrequency nerve ablation is an effective management with the problem of neural anatomic variation and regeneration [4]. This study was designed to evaluate the efficacy and safety of radiofrequency ablation under endoscopic guidance (ERFA) in the treatment of chronic lumbar zygapophysial joint pain.

Methods

Inclusion criteria are as follows: (1) chronic low back pain with a course longer than 3 months; (2) failed 2

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Endoscopic facet joint denervation for treatment of chronic lower back pain

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ABSTRACT

Objectives: Percutaneous radiofrequency is an established method for treatment of chronic low back pain of intervertebral facet etiology. Endoscopic techniques have the advantage of visualization of the facet joint and the dorsal medial ramus and thus allow for more accurate denervation. It was thus hypothesized that pain reduction is vaster and longer enduring.

Patients and Methods: A total of 98 consecutive patients that underwent endoscopic facet joint denervation (EFJD) were included in this study. Prior to intervention and for follow-up, patients were asked to complete VAS_{pain}, ODI, COMI and EQ5D questionnaires.

Results: VAS_{pain} was reduced significantly (EFJD: $p < 0.001$) at last follow-up. Values for ODI, COMI and EQ5D showed significant improvements towards subjective well-being at last follow-up.

Conclusion: EFJD is a promising technique for the treatment of facet joint syndrome caused CLBP as it contributes to sustaining significant pain reduction and improvement of subjective quality of life parameters.

1. Introduction

Chronic low back pain (CLBP) has a life time prevalence reported to be as high as 85% [1]. As CLBP is associated with depression, immobilization, deactivation and limitation to participate on daily life, it does not only yield individual suffering but is of tremendous social and economic importance [9].

Although symptoms may be similar, CLBP can be caused by malfunction or structural deficits of different anatomical structures such as lumbar intervertebral discs, nerve roots, fascia, spinal ligaments, osteophytes and muscles. In the majority of cases, however, degenerated lumbar facet (zygapophyseal) joints account for the pain [21].

The treatment of CLBP due to facet joint (FJ) degeneration is usually initiated by conservative treatment procedures like physiotherapy and manual treatment. Eventually, psychological therapy and pharmacological/ analgesic measures are indicated. In clinical routine, periarticular FJ infiltration with steroids (e.g. cortisone) and local anesthetics (e.g. bupivacaine) are used for diagnostic and therapeutic purposes although the effectiveness of the latter remains questionable [16]. If patients reported relief of pain after infiltration, percutaneous radio-frequency ablation (PRFA) of the dorsal medial branch yields a better success rate [2]. Alternatively and only recently, the dorsal medial branch, which is innervating the (hypertrophic) FJ capsule, can be ablated endoscopically [24].

While PRFA is a well-established and described treatment procedure, there is only limited evidence on endoscopic techniques. This, however, is of special interest as endoscopic facet joint denervation (EFJD) allows for full visualization and selective ablation of the dorsal medial branch [7].

This study was set up to investigate clinical outcome parameters in a large cohort of patients that underwent EFJD and to compare EFJD results with PRFA results from literature.

2. Material and methods

In the time between 2015 and 2017 a total of 107 consecutive and eligible patients undergoing EFJD in our institution were included in this study.

2.1. Ethics

The study was approved by the institutional ethics committee.

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Technical Note

Endoscopic Sacrolumbar Facet Joint Denervation in Osteoarthritic and Degenerated Zygapophyseal Joints

Sebastian G. Walter, M.D., Frank Alexander Schildberg, Ph.D., and Yorck Rommelspacher, M.D.

Abstract: Chronic low-back pain (CLBP) has an increasing incidence and yields a tremendous health economic burden. There are different anatomic structures that may be responsible for CLBP, such as lumbar intervertebral discs, sacroiliac joints, nerve root dura, fascia, ligaments, and muscles. However, to a large extent, CLBP is associated with structural changes in and around the facet (zygapophyseal) joint. If conservative treatment strategies fail, symptoms and pain can effectively be reduced by denervation or rhizotomy of the medial branch of the dorsal ramus of the spinal nerve through radiofrequency ablation. In this technical description with video, we present an endoscopic technique for radiofrequency rhizotomy. This technique has the advantage of directly visualizing the facet joint as well as its surrounding structures including the medial branches.

Chronic low-back pain (CLBP) has a prevalence of 3% to 10% and is associated with depression, immobilization, and inability to work.[1] This is particularly true for elderly patients, and thus the incidence of CLBP will further increase for demographic reasons.[2] Therefore, CLBP is of great health economic relevance.[3]

There are different structures that may be responsible for CLBP, such as lumbar intervertebral discs, sacroiliac joints, nerve root dura, fascia, ligaments, and muscles. However, the lumbar facet (zygapophyseal) joints (FJs) are a major reason for CLBP.[4]

According to the National Institute for Health and Care Excellence, patients with CLBP should primarily be provided with information and advice to self-manage at all steps of the treatment pathway and should be encouraged to return to work and normal activities of daily living. In cases of specific episodes of low-back pain, group exercise programs, manual treatment, and psychological therapy should be considered. If these measures fail, pharmacologic therapy and concomitant physical and psychological therapy are indicated. In cases of therapy-refractory pain, radiofrequency (RF) ablation of the dorsal medial branch and surgical approaches such as fusion become relevant.[5]

Although there is almost no evidence of the effectiveness of intra-articular or periarticular FJ infiltration as treatment (steroids [e.g., cortisone] and local anesthetics [e.g., bupivacaine]), it remains a widespread standard.[4,6,7] Yet, there is evidence that this technique may serve accurate diagnostic purposes if performed correctly.[8] Thus, positive infiltration (i.e., essential pain relief within 3 hours after infiltration) is commonly performed before RF thermocoagulation of the FJ.

RF can be performed either under radiologic control or endoscopically. The latter poses several advantages that will be explained later.

Surgical Technique

Informed consent was obtained from the patient involved in this study. Before intervention, patients have to respond to periarticular infiltration (medial branch of the dorsal ramus of the spinal nerve blockade) with symptomatic pain relief within 3 hours after injection. Furthermore, other pathologies (vertebral body fractures, malignancies, and so on) have to be excluded clinically and radiologically before FJ denervation. In addition, contraindications have to be assessed preoperatively (Table 1).

For surgery, patients undergo local anesthesia with concomitant sedation or undergo general anesthesia.

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Clinical Study

Endoscopic Radiofrequency Ablation of the Sacroiliac Joint Complex in the Treatment of Chronic Low Back Pain: A Preliminary Study of Feasibility and Efficacy of a Novel Technique

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Background. Radiofrequency ablation (RFA) is a less invasive technique for treatment of sacroiliac joint (SIJ) pain. *Objective*. To evaluate the feasibility and efficacy of endoscope-guided RFA for the treatment of CLBP from the SIJ complex. *Methods*. In this retrospective study, the medical records of 17 patients who underwent endoscope-guided RFA of the SIJ complex were reviewed. A bipolar radiofrequency probe was used to lesion the posterior capsule of the SIJ as well as the lateral branches of S1, S2, S3, and the L5 dorsal ramus in multiple locations. We visualized the ablation area using endoscope. We assessed visual analogue scale (VAS) and the Oswestry disability index (ODI) preoperatively, immediately postop, and at 1-, 3-, and 6-month postop outpatient clinic visits. Patient satisfaction of the procedure was assessed in percentages. *Results*. The mean duration of operation was 20 to 50 minutes. The mean VAS and the ODI scores decreased significantly immediately after the procedure and were kept significantly lower than baseline levels during the follow-up periods. No complications occurred perioperatively and during the follow-up periods. 88.6% of patients were satisfied with the procedure. *Conclusions*. Our preliminary results suggest that endoscope-guided RFA may be alternative option to treat CLBP secondary to SIJ complex.

1. Introduction

Chronic low back pain (CLBP) that lasts for six months or longer is estimated to occur in 60–80% of the general population in their lifetime [1] and is associated with substantial healthcare costs. The sacroiliac joint (SIJ) complex is one of the major sources of chronic low back pain, accounting for around 10–33% of the total number of CLBP cases [1–5]. The SIJ complex consists of the joint capsule, various muscular and ligamentous structures overlying the joint, and neural structures that innervate the SIJ [6]. Current treatment options for SIJ complex-mediated CLBP include intra-articular and periarticular steroid injections, SIJ fusion, and radiofrequency ablation of the neural structures innervating the SIJ. Intra-articular injection of the joint using a mixture of steroids and local anesthetics is a simple procedure and provides quick pain relief, but the effect is short-lived [7]. In addition, SIJ fusion is an invasive surgical procedure that should be reserved for cases refractory to nonoperative measures [8, 9]. On the other hand, radiofrequency ablation (RFA) of the SIJ complex offers longer-lasting effects and has gained wide attention in the last decade [10], with increasing numbers of reports advocating for its efficacy [7, 11–14]. RFA is usually performed under fluoroscopic guidance. The target structures are the lateral branches of the sacral rami, the dorsal ramus of L5, and the ligamentous structures overlying the joint. However, variations in the pattern of innervation exist between individuals, which provides a challenge for surgeons [15]. Due to these variations, different RFA target locations and techniques have been proposed to overcome

COMPLICATIONS

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Clinical Study

Full-endoscopic spine surgery diminishes surgical site infections – a propensity score-matched analysis

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Abstract

BACKGROUND CONTEXT: Surgical site infections (SSI) are one the most frequent and costly complications following spinal surgery. The SSI rates of different surgical approaches need to be analyzed to successfully minimize SSI occurrence.

PURPOSE: The purpose of this study was to define the rate of SSIs in patients undergoing full-endoscopic spine surgery (FESS) and then to compare this rate against a propensity score-matched cohort from the National Surgical Quality Improvement Program (NSQIP) database.

DESIGN: This is a retrospective multicenter cohort study using a propensity score-matched analysis of prospectively maintained databases.

PATIENT SAMPLE: One thousand two hundred seventy-seven non-instrumented FESS cases between 2015 and 2021 were selected for analysis. In the nonendoscopic NSQIP cohort we selected data of 55,882 patients.

OUTCOME MEASURES: The occurrence of any SSI was the primary outcome. We also collected any other perioperative complications, demographic data, comorbidities, operative details, history of smoking, and chronic steroid intake.

METHODS: All FESS cases from a multi-institutional group that underwent surgery from 2015 to 2021 were identified for analysis. A cohort of cases for comparison was identified from the NSQIP database using Current Procedural Terminology of nonendoscopic cervical, thoracic, and lumbar procedures from 2015 to 2019. Trauma cases as well as arthrodesis procedures, surgeries to treat pathologies affecting more than 4 levels or spine tumors that required surgical treatment were excluded. In addition, nonelective cases, and patients with wounds worse than class 1 were also not

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Abbreviations: FESS, full-endoscopic spine surgery; SSI, surgical site infection; MISS, minimally invasive spinal surgery

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Contraindications and Complications of Full Endoscopic Lumbar Decompression for Lumbar Spinal Stenosis: A Systematic Review

Chang-Il Ju, Pius Kim, Sang-Woo Ha, Seok-Won Kim, Seung-Myung Lee

■ OBJECTIVE: **The purpose of this study was to suggest appropriate indications and contraindications for full endoscopic surgery and to predict the prognosis for the incidence of complications by reviewing the literature on full endoscopic lumbar decompression for various spinal stenoses and systematically analyzing the contraindications and complications of endoscopic surgery.**

■ METHODS: **We searched the PubMed/MEDLINE database to identify articles on full endoscopic decompression for lumbar spinal stenosis. The levels of evidence in all studies were classified according to the method adopted by the North American Spine Society (NASS) 2005. Full endoscopic lumbar decompression was divided into interlaminar and transforaminal decompressions. We selected articles that contained preoperative contraindications and complications during and after surgery. We analyzed the evidence level and classified the prescribed contraindications and complications according to the literature.**

■ RESULTS: **We identified 362 articles, of which 57 met our criteria, with evidence ranging from levels I to V. After reviewing the literature on full endoscopic lumbar decompression, pure back pain without neurogenic symptoms and instability/deformities requiring stabilization were found to be contraindications. Also, in transforaminal decompression, central stenosis or complex foraminal stenoses were contraindications. Dysesthesia (most common), untreated pain, dural tear, disc herniation, infection, incomplete decompression, and other complications have been reported as complications of transforaminal decompression.**

On the other hand, dural tear (most common), epidural hematoma, transient dysesthesia, untreated pain, motor weakness, and other complications have been reported in interlaminar decompression.

■ CONCLUSIONS: **Full endoscopic lumbar surgery, including transforaminal and interlaminar decompression, is a safe and effective surgical option for treating lumbar spinal stenosis; however, it is important to select the transforaminal or interlaminar approach according to the indication.**

INTRODUCTION

With the development of endoscopic lumbar surgery technology, it has become possible to treat various lumbar degenerative diseases such as lumbar spinal stenosis, foraminal stenosis, and lumbar disc herniation with endoscopic surgery. However, as the indications for full endoscopic spinal surgery expand, more advanced techniques are required. With these developments, the indications for surgery have greatly expanded, but the incidence of complications has also increased.

Lumbar spinal stenosis is a common lumbar degenerative disease characterized by narrowing of the spinal canal, leading to radicular leg pain, back pain, and neurological intermittent claudication. Hypertrophy of the yellow ligament, articular process, and disc herniation are the main causes that aggravate the clinical symptoms of lumbar stenosis. Nerve compression due to these degenerative changes manifests as lower back pain and

Key words
- Complication
- Contraindication
- Full endoscopic lumbar decompression
- Interlaminar
- Lumbar spinal stenosis
- Transforaminal

Abbreviations and Acronyms
NASS: North American Spine Society
PRISMA: Preferred Reporting Items for Systematic Review and Meta-Analysis
RCT: Randomized controlled trial

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Complications of Full-Endoscopic Lumbar Discectomy versus Open Lumbar Microdiscectomy: A Systematic Review and Meta-Analysis

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■ OBJECTIVE: **Endoscopic lumbar discectomy has been an alternative for treating lumbar disc herniation. Evidence-based study for the benefit zone of full-endoscopic lumbar discectomy (FELD) is necessary. The study compared the complication risks between the FELD and open discectomy or microdiscectomy.**

■ METHODS: **The literature search was from 4 online databases for randomized controlled trials (RCTs) and cohort studies. The meta-analysis of different study designs was conducted separately. Complication rates were considered primary outcomes, and the recurrence and revision rates were considered secondary outcomes.**

■ RESULTS: **Six RCTs and thirteen cohort studies met the eligibility criteria. The meta-analysis was conducted separately. From the pooled RCT meta-analysis, the overall complication rates of FELD and open discectomy/microdiscectomy were 5.5% and 10.4%, respectively. The moderate-quality evidence suggested that FELD had a lower risk of overall complications (risk ratio [RR] = 0.55, 95% confidence interval [CI] = 0.31–0.98). There was no significant difference in specific complications and recurrence. The analysis of cohort studies revealed no significant difference in overall complications, but there was significant heterogeneity in the results. The risk of dural injury was significantly lower for FELD (RR = 0.46, 95% CI = 0.22–0.96). The pooled meta-analysis from cohort studies suggested a higher risk of transient dysesthesia (RR = 3.70, 95% CI = 1.54–8.89), residual fragment (RR = 5.29, 95% CI = 2.67–10.45), and revision surgeries (RR = 1.53, 95% CI = 1.12–2.08) for FELD.**

■ CONCLUSIONS: **The current evidence showed a lower risk of overall complications for FELD. The quality of evidence was moderate to low, and the risk of bias from the primary literature should be concerned.**

INTRODUCTION

Lumbar disc herniation (LDH) is a common etiology of chronic low back pain with radiating leg pain.[1] LDH causes a significant burden on health care services and the economy worldwide.[2,3] Patients with symptoms refractory to conservative therapy for at least 6 weeks are candidates for surgical intervention.[4] The goal of the operation is to relieve nerve root compression by resection of the herniated lumbar disc.[5,6] Open discectomy (OD) and microdiscectomy (MD) are 2 similar procedures with the only difference of visual enhancement with a microscope or loupes during discectomy. OD and MD collectively produce excellent short-term clinical

Key words
- Complications
- Endoscopic discectomy
- Lumbar disc herniation
- Microdiscectomy
- Recurrence

Abbreviations and Acronyms
CI: Confidence interval
FELD: Full-endoscopic lumbar discectomy
LDH: Lumbar disc herniation
MD: Microdiscectomy
MISS: Minimally invasive spine surgery
NOS: Newcastle-Ottawa Quality Assessment Scale
OD: Open discectomy
RCT: Randomized controlled trial
RR: Risk ratio

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Chao-Chun Yang and Chien-Min Chen had equal contribution to the paper and were co—first authors.

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ORIGINAL PAPER

Comparison of hidden blood loss and clinical efficacy of percutaneous endoscopic transforaminal lumbar interbody fusion and minimally invasive transforaminal lumbar interbody fusion

Meng Ge[1,2] · Yuan Zhang[2,3] · Hang Ying[4] · Chenchen Feng[1] · Yanlei Li[1,2] · Jinlong Tian[1,2] · Tingxiao Zhao[1] · Haiyu Shao[1] · Yazeng Huang[1]

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Abstract

Purpose Hidden blood loss (HBL) is a growing area of interest for spinal surgeons. Simultaneously, spine surgeons' pursuit of minimally invasive spine surgery has never ceased, as evidenced by the increasing number of articles comparing percutaneous endoscopic transforaminal lumbar interbody fusion (Endo-TLIF) and minimally invasive transforaminal lumbar interbody fusion (Mis-TLIF). However, there has been no comparison of HBL between Endo-TLIF and Mis-TLIF. This study aimed to compare HBL, visible blood loss (VBL), and total blood loss (TBL) following Endo-TLIF and Mis-TLIF and evaluate the clinical significance of these procedures.

Methods Between October 2017 and October 2019, 370 patients underwent lumbar interbody fusion at our institution and were followed up for at least 24 months. Our study included 41 Endo-TLIF and 43 Mis-TLIF cases. We recorded each patient's age, height, weight, and haematocrit and calculated the TBL, which was used to indirectly obtain the HBL. Additionally, we compared the clinical outcomes of these two groups, including visual analogue scores for the lumbar spine and leg (VAS-Back; VAS-Leg), Oswestry Disability Index (ODI), Japanese Orthopaedic Association (JOA) scores, disease type, operative segment, and intervertebral fusion and complication rates.

Results Endo-TLIF had significantly lower HBL, VBL, and TBL values than Mis-TLIF ($P < 0.05$ for all). Although Endo-TLIF contained significantly less HBL than Mis-TLIF, the HBL to TBL ratio was statistically greater in Endo-TLIF (91%) than in Mis-TLIF (87%). Concerning clinical outcomes, VAS-Back, VAS-Leg, ODI, JOA, and Endo-TLIF demonstrated greater improvement rates than Mis-TLIF one week post-operatively. However, at the final follow-up, VAS-Back, VAS-Leg, ODI, and JOA scores all demonstrated a trend toward sustained improvement, with no statistically significant between-procedure difference. There were no statistically significant between-procedure differences in disease type, surgical segment, and complication or fusion rates.

Conclusion Endo-TLIF significantly reduced HBL, VBL, and TBL compared to Mis-TLIF and improved short-term clinical outcomes; however, long-term clinical outcomes and fusion rates remained comparable between the two groups, as did the incidence of peri-operative complications.

Keywords Hidden blood loss · Visual blood loss · Total blood loss · Percutaneous endoscopic transforaminal lumbar interbody fusion · Minimally invasive transforaminal lumbar interbody fusion

Introduction

Lumbar spine fusion is an effective surgical technique for treating various lumbar spine disorders such as spinal stenosis and spondylolisthesis [1]. While open procedures such as posterior lumbar interbody fusion (PLIF) and transforaminal lumbar interbody fusion (TLIF) remain effective, many patients, particularly older adults, cannot tolerate them because of their numerous associated complications

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RESEARCH ARTICLE Open Access

Enhanced recovery after surgery pathway reduces the length of hospital stay without additional complications in lumbar disc herniation treated by percutaneous endoscopic transforaminal discectomy

Wang Duojun[1†], Zhang Hui[1†], Lin Zaijun[1], Ge Yuxiang[2*] and Chen Haihong[2*]

Abstract

Background: Enhanced recovery after surgery (ERAS) pathway in spine surgery is increasingly popular which can reduce the length of hospital stay (LOS). However, there are few studies on the safety and effectiveness of ERAS pathway in the treatment of single-level lumbar disc herniation (LDH) by percutaneous endoscopic transforaminal discectomy (PETD). The aim of this study was to investigate whether ERAS can reduce LOS of patients with single segment LDH treated by PETD.

Methods: We reviewed the outcomes of all LDH patients (L4/5) who had been treated with PETD at our institution. Quasi-experimental study was adopted between patients treated in an ERAS after PETD with those rehabilitated on a traditional pathway. The two groups were analyzed for LOS, operation time, complications, visual analog scale (VAS), Oswestry Dysfunction Index (ODI), hospitalization expenses (HE), and improved MacNab efficacy assessment criteria (MacNab).

Results: A total of 120 single segment LDH patients (ERAS pathway 60 cases, traditional care pathway 60 cases) who were selected from January 2019 to January 2021 met the inclusion criteria. There was a significant difference in mean LOS postoperative VAS scores and ODI on the 3rd day after surgery between the two groups ($P < 0.05$). The incidence of complications and HE were similar in the two groups ($P > 0.05$). The mean LOS decreased from 3.47 ± 1.14 days to 5.65 ± 1.39 days after application of ERAS pathway ($P < 0.05$).

Conclusions: The ERAS pathway reduced LOS without resulting in additional complications after PETD. These findings support the application of the perioperative ERAS pathway in the treatment of single-level LDH with PETD.

Level of evidence: Level IV, therapeutic

Keywords: Enhanced recovery after surgery (ERAS), Lumbar disc herniation (LDH), Percutaneous endoscopic transforaminal discectomy (PETD), Length of hospital stay (LOS)

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frontiers in Surgery

SYSTEMATIC REVIEW
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Eight Surgical Interventions for Lumbar Disc Herniation: A Network Meta-Analysis on Complications

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Objective: Therapeutic options for lumbar disc surgery (LDH) have been rapidly evolved worldwide. Conventional pair meta-analysis has shown inconsistent results of the safety of different surgical interventions for LDH. A network pooling evaluation of randomized controlled trials (RCT) was conducted to compare eight surgical interventions on complications for patients with LDH.

Methods: PubMed, Embase, and the Cochrane Central Register of Controlled Trials (CENTRAL) were searched for RCT from inception to June 2020, with registration in PROSPERO (CRD42020176821). This study is conducted in accordance with Cochrane guidelines. Primary outcomes include intraoperative, post-operative, and overall complications, reoperation, operation time, and blood loss.

Results: A total of 27 RCT with 2,948 participants and eight interventions, including automated percutaneous lumbar discectomy (APLD), chemonucleolysis (CN), microdiscectomy (MD), micro-endoscopic discectomy (MED), open discectomy (OD), percutaneous endoscopic lumbar discectomy (PELD), percutaneous laser disc decompression (PLDD), and tubular discectomy (TD) were enrolled. The pooling results suggested that PELD and PLDD are with lower intraoperative and post-operative complication rates, respectively. TD, PELD, PLDD, and MED were the safest procedures for LDH according to complications, reoperation, operation time, and blood loss.

Conclusion: The results of this study provided evidence that PELD and PLDD were with lower intraoperative and post-operative complication rates, respectively. TD, PELD, PLDD, and MED were the safest procedures for LDH according to complications, reoperation, operation time, and blood loss.

Systematic Review Registration: PROSPERO, identifier CRD42020176821.

Keywords: lumbar disc herniation, minimally invasive surgery, network meta-analysis, reoperation, complication

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INTRODUCTION

Lumbar disc herniation (LDH) is highly associated with inflammation in the context of low back pain (1). It is a common disease in spine surgery and a primary cause of sciatica, which affects 1–2% of the general population in the USA annually (2, 3). Approximately, 5% of men and 2.5% of women will experience sciatica at some point in their lives (4). Many cases of acute sciatica

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BMC Musculoskeletal Disorders

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Complications and risk factors of percutaneous endoscopic transforaminal discectomy in the treatment of lumbar spinal stenosis

Ning Fan†, Shuo Yuan†, Peng Du, Qichao Wu, Tianyi Wang, Aobo Wang, Jian Li, Xiaochuan Kong, Wenyi Zhu and Lei Zang*

Abstract

Background: With the advancements in surgical methods, optical designs, and surgical instruments, percutaneous endoscopic transforaminal discectomy (PETD) has become an effective and minimally invasive procedure to treat lumbar spinal stenosis (LSS) in recent years. Few studies have focused on the complications associated with the treatment of LSS using percutaneous endoscopic lumbar discectomy (PELD). This study aimed to summarize the complications of PETD and identify the associated risk factors.

Methods: Complications in a total of 738 consecutive LSS patients who underwent single-level PETD were retrospectively recorded and analyzed between January 2016 and July 2020. In addition, a matched case-control study was designed, and according to the date of operation, the control group was matched with patients without complications, with a matching ratio of 1:3. Demographic parameters included age, sex, BMI, smoking and drinking status, comorbidity, and surgical level. The radiological parameters included grade of surgical-level disc degeneration, number of degenerative lumbar discs, grade of lumbar spinal stenosis, degenerative lumbar scoliosis, lumbar lordosis, disc angle, and disc height index. Univariate analysis was performed using independent samples t-test and chi-squared test.

Results: The incidence of different types of complications was 9.76% (72/738). The complications and occurrence rates were as follows: recurrence of LSS (rLSS), 2.30% (17/738); persistent lumbosacral or lower extremity pain, 3.79% (28/738); dural tear, 1.90% (14/738); incomplete decompression, 0.81% (6/738); surgical site infection, 0.41% (3/738); epidural hematoma, 0.27% (2/738); and intraoperative posterior neck pain, 0.27% (2/738). Univariate analysis demonstrated that age, the grade of surgical-level disc degeneration ($P < 0.001$) and the number of disc degeneration levels ($P = 0.004$) were significantly related to the complications.

Conclusion: Complications in the treatment of LSS using PELD included rLSS, persistent pain of the lumbosacral or lower extremity, dural tear, incomplete decompression, surgical site infection, epidural hematoma, and intraoperative posterior neck pain. In addition, old age, severe grade of surgical-level disc degeneration and more disc degeneration levels significantly increased the incidence of complications.

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REVIEW ARTICLE

Complication rates of different discectomy techniques for symptomatic lumbar disc herniation: a systematic review and meta-analysis

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Abstract

Purpose This meta-analysis aims to compare the complication rates of discectomy/microdiscectomy (OD/MD), microendoscopic discectomy (MED), percutaneous endoscopic lumbar discectomy (PELD), percutaneous laser disc decompression (PLDD), and tubular discectomy for symptomatic lumbar disc herniation (LDH) using general classification and modified Clavien–Dindo classification (MCDC) schemes.

Methods We searched three online databases for randomized controlled trials (RCTs) and cohort studies. Overall complication rates and complication rates per the above-mentioned classification schemes were considered as primary outcomes. Risk ratio (RR) and their 95% confidence intervals (CI) were evaluated.

Results Seventeen RCTs and 20 cohort studies met the eligibility criteria. RCTs reporting OD/MD, MED, PELD, PLDD, and tubular discectomies had overall complication rates of 16.8% and 16.1%, 21.2%, 5.8%, 8.4%, and 25.8%, respectively. Compared with the OD/MD, there was moderate-quality evidence suggesting that PELD had a lower risk of overall complications (RR = 0.52, 95% CI 0.29–0.91) and high-quality evidence suggesting a lower risk of Type I complications per MCDC (RR = 0.37, 95% CI 0.16–0.81). Compared with the OD/MD data from cohort studies, there was low-quality evidence suggesting a higher risk of Type III complications per MCDC (RR = 10.83, 95% CI 1.29–91.18) for MED, higher risk of reherniations (RR = 1.67,95% CI 1.05–2.64) and reoperations (RR = 1.75, 95% CI 1.20–2.55) for PELD, lower risk of overall complication rates (RR = 0.42, 95% CI 0.25–0.70), post-operative complication rates (RR = 0.42, 95% CI 0.25–0.70), Type III complications per MCDC (RR = 0.39, 95% CI 0.22–0.69), reherniations (RR = 0.56, 95% CI 0.33–0.97) and reoperations (RR = 0.39, 95% CI 0.22–0.69) for PLDD.

Conclusions Compared with the OD/MD, results of this meta-analysis suggest that PELD has a lower risk of overall complications and a lower risk of complications necessitating conservative treatment.

Graphic abstract

These slides can be retrieved under Electronic Supplementary Material.

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s00586-020-06389-5) contains supplementary material, which is available to authorized users.

Extended author information available on the last page of the article

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Incidental Durotomy During Endoscopic Stenosis Lumbar Decompression: Incidence, Classification, and Proposed Management Strategies

Hyeun Sung Kim, Harshavardhan D. Raorane, Pang Hung Wu, Dong Hwa Heo, Sagar B. Sharma, Il-Tae Jang

OBJECTIVE: **We sought to review the types of incidental durotomies (IDs) that occurred during the endoscopic stenosis lumbar decompression through interlaminar approach (ESLD) and discuss the management strategies according to our classification.**

METHODS: **A retrospective evaluation was performed for patients with spinal stenosis who underwent ESLD. Out of 330 patients, 27 patients of ID were clinically evaluated preoperatively and postoperatively on the basis of a visual analog scale score, Oswestry Disability Index, and MacNab's criteria. ID patterns are classified according to the size, location, and involvement of neural elements. Intraoperative and postoperative surgical management was evaluated.**

RESULTS: **Intraoperative incidence of ID was 8.2%. According to lumbar levels, 11 (40.7%) occurred at L3-4, 12 (44.4%) at L4-5, and 4 (14.8%) at L5-S1 ID cases. IDs were divided into 4 types: 29.6% are type 1, 70% are type 2, 7.4% are type 3, and 3.7% are type 4. Overall for mean and standard deviation preoperative, 1 week postoperative, 3 months, and final follow-up for visual analog scale are 7.6 $\pm$ 1.4, 3.3 $\pm$ 1.1, 2.6 $\pm$ 1.1, and 1.9 $\pm$ 1.3, and for Oswestry Disability Index are 74.5 $\pm$ 9.0, 32.3 $\pm$ 9.4, 27.3 $\pm$ 7.2, and 24.4 $\pm$ 6.5 after patch blocking dura repair of ID.**

CONCLUSIONS: **ID is a more common surgical complication in ESLD compared with the transforaminal approach. The endoscopic patch blocking dura repair technique should be considered in type 1 to type 3A of dura tear with good prognosis and clinical outcome. Consideration is made for conversion to open repair in types 3B, 3C and 4 dura tears with fair to poor outcome.**

INTRODUCTION

Incidental durotomy (ID) is the most common intraoperative complication of a spine surgery. Incidence of ID in an open-spine surgery ranges from 1%–17%.[1-10] Higher incidence of ID is associated with an increase in the patient's age, reduced surgeon's experience, instrumentation, number of levels, and revision surgery.[7,8,11,12] ID is associated with short-term and long-term sequelae, such as persistent cerebrospinal fluid leak, pseudomeningocele formation, dural cutaneous fistula, meningitis, epidural abscess, and neurologic deficit. It ultimately affects the outcome of spine surgery and patient's quality of life postoperatively.[2,3,10]

Advantages of the endoscopic spine surgery (ESS) are minimal damage to the posterior bony structures and paraspinal muscles, which leads to minimal postoperative pain, reduced blood loss, early rehabilitation, and return to work.[13-15] ID is also a possible complication during ESS, and converting it to an open surgery can compromise the outcome of surgery. In 12 previously reported studies, overall incidence of ID during the ESS is 2.7% with range from 0%–8.6%.[16,17] To our knowledge there are few studies reported on the intraoperative management strategies regarding one of the most common complications in ESS.

The objective of this study is to review all the types of IDs that occurred during the endoscopic stenosis lumbar decompression (ESLD) through interlaminar approach and discuss the management strategies with respect to endoscopic classification.

Key words
- Endoscopic stenosis lumbar decompression
- Incidental durotomy
- Nontraumatic titanium clips
- Patch blocking dural repair technique

Abbreviations and Acronyms
CSF: Cerebrospinal fluid
ESLD: Endoscopic stenosis lumbar decompression
ESS: Endoscopic spine surgery
ID: Incidental durotomy
ODI: Oswestry Disability Index
PBDR: Patch blocking dural repair technique
VAS: Visual analog scale

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ORIGINAL ARTICLE

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Is Full Endoscopic Lumbar Discectomy Less Invasive Than Conventional Surgery? A Randomized MRI Study

Leonello Tacconi[1], *Francesco Signorelli*[2], *Enrico Giordan*[3]

BACKGROUND: **In the present randomized prospective study, we compared the surgical invasiveness using a quantitative volumetric analysis of postoperative paravertebral muscle signal intensity changes between transforaminal full endoscopic lumbar discectomy (FELD) and open discectomy (OD).**

METHODS: **We prospectively collected the data from 50 patients with a single-level lumbar foraminal herniation, invalidating radicular pain, and adequate imaging studies available (postoperative magnetic resonance imaging [MRI] <24 hours). These patients had been randomly assigned to FELD ($n = 25$) or OD ($n = 25$). Data were collected on age, sex, leg and back pain, complications, and follow-up time. Muscle segmentations were performed manually using 3DSlicer software on postoperative isovolumetric T1-weighted contrast-enhanced and T2-weighted short tau inversion recovery MRI scans. Both sequences were processed using multiplanar reconstruction in orthogonal planes. The clinical and demographic characteristics and volumetric data were then compared between the 2 groups.**

RESULTS: **We found a higher mean volume of paravertebral muscle signal alterations among the OD-treated patients in both T2-weighted short tau inversion recovery MRI ($P \leq 0.001$) and T1-weighted contrast-enhanced MRI ($P \leq 0.001$) scans than among the FELD-treated patients. No differences were found between the median preoperative and postoperative leg pain between the 2 groups ($P = 1.000$). The median scores for postoperative back pain were significantly lower for the FELD group ($P \leq 0.001$), as was the median interval from surgery to autonomous mobilization ($P = 0.001$).**

CONCLUSIONS: **We found a significant difference in signal intensity of the paravertebral muscles between the FELD and OD groups, reflective of the minor surgical invasiveness of endoscopic discectomy. FELD resulted in less trauma to the paraspinal muscles, possibly also reducing inflammatory cytokine release and, therefore, is a valuable tool for spinal surgeons.**

INTRODUCTION

Full endoscopic lumbar discectomy (FELD) has become an alternative to traditional open discectomy (OD) in selected cases.[1,2] It has been well documented that the surgical outcomes with FELD are comparable to those with OD and minimally invasive discectomy procedures in terms of postoperative pain, operative time, interval to mobilization, and time to discharge, with even better results in terms of blood loss.[3,4] Also, some investigators have reported that the remission time and patients' postoperative discomfort are milder after FELD than after OD.[5] FELD seems to have minor effects on the postoperative changes in the lumbar disc,

Key words
- Discectomy
- Endoscopic
- Minimally invasive
- Percutaneous
- Transforaminal

Abbreviations and Acronyms
CPK: Creatinine phosphokinase
FELD: Full-endoscopic lumbar discectomy
MRI: Magnetic resonance imaging
OD: Open discectomy
T1-CE: T1-weighted contrast-enhanced
T2-STIR: T2-weighted short tau inversion recovery
TE: Echo time
TR: Repetition time
VAS: Visual analog scale

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Incidence and Implications of Incidental Durotomy in Transforaminal Endoscopic Spine Surgery: Case Series

Albert E. Telfeian[1], Jian Shen[2], Rohaid Ali[1], Adetokunbo Oyelese[1], Jared Fridley[1], Ziya L. Gokaslan[1]

OBJECTIVE: **To evaluate the incidence and outcomes of incidental durotomy in transforaminal endoscopic spine surgery.**

METHODS: **Transforaminal lumbar endoscopic procedures were performed by 2 surgeons in 907 patients over a period of 4 years from 2014 to 2018. Patient data were evaluated retrospectively in these patients with a minimum follow-up of 1 year.**

RESULTS: **In 907 patients over 4 years there were 5 durotomies: 4 incidental and 1 intentional. The rate for incidental durotomy was therefore 0.4%. There were no adverse outcomes from the incidental durotomies, and only 1 patient noted a headache.**

CONCLUSIONS: **Incidental durotomy is a rare complication of transforaminal lumbar endoscopic spine surgery and appears to occur more likely in patients who have undergone previous spine surgery at the site of the endoscopic procedure, not unexpectantly. Glues, patches, and bedrest were among the various methods used after durotomy. In this series there were no cases of symptomatic spinal fluid leakage or pseudomeningocele seen. Only 20% of patients who had durotomies noted a headache in the immediate postoperative period.**

INTRODUCTION

Dural tears in lumbar spine surgery represent a significant morbidity to patients: incomplete surgeries, arachnoiditis, repeat surgeries, meningitis, headache, fistula, and even subarachnoid hemorrhage and subdural hemorrhage. Reports of the incidence of durotomy in lumbar spine surgery range from 1%–17% and with the incidence generally depending on the complexity of the surgery.[1-4] In microendoscopic spine surgery, a minimally invasive spine surgery performed through a tubular retractor, the incidence has been reported to be between 0% and 8.7%.[5-7] In fully endoscopic spine surgery performed through a working channel endoscope, a multiinstitutional study reported an incidence of unintended durotomy of 0.54%.[8] Here we examine a larger patient series focusing only on the incidence, implications, and treatment strategies for unintended durotomy in transforaminal endoscopic spine surgery.

MATERIALS AND METHODS

This study is a retrospective chart review of 907 patients operated on by 2 surgeons between 2014 and 2018 with a minimum follow-up of 1 year. All surgical documentation for each patient was reviewed in this retrospective review. The focus of this study is on the incidence, implication, and treatment of incidental durotomy in endoscopic lumbar spine surgery. Patient follow-up was at 2 weeks, 6 weeks, 3 months, and 1 year after surgery. Endoscopic lumbar procedures in this series included only transforaminal procedures for diskectomy or foraminotomy (1 cyst resection and fenestration is included). Interlaminar procedures were not included.

Operative Procedure

For the endoscopic (Joimax TESSYS [Joimax, Karlsruhe, Germany]) lumbar procedure, the patient was positioned in the prone position on a Wilson frame with flexed hips and knees. The procedure was done under local anesthesia (1% lidocaine with epinephrine) and intravenous sedation; the level of anesthetic was titrated, so the patient was able to communicate with the surgeon throughout the procedure. Percutaneous entry was established through the skin between 8 cm and 16 cm lateral to the midline. Using intermittent

Key words
- CSF leak
- Durotomy
- Endoscopic spine surgery
- Minimally invasive spine
- Transforaminal

Abbreviations and Acronyms
MRI: Magnetic resonance imaging

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Original research

Comparison of tissue damages caused by endoscopic lumbar discectomy and traditional lumbar discectomy: A randomised controlled trial

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ABSTRACT

Objectives: This study aimed to compare the clinical efficacies of percutaneous endoscopic lumbar discectomy (PELD) and traditional open lumbar discectomy (OD).
Methods: The pre-operative and post-operative blood loss, hospital stays and wound sizes of the patients in the two groups were recorded. Enzyme-Linked immunosorbent assay was used to measure the changes of interleukin-6 (IL-6), C-reactive protein (CRP) and creatine phosphokinase (CPK) pre-operation and 1 h, 6 h, 12 h, 24 h and 48 h after corresponding surgery. Visual Analog Scale and Modified MacNab Criteria were used to assess post-operative results.
Results: Patients in the PELD group had less blood loss ($p < 0.01$), shorter hospitalization hours ($p < 0.01$) and smaller surgical wounds ($p < 0.01$) than the patients underwent traditional OD surgery. MacNab evaluated that the levels of satisfaction were above 90% in both groups post-operative six months. There was no significant difference in pain index between the two groups ($p > 0.05$). Furthermore, the levels of CRP, CPK and IL-6 in the PELD group were all lower than those in the OD group with a significant difference ($p < 0.01$).
Conclusion: The PELD had less damage to human tissues than the traditional OD. PELD has a clear promotional value in clinical.
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1. Introduction

The spinal musculoskeletal system is destroyed in the traditional open lumbar discectomy (OD), which could easily induce neural adhesion, spinal structural damages, instability and other complications [1]. Therefore, the caused trauma could lead to a series of reactions *in vivo*, including ascent of stress hormones, production of pro-inflammatory cytokines, as well as abnormal metabolic phenomenon [2–5]. And the systemic cytokines caused by tissue damages could produce a series of adverse reactions and affect the important organs in human immune system. The minimally invasive surgery aims to achieve the least amount of trauma to human body by changes of special instruments, such as endoscopes and laser, and progresses of surgical technologies. Thus the damage of human organs and immune response caused by systemic cytokines due to the tissue damage from this surgery would be reduced [6–11].

Therefore, the levels of systemic cytokines could be used to assess the postoperative tissue damages. Percutaneous endoscopic lumbar discectomy (PELD) is a new type of spinal minimally invasive surgery in recent years, which does not needs general anesthesia and has a different surgery way and method from the traditional surgery [12,13]. PELD, a safe procedure for soft disc herniation, causes few damage to muscular and ligamentous [14]. Furthermore, some researchers have applied PELD to treat single level soft lumbar disc herniation and have received favorable consequences [15]. Nevertheless, there are few objective experimental data to confirm that PELD could cause less tissue damages than OD.

This study aimed to compare the clinical results, including pre-operative and post-operative blood loss, hospital stay, wound size, Visual Analog Scale (VAS), post-operative satisfaction and times of work recovery of PELD and traditional OD. In addition, the pre-operative and post-operative changes of systemic cytokines were analyzed to confirm that PELD had the potential to cause fewer

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EXPERT REVIEWS

Transforaminal percutaneous endoscopic lumbar discectomy: technical tips to prevent complications

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Transforaminal percutaneous endoscopic lumbar discectomy is regarded as an effective alternative to open discectomy. Remarkable technical evolution now enables selective endoscopic removal of an epidurally extruded disc fragment. As a result, the surgical indications for this technique are becoming broader. However, as the use of endoscopic techniques increases in spinal procedures, related complications emerge as important problems. These include postoperative dysesthesia, dural tears, hematoma, infection and visceral injury. There are several technical guidelines to increase the effectiveness of endoscopic techniques and prevent complications. Initial landing should be as close to the target as possible. Complete herniotomy after thorough release of annular anchorage is a key to success. The definitive end point of the procedure is free mobilization of neural tissues, not direct exposure of neural tissues.

Keywords: complication • endoscopic • herniotomy • lumbar discectomy • selective discectomy • transforaminal

Transforaminal percutaneous endoscopic lumbar discectomy (PELD) is regarded as a safe and effective procedure for treating soft disc herniation. The advantages of this procedure include preservation of posterior structures and a similar effectiveness to that of traditional open discectomy [1–4]. Recently, PELD has undergone remarkable technical evolution. In the early era of this procedure, the basic concept was to achieve indirect neural decompression within the central nucleus region. Subsequently, the decompression focus moved onto subannular-protruded disc herniation. As the working zone has now been shifted towards epidurally extruded disc herniation, the current aim of this procedure is to achieve selective epidural fragmentectomy and direct neural decompression, while preserving the central nucleus [5,6]. Several randomized controlled studies have demonstrated the effectiveness of this novel procedure [2,7–9]. However, with the increase in use of PELD, various adverse events or complications of this procedure are emerging [10–13]. The purpose of this article is to describe various complications associated with PELD and discuss technical tips in order to increase effectiveness of PELD and prevent complications.

Surgical technique

The procedures are performed according to the standard transforaminal endoscopic selective discectomy technique under local anesthesia [2,6,7,9,14]. The patient is placed prone on a radiolucent table and kept conscious during the procedure to enable monitoring of any changes in symptoms and signs. The skin entry point is typically approximately 8–13 cm from the midline. The entry point is dictated by the size of the patient, the dimensions of the facet joints and the desired location for the tip of the needle in the triangular working zone. To determine the appropriate entry point, preoperative imaging studies and intraoperative fluoroscopy should be performed. An 18-gauge spinal needle is inserted after infiltration of local anesthetic. The needle tip is positioned at one point of the medial-to-lateral pedicular line on the anteroposterior fluoroscopic projection and at the posterior vertebral line on the lateral projection. Before the insertion of the needle, a preemptive epidural blockade with 0.5% lidocaine is performed to prevent approach-related pain. After the insertion of the needle into the disc, 1 ml of indigocarmine dye is

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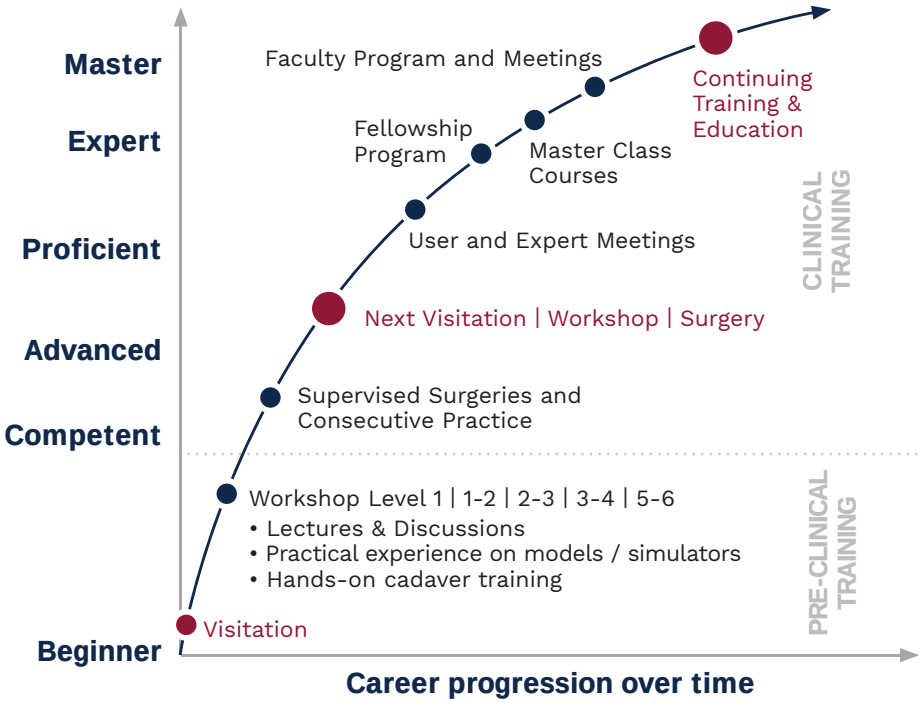

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