Original Study

Patient selection protocols for endoscopic transforaminal, interlaminar, and translaminar decompression of lumbar spinal stenosis

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Background: The indications of different endoscopic and endoscopically assisted translaminar approaches for lumbar spinal stenosis are not well-defined, and validated protocols for the use of the transforaminal over the interlaminar approach are lacking.

Methods: We performed a retrospective study employing an image-based patient stratification protocol of stenosis location (type I—central canal, type II—lateral recess, type III—foraminal, type IV—extraforaminal) and clinical outcomes on 249 patients consisting of 137 (55%) men and 112 (45%) women with an average age of 56.03±16.8 years who underwent endoscopic surgery for symptomatic spinal stenosis from January 2013 to February 2019. The average follow-up of 38.27±27.9 months. The primary clinical outcome measures were the Oswestry Disability Index (ODI), Visual Analogue Scale (VAS), and modified Macnab criteria.

Results: The frequency of stenosis configuration in decreasing order was as follows: type I—121/249; 48.6%, type III—104/249; 41.8%, type II—15/249; 6%, and type IV—9/249; 3.6%. The transforaminal approach (137/249; 55.0%) was used in most type II to IV lesions followed by the interlaminar approach (78/249; 31.3%), and the full endoscopic approach (12/249; 4.8%), and the endoscopically assisted translaminar approach (8/249; 3.2%) which was exclusively used for type I lesions. Macnab outcomes analysis showed Excellent in 47 patients (18.9%), Good in 178 (71.5%), Fair in 18 (7.2%) and Poor in 6 (2.4%), respectively. Paired two-tailed *t*-test showed statistically significant VAS (5.46±2.1; $P<0.0001$) and ODI (37.1±16.9; $P<0.0001$) reductions as a result of the endoscopic decompression surgery. Cross-tabulation of the Macnab outcomes versus the endoscopic approach and surgical technique confirmed beneficial association of the approach selection with Excellent ($P=0.001$) and Good ($P<0.0001$) outcomes with statistically significance.

Conclusions: This study suggests that in the hands of skilled endoscopic spines surgeon use of an image-based stenosis location protocol may contribute to obtaining *Excellent* and *Good* clinical outcomes in a high percentage (93%) of patients suffering from lumbar stenosis related radiculopathy. Additional comparative studies should examine the prognostic value of choosing the endoscopic approach on the basis of the proposed four-type stenosis protocol by correlating its impact on outcomes with preoperative diagnostic injections and intraoperative direct visualization of symptomatic pain generators under local anesthesia and sedation.

Keywords: Endoscopic decompression; spinal stenosis; patient selection algorith

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Introduction

Spinal stenosis is one of the most frequent indications for surgery in the lumbar spine (1-13). With the increase in life expectancy and changes in societal expectation of higher functioning, on the whole, spine surgery is performed at a much higher rate and advanced age alone is no longer a contraindication for surgery (7,8). Risk factors with surgery in the lumbar spine in the elderly are similar to those in younger patients with the majority of unintended postoperative hospital readmission taking place because of poorly managed medical comorbidities rather than surgical site problems (5,6,11-13). Endoscopic spine surgery is an attractive alternative to open surgery because it is associated with a much lower risk of dural tears, nerve injuries, postoperative cardiopulmonary problems, and complication rates when compared to those reported with traditional open translaminar surgery (14,15).

Over the last ten years, endoscopic spine surgical techniques (ESST) have gained significant traction around the world with numerous publications coming out of hotspots in Asia reporting on the implementation of a variety of technology innovations and clinical protocols intended to facilitate ease of use with the endoscopic spinal decompression surgery and improve its associated clinical outcomes (16,17). Some of the most relevant advantages of ESST over other types of minimally invasive translaminar procedures are:

(I) Minimal bleeding and better viewing due to constant irrigation with physiological saline at pressures above 40 mmHg thereby maintaining venous compression;
(II) Direct and magnified visualization of the spinal anatomy at a much greater detail through a large visual field of view;
(III) The ability to simultaneously test and treat common pain generators within a spinal motion segment at an exceptional ability to access the different compartments of the lumbar spine (i.e., intradiscal- and epidural space) with greater mobility when compared to traditional translaminar microsurgery using the microscope without having to excessively retract nerve roots is unprecedented and unique to spinal endoscopy.

While these advantages of endoscopic spine surgery are widely accepted, and a myriad of clinical outcome studies suggest favorable clinical results in the majority of patients with success rates being reported in the 60% to 90% range (14,18-39), patient selection criteria for the different ESST approaches (transforaminal or interlaminar) are less well defined as they largely depend on the available equipment resources and more importantly on the skill level of the operating surgeon. This problem is particularly evident when surgery at the L5/S1 level is considered. Anatomical considerations such as a high-riding ilium or obliterated lateral access to the L5/S1 neuroforamen due to a hypertrophied superior or inferior articular process, or sacral alar may impact preoperative planning for the most suitable access to the painful compressive pathology. Additional problems may arise from transitional anatomy or a small or absent interlaminar window. A low pelvic incidence or a high sacral slope may make access to the intervertebral disc space difficult as well. Moreover, many times, the natural aging of the lumbar spine obliterates landmarks and distorts the otherwise familiar normal anatomy. In those patients, the operating surgeon may find the additional use of a tubular retractor system commonly used during translaminar microsurgery a useful aid during the endoscopic decompression. A hybrid endoscopy/tubular retractor or an endoscopically assisted tubular retractor surgery may be an additional consideration, particularly when attempting a more complex endoscopic decompression fusion surgery requiring an expanded foraminoplasty or involving placement of an interbody fusion cage. Employing well-thought-out algorithm stratifying patients preoperatively for the most suitable endoscopic or endoscopically-assisted decompression technique in the authors' opinion has the potential to achieve favorable clinical ESST outcomes with higher consistency—a consideration that perhaps is of relevance to the novice endoscopic spine surgeon.

Therefore, this study aimed at testing an image-based

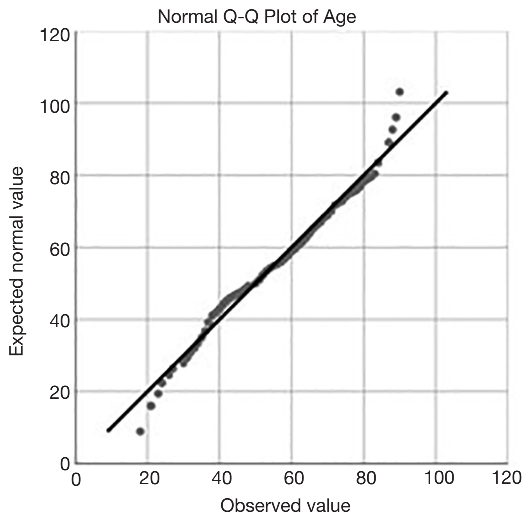

Figure 1 The quantile-quantile plot of the endoscopy patients' age shows normal distribution. The average age was 56.03±16.8 years ranging from 18 to 90 years.

endoscopic approach algorithm (EAA) consisting of four types to suggest a preferred endoscopic approach. Patient-specific criteria taken into consideration include the extent and location of the symptomatic compressive pathology, as well as access constraints dictated by the patient's anatomy at the surgical level. The authors analyzed clinical outcomes with the application of this EAA over five years by only including patients with a minimum two-year follow-up using Oswestry Disability Index (ODI) (40), Visual Analogue Scale (VAS) (41), and modified Macnab criteria (42) as the primary clinical outcome measures.

Methods

Patients

This study included patients that underwent spinal stenosis surgery for symptomatic claudication leg between from January 2013 to February 2019. A total of 249 patients were selected for this analysis. There were 137 (55%) men and 112 (45%) women. Their age was 56.03±16.8 years ranging from 18 to 90. Quantile-quantile plot (Q-Q plot) showed normal age distribution among patients of this study (*Figure 1*). The minimum follow-up requirement of two years could be met by most patients. The average follow-up was 38.27±27.906 months ranging from 8 months to 10 years. All patients signed an informed consent form prior to surgery and before including them in this study.

Inclusion/exclusion criteria

Patients were included in this study if the following criteria were used:

- (I) Symptomatic lumbar radiculopathy, dysesthesias, or decreased motor function;
- (II) Lumbar magnetic resonance imaging (MRI) showing central, foraminal, lateral recess or extraforaminal stenosis;
- (III) Unrelenting pain, in spite of physical therapy, non-steroidal anti-inflammatories (NSAIDs), and transforaminal epidural steroid injections (TESI) for a minimum 8 weeks.

The following exclusion criteria were employed:

- (I) Metastatic disease;
- (II) Infection;
- (III) Acute disc herniation;
- (IV) Patients who had surgical procedures on the cervical or lumbar spine, or other pain management procedures such as implantation of pain stimulators.

Patient selection protocol & surgical approach

An algorithm was designed classifying patients into four groups according to the anatomic location and extent of stenosis, as illustrated by MRI imaging examples shown in *Figure 2*: type I—central canal stenosis (less than 100 mm^2 cross-sectional area) (43), type II—lateral recess stenosis, type III—foraminal stenosis, and type IV—extraforaminal stenosis (3), they were subdivided according to the level of the lumbar spine that was compromised from L1 to L5 (*Figure 2*) (44). Patients with instability, obliquity of the facet joints, and those requiring surgery at the L5/S1 level were given additional considerations. The preoperative decision making algorithm is shown in *Figure 3*. The following surgical techniques were employed in this study.

Endoscopically assisted posterior decompression

In cases of central spinal, a tubular retractor system measuring 13 mm in diameter was placed through a small skin incision over the posterior elements of the surgical level after serial dilatators of the surgical corridors. This retractor system was also used for the percutaneous application of transpedicular screws in patients with concomitant spondylolisthesis. The individual steps were similar to traditional translaminar decompression and involved a proximal hemilaminectomy, a complete facetectomy, a distal

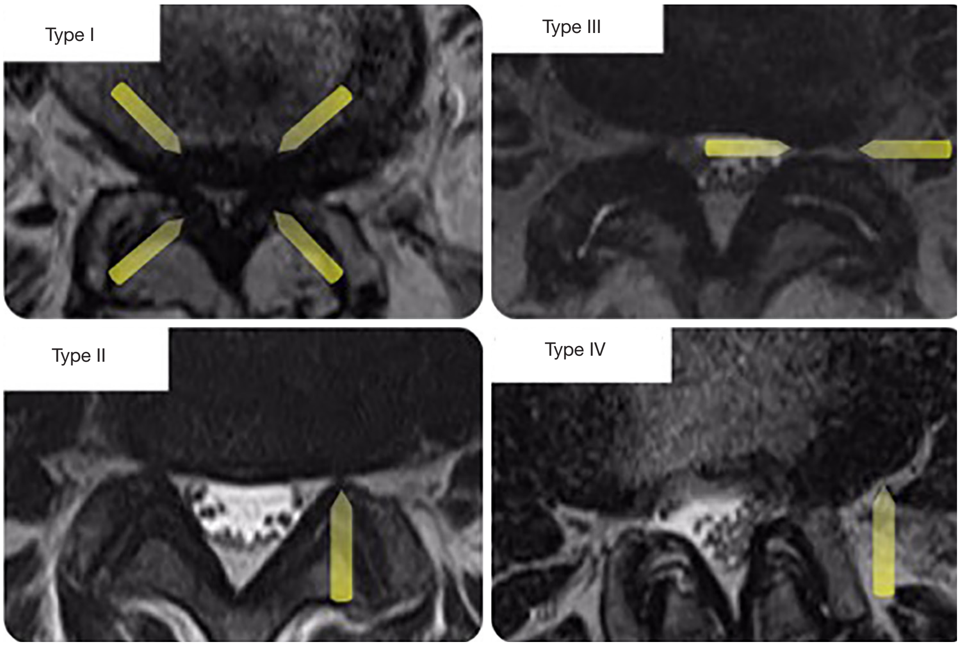

Figure 2 Algorithm employed in the grading of spinal stenosis by location of the compressive pathology: type I—central canal stenosis, type II—lateral recess stenosis, type III—foraminal stenosis, and type IV—extraforaminal stenosis. The endoscopic approach was chosen on the basis of this protocol.

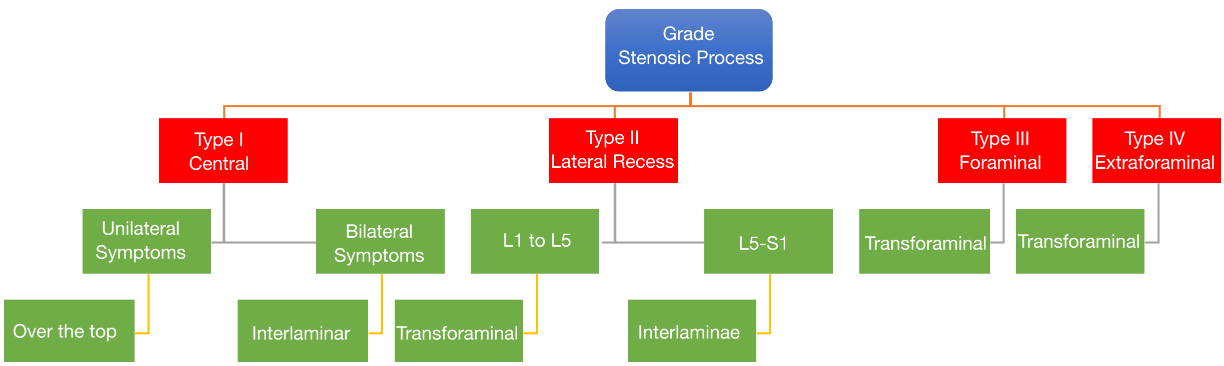

Figure 3 Algorithm employed in the grading of spinal stenosis by location of the compressive pathology: type I—central canal stenosis, type II—lateral recess stenosis, type III—foraminal stenosis, and type IV—extraforaminal stenosis. The endoscopic approach was chosen on the basis of this protocol.

hemilaminectomy, additional dissection of ligamentum flavum to achieve decompression of the central and lateral canal to expose the traversing and exiting nerve roots finally. This was followed by an over-the-top decompression of the contralateral recess in patients with bilateral symptoms. The authors preferred handheld manipulation of the tubular retractor system rather than a fixed position with a retractor arm on the predominantly symptomatic side. Bilateral skin incisions and decompression maneuvers were rarely necessary.

Transforaminal percutaneous endoscopic lumbar discectomy

The transforaminal decompression was performed under conscious sedation and local anesthesia. The authors place an endoscopic working cannular after serial dilation onto the lateral aspect of the foramen and perform a foraminoplasty and an outside-in decompression popularized by Hoogland (37,45,46) under direct visualization that has been described elsewhere (20,22,23,26). It is crucial to directly visualize and release the exiting and transversing roots. The authors prefer to perform the transforaminal surgery in the prone position and lumbar flexion using a 1.5-cm incision through which they employ a 7 mm working cannula to accommodate the 20° endoscope. The endoscopic decompression includes removal of the pars interarticularis rostrally, the facet joint complex, and the super articular process distally up to the pedicle. These decompression maneuvers would be of particular importance if an interbody fusion were also planned in patients with spondylolisthesis described below (47).

Transforaminal percutaneous endoscopic lumbar fusion

Patients requiring fusion and endoscopically assisted interbody fusion procedure was performed (47). After the aforementioned endoscopic decompression procedures, the vertebral endplates were decorticated and prepared using a 4-mm round drill bit. Rongeurs were used to extract loose disc fragments. A bipolar radiofrequency probe was used to control bleeding from epidural veins. Prior to placement of the cage and bone graft, the fusion bed was irrigated with physiological saline and antibiotics. Cancellous bone allograft was impacted into the intervertebral space anterior and lateral to the anticipated position of the fusion cage, which was typically placed over a nitinol guidewire under biplanar fluoroscopic guidance.

Interlaminar approach

During the interlaminar approach, originally popularized by Ruetten *et al.* (19,25,29,48), surgical access is created with the patient in the prone position, under conscious sedation. The skin incision is made as nearly medial in the craniocaudal middle of the interlaminar window as possible. A dilator, 6.9 mm in outer diameter, is inserted bluntly to the lateral edge of the interlaminar window. An operating sheath, with 7.9 mm outer diameter and beveled opening, is directed toward the ligamentum flavum. After that, the procedure is performed under visual control and constant irrigation, with a 25° rod lens endoscope with a 4.2 mm working channel measuring 165 mm in length.

Outcome & statistical analysis

Primary clinical outcomes measures for patients of this study were the modified Macnab criteria at the final follow-up (49). Also, pre- and postoperative VAS (41) and 40 scores were obtained. Statistical tests employed in the outcome analysis of this study included paired two-tailed *t*-test, and two-way cross-tabulation statistics to measure any statistically significant association between variables using IBM SPSS Statistics software, Version 25.0. Pearson Chi-Square and Fisher's Exact test were employed to assess the strength of association between variables statistically. The mean, range, and standard deviation, and percentages of all nominal variables were calculated.

Results

Analysis of the level distribution shows that L4/5 (115/249; 46.2%) and L5/S1 (83/249; 33.3%) followed by the L3/4 level (27/249; 10.8%) were the most commonly operated level. The remaining levels were operated on at a much lower frequency (*Table 1*). The majority of patients had surgery for herniated disc (135 patients). Another 101 patients were treated for spinal stenosis and another 13 for spondylolisthesis. The latter patients were treated with endoscopically assisted interbody and non-segmental fusion with an interbody fusion cage, bone graft, and percutaneous pedicle screws (*Table 2*). There were no major complications, such as hematomas, deep venous thrombosis, pulmonary embolus, infections, dural tears, graft extrusion, or neurological deficits. The fusion patients went on to have a successful clinical outcome with radiographic evidence of fusion. There were three patients suffering from recurrent disc herniations. They were ultimately treated with a revision endoscopic transforaminal discectomy surgery.

There was no statistically significant difference between left- (112/249; 45%) versus right-sided (126/249; 50.6%) approach. Another 11 (4.4%) patients had bilateral surgery. Regardless of the presence of associated stenosis or spondylolisthesis, patients' disc herniations were graded as central in 129 of the 249 (51.8%), and as paracentral in the remaining 120 patients (48.2%). Thirteen patients also had associated spondylolisthesis (5.2%). The grading analysis of the stenosis configuration in the symptomatic surgical spinal motion segment showed that central canal stenosis (type I) was the most common scenario. It was the reason for surgical decompression in 121 (48.6%) patients. Foraminal stenosis (type III) was second most common scenario and the reason for endoscopic decompression in 104 patients (41.8%). Lateral recess (15/249; 6%), and extraforaminal stenosis (9/249; 3.6%) were by far less common reasons for endoscopic surgery.

Table 1 Distribution of surgical levels of patients undergoing spinal endoscopy (n=249)

Level	Frequency	Percent	Valid percent	Cumulative percent
L1–L2	1	0.4	0.4	0.4
L2–L3	3	1.2	1.2	1.6
L2–L3/L4–L5	1	0.4	0.4	2.0
L2–L3/L5–S1	1	0.4	0.4	2.4
L2–L3	1	0.4	0.4	2.8
L3–L4	27	10.8	10.8	13.7
L3–L4/L4–L5	1	0.4	0.4	14.1
L3–L4/L5–S1	1	0.4	0.4	14.5
L3–L5	4	1.6	1.6	16.1
L4–L5	115	46.2	46.2	62.2
L4–S1	11	4.4	4.4	66.7
L5–S1	83	33.3	33.3	100.0
Total	249	100.0	100.0	

The most commonly used endoscopic approach was the transforaminal approach (137/249; 55.0%) followed by the interlaminar approach (78/249; 31.3%), the full endoscopic approach (12/249; 4.8%), and by the endoscopically assisted translaminar approach (8/249; 3.2%). If one includes the full-endoscopic decompressions and transforaminal fusion surgeries, the transforaminal approach was employed in 61% of all patients of this study (*Table 3*). Most of the fusion patients treated with pedicle screws (8/249; 3.2%) were endoscopically treated with the interlaminar approach. The remaining six endoscopically assisted procedures are listed in *Table 3*. At minimum follow-up and using the Macnab criteria, *Excellent* results were obtained in 47 patients (18.9%), *Good* in 178 (71.5%), *Fair* in 18 (7.2%) and *Poor* in 6 (2.4%) respectively (*Table 4*). The mean preoperative VAS was 7.9±1.5. and was reduced to 2.4±1.6 at final follow-up. The mean preoperative ODI was 49.1±17.5 and was reduced to 12.0±9.2 at final follow-up. Paired two-tailed *t*-test showed statistically significant VAS (P<0.0001) and ODI (P<0.0001) reductions as a result of the endoscopic surgery treatments (*Table 5*). Cross-tabulation of the Macnab outcomes versus the endoscopic approach and surgical technique using the stenosis grading by type is summarized in *Table 6*. Chi-square testing confirmed that the choice of endoscopic approach according to the proposed stenosis grading algorithm was associated with *Excellent* (Pearson Chi-square P=0.001) and *Good* (Pearson Chi-square P<0.0001) clinical outcomes according to modified Macnab criteria in statistically significant manner (*Table 7*). Even in the minimal number patients (11/249) with *Fair*—still improved—outcomes the choice of chosen approach was still associated with anatomic location of the stenotic process at a statistically significant level (Pearson Chi-square P=0.007).

Discussion

Patient selection for the endoscopic spinal surgery is of utmost importance (38,50,51). Understanding the pain generator is the key to obtaining favorable clinical outcomes (51). The indications for surgery are defined by unrelenting radiculopathy and neurogenic claudication symptoms that do not respond to non-operative medical care, physical therapy, and NSAIDs. Spinal injections are also often employed and are in some cases required by insurance carriers before authorizing surgery. The radiologists—willingly or not—have found themselves in the middle of the medical necessity discussion that was created by the insurance industry to determine whether proposed lumbar spine surgery is a covered benefit for the unaware patient seeking treatment (21,52). In the authors opinion, this development has somewhat distorted the role of advanced imaging studies in preoperative decision making. Nowadays, the MRI scan is often used as the

Table 2 Diagnosis, laterality of approach, and type of classified stenosis configuration in patients undergoing spinal endoscopy (n=249)

Diagnosis	Frequency	Percent	Valid percent	Cumulative percent
Herniated disc	135	54.2	54.2	54.2
Spondylolisthesis	13	5.2	5.2	59.4
Stenosis	101	40.6	40.6	100.0
Total	249	100.0	100.0	
Laterality				
Bilateral	11	4.4	4.4	4.4
Left	112	45.0	45.0	49.4
Right	126	50.6	50.6	100.0
Total	249	100.0	100.0	
Type of classified stenosis				
I	121	48.6	48.6	48.6
II	15	6.0	6.0	54.6
III	104	41.8	41.8	96.4
IV	9	3.6	3.6	100.0
Total	249	100.0	100.0	

Table 3 Endoscopic approaches and surgical procedures in spinal endoscopy patients (n=249)

Approach & endoscopic surgery	Frequency	Percent	Valid percent	Cumulative percent
Full endoscopic	12	4.8	4.8	4.8
Interlaminar	78	31.3	31.3	36.1
Interlaminar with pedicle screw fusion	8	3.2	3.2	39.4
Transforaminal	137	55.0	55.0	94.4
Transforaminal with pedicle screw fusion	2	0.8	0.8	95.2
Transforaminal with soft interbody fusion	3	1.2	1.2	96.4
Translaminar	8	3.2	3.2	99.6
Translaminar pedicle screw fusion	1	0.4	0.4	100.0
Total	249	100.0	100.0	

"holy grail" of spine care discounting patient and physician input and other objective findings arising from history and physical examination, and other diagnostic test of higher prognostic value (22) than advanced cross-sectional imaging whose reporting of the surgical endoscopic anatomy often lacks detail. This has prompted the authors of this study to reevaluate the routine day-to-day use of the lumbar MRI scan in endoscopic spine surgery practice to overcome the dichotomy left by insufficient reporting of the clinically relevant stenotic lesions and the need to endoscopically treat compressive pathology often confined to a small area under the facet joint or in the lateral recess. This diagnostic gap was shown to affect up to thirty percent of patients complaining of the sciatica-type low back, and

Table 4 Modified Macnab outcomes of patients undergoing spinal endoscopy (n=249)

Macnab criteria	Frequency	Percent	Valid percent	Cumulative percent
Good	178	71.5	71.5	71.5
Excellent	47	18.9	18.9	90.4
Fair	18	7.2	7.2	97.6
Poor	6	2.4	2.4	100.0
Total	249	100.0	100.0	

Table 5 Paired *t*-testing of preoperative versus postoperative VAS and ODI outcomes in patients undergoing spinal endoscopy (n=249)

Outcome measure	Mean	N	Std. deviation	95% CI of the difference	Std. error mean	t	df	Sig. (2-tailed)
Paired samples statistics (*t*-test)								
Preoperative VAS	7.8755	249	1.54651		0.09801			
Postoperative VAS	2.4096	249	1.59664		0.10118			
Preoperative ODI	49.0763	249	17.47274		1.10729			
Postoperative ODI	11.97	249	9.183		0.582			
Paired differences								
Pair 1: preoperative VAS – postoperative VAS	5.46586		2.09835	5.20395–5.72777	0.13298	41.104	248	<0.0001
Pair 2: preoperative ODI – postoperative ODI	37.10442		16.90358	34.99457–39.21427	1.07122	34.638	248	<0.0001

VAS, Visual Analogue Scale; ODI, Oswestry Disability Index.

leg pain which did not meet traditional medical necessity criteria based on MRI reporting yet underwent successful endoscopic decompression (20). Therefore, the authors decided to formally analyze the benefit of an image-based patient stratification protocol they serendipitously employed over the years in their endoscopic spine practice. This protocol focused on determining the best endoscopic approach to a symptomatic stenotic process in the lumbar spine to aid the surgeon in obtaining clinical improvements with the endoscopic surgery reliably.

For this purpose, patients were stratified into four types of spinal stenosis assigning them to one predominant category which the authors thought correlated best with the primary pain generator corroborated by diagnostic injections as well as the patients' history and physical examination. Stratifying patients based on the authors' extensive clinical experience of successful clinical outcomes to one of these four stenosis types was predominantly based on MRI and CT cross-sectional imaging. The intent was to formalize a preoperative decision-making algorithm that would suggest to the endoscopic spine surgeon the most preferred approach and surgical technique based on ease of use to relieve the patient's symptoms. It goes without saying that the surgeon's technical abilities primarily drive clinical outcomes with endoscopic spinal surgery. Only endoscopic surgeons with the best skills will be able to reliably obtain clinical results by continuously adhering to the highest diagnostics standards. Given the diagnostic gap in the lumbar MRI scan, the authors wanted to correlate the choice of endoscopic approach with the stenosis type and the associated clinical outcomes.

Results of this study showed that favorable clinical outcomes could be obtained with the endoscopic decompression and endoscopically assisted fusion surgery in the vast majority of patients. Only 7% of the study patients did not have *Excellent* and *Good* clinical outcomes according to the modified Macnab criteria. However, 93% of them did (*Table 4*). This was supported by statistically significant

Table 6 Macnab outcomes cross-tabulated by stenosis type and endoscopic approach and surgical procedure (n=249)

Macnab	Approach	Type of stenosis				Total
		I	II	III	IV	
Excellent	Full endoscopic	0	0	2	0	2
	Interlaminar	12	1	0	0	13
	Interlaminar with pedicle screw fusion	2	0	0	0	2
	Transforaminal	4	2	19	2	27
	Translaminar	1	0	0	1	2
	Translaminar pedicle screw fusion	0	0	1	0	1
	Total	19	3	22	3	47
Good	Full endoscopic	6	2	2	0	10
	Interlaminar	50	0	4	0	54
	Interlaminar with pedicle screw fusion	5	1	0	0	6
	Transforaminal	19	7	66	5	97
	Transforaminal with pedicle screw fusion	1	1	0	0	2
	Transforaminal with soft interbody fusion	1	0	1	1	3
	Translaminar	4	1	1	0	6
	Total	86	12	74	6	178
Fair	Interlaminar	7		0		7
	Transforaminal	4		7		11
	Total	11		7		18
Poor	Interlaminar	4		0		4
	Transforaminal	1		1		2
	Total	5		1		6
Total	Full endoscopic	6	2	4	0	12
	Interlaminar	73	1	4	0	78
	Interlaminar with pedicle screw fusion	7	1	0	0	8
	Transforaminal	28	9	93	7	137
	Transforaminal with pedicle screw fusion	1	1	0	0	2
	Transforaminal with soft interbody fusion	1	0	1	1	3
	Translaminar	5	1	1	1	8
	Translaminar pedicle screw fusion	0	0	1	0	1
	Total	121	15	104	9	249

reductions of the VAS and ODI scores as well (*Table 5*). The success rate of this study is approximately 10% higher than reported with most spine endoscopic outcome studies (14-17,20,22,23,26,31,38,50,51,53-55). The results of crosstabulation and chi-square statistical analysis of the chosen surgical approach and procedure with the type of stenosis and the correlated clinical outcomes showed a statistically significant association with successful resolution

Table 7 Chi-square testing of Macnab outcomes cross-tabulation against stenosis type and endoscopic approach/surgical procedure (n=249)

Macnab (Chi-square tests)	Statistical test	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Excellent	Pearson Chi-square	36.704[b]	15	0.001		
	Likelihood ratio	41.561	15	0.000		
	N of valid cases	47				
Good	Pearson Chi-square	103.065[e]	18	0.000		
	Likelihood ratio	108.488	18	0.000		
	N of valid cases	178				
Fair	Pearson Chi-square	7.289[c]	1	0.007		
	Continuity correction[d]	4.857	1	0.028		
	Likelihood ratio	9.636	1	0.002		
	Fisher's exact test				0.013	0.010
	N of valid cases	18				
Poor	Pearson Chi-square	2.400[f]	1	0.121		
	Continuity correction[d]	0.150	1	0.699		
	Likelihood Ratio	2.634	1	0.105		
	Fisher's exact test				0.333	0.333
	N of valid cases	6				
Total	Pearson Chi-square	139.206[a]	21	0.000		
	Likelihood ratio	149.678	21	0.000		
	N of valid cases	249				

[a], 25 cells (78.1%) have expected count less than 5. The minimum expected count is 0.04. [b], 20 cells (83.3%) have expected count less than 5. The minimum expected count is 0.06. [c], 3 cells (75.0%) have expected count less than 5. The minimum expected count is 2.72. [d], computed only for a 2×2 table. [e], 23 cells (82.1%) have expected count less than 5. The minimum expected count is 0.07. [f], 4 cells (100.0%) have expected count less than 5. The minimum expected count is 0.33.

of the patients' symptoms (*Tables 6* and 7). However, attributing these successful outcomes solely to the choice of endoscopic approach would be an oversimplification of the diagnostic workup necessary to identify the primary pain generator preoperatively, and intraoperatively during direct visualization of the painful pathoanatomy within and outside the diseased intervertebral disc in the awake yet sedated patient who is asked during surgery to verbalize familiar or concordant pain during the videoendoscopic examination. The choice of a preferred approach to the painful compressive pathology may improve access to surgical anatomy—a consideration particularly relevant to the novice endoscopic spine surgeon—but it cannot substitute the required attention to detail in working up the painful pathoanatomy. In other words, employing the four-type approach selection protocol (*Figure 2*) is not a guarantee of successful clinical outcomes with the endoscopic surgery. It merely positions the surgeon to obtain most favorable access and not be limited by obstruction due to variation (transitional) or distortion of normal anatomy by hypertrophic degeneration of the facet joints, vertical collapse, and osteophytes.

The choice of the endoscopic approach may seem a trivial problem on the surface. In fact, 61% of all endoscopic and endoscopically assisted surgeries involved the transforaminal approach. It is the workhorse approach of spinal endoscopy and works well for most levels above the L5/S1 motion segment. At L5/S1, several anatomical considerations may dictate the use of additional approaches other than the transforaminal approach. What stands out though that the interlaminar approach was almost exclusively used in the treatment of type I—or central stenosis (*Table 6*) while there were many applications of the transforaminal approach in all four stenosis types including central stenosis. It was clearly the favorite endoscopic surgical approach employed by the two endoscopic spine surgeons who contributed their cases to this analysis because of its versatility. In the opinion of this team of authors, the transforaminal approach empowers the skilled endoscopic spine surgeon to deal with the most common painful pathoanatomical scenarios. Exceptions to this rule exist, and combination approaches are sometimes the best solution. They are encompassed in the four-zone stenosis protocol proposed by the authors.

Conclusions

The proposed four-zone stenosis protocol may aid the endoscopic spine surgeon in selecting the preferred endoscopic approach to the painful lumbar spine pathology. Selecting the best approach may facilitate achieving the goals of the endoscopic surgery. It is evident that additional comparative studies should examine the prognostic value of choosing the endoscopic approach based on the proposed four-type stenosis protocol by correlating its impact on outcomes with preoperative diagnostic injections and direct intraoperative visualization of symptomatic pain generators under local anesthesia and sedation.

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Footnote

Conflicts of Interest: The authors have no direct (employment, stock ownership, grants, patents), or indirect conflicts of interest (honoraria, consultancies to sponsoring organizations, mutual fund ownership, paid expert testimony). The authors are not currently affiliated with or under any consulting agreement with any vendor that the clinical research data conclusion could directly enrich. This manuscript is not meant for or intended to endorse any products or push any other agenda other than to report the associated clinical outcomes with use of endoscopy versus laser. The motive for compiling this clinically relevant information is by no means created and/or correlated to directly enrich anyone due to its publication. This publication was intended to substantiate contemporary endoscopic spinal surgery concepts to facilitate technology advancements.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. IRB approval was obtained for this study (CEIFUS 106-19). Written informed consent was obtained from the patient for publication of this Original Study and any accompanying images.

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