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PERCEPTION OF THE LEARNING CURVE FOR ENDOSCOPIC SPINE PROCEDURES, A SURVEY OF SPINAL SURGEONS IN LATAM

PERCEPÇÃO DA CURVA DE APRENDIZADO PARA PROCEDIMENTOS ENDOSCÓPICOS DE COLUNA, UMA PESQUISA COM CIRURGIÕES DE COLUNA DA LATAM

PERCEPCIÓN DE LA CURVA DE APRENDIZAJE PARA PROCEDIMIENTOS ENDOSCÓPICOS DE COLUMNA, UNA ENCUESTA A CIRUJANOS DE COLUMNA DE LATAM

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ABSTRACT

Objective: Full endoscopic uniportal spine procedures offer the advantages of minimally invasive surgery. One of the reasons its worldwide acceptance hasn't been as expected is because of the perception of a long learning curve. This multicentric survey-based study is designed to identify the perception of the learning curve needed for full endoscopic spine procedures. It was applied to spine surgeons of Latin America and looked to assess the different variables that influence the perception of a learning curve. Methods: A 23-item questionnaire focusing on demographics, experience, and education regarding full endoscopic spine surgery was sent to all registered surgeons in the AO Spine LATAM (a specialty group within the AO Foundation) database. Data analysis was done based on the answers provided. Results: 296 members (out of 1164 AOSpine active members) answered the survey. 54.73% of the responders think that the best way to learn the technique is a combination of an Observership with an expert surgeon, cadaveric or model workshop, and operating with an expert. Most of the responders agree that 26 is the average of surgeries needed to master either the interlaminar approach or the transforaminal approach. Conclusions: The learning curve perceived by spine surgeons is below what is reported in the literature for both interlaminar and transforaminal approaches. Endolif was found to be the least performed procedure. ***Level of Evidence I; Local and current random sample surveys (or censuses).***

Keywords: Minimally Invasive Surgical Procedures; Learning curve; Perception; Endoscopy.

RESUMO

Objetivo: O procedimento endoscópico uniportal completo da coluna oferece toda a vantagem da cirurgia minimamente invasiva. Pensa-se que uma das razões pelas quais a sua aceitação mundial não tem sido a esperada é a percepção de uma longa curva de aprendizagem. Este é um desenho de estudo multicêntrico baseado em pesquisa para identificar a percepção da curva de aprendizado necessária para procedimentos endoscópicos completos de coluna, aplicado a cirurgiões de coluna da América Latina, buscando avaliar as diferentes variáveis que influenciam a percepção da curva de aprendizado. Métodos: Um questionário de 23 itens com foco em dados demográficos, experiência e educação em relação à cirurgia endoscópica completa da coluna foi enviado a todos os cirurgiões registrados no banco de dados AO Spine LATAM (um grupo especializado dentro da Fundação AO). A análise dos dados foi feita com base nas respostas fornecidas. Resultados: 296 membros (de 1.164 membros ativos da AOSpine) responderam à pesquisa. 54,73% dos respondentes pensam que a melhor forma de aprender a técnica é combinar um Observership com um cirurgião especialista, oficina cadavérica ou de modelos, e operar com um especialista. A maioria dos respondentes concorda que 26 é a média de cirurgias necessárias para dominar a abordagem interlaminar ou transforaminal. Conclusões: A curva de aprendizado percebida está abaixo daquela relatada na literatura tanto para a abordagem interlaminar quanto para a transforaminal. O Endolif foi o procedimento menos realizado. ***Nível de evidencia I; Pesquisas de Amostras Aleatórias (ou censos) Locais e Atuais.***

Descritores: *Procedimentos Cirúrgicos Minimamente Invasivos; Curva de aprendizado; Percepção; Endoscopia.*

RESUMEN

Objetivo: El procedimiento uniportal endoscópico completo de columna ofrece todas las ventajas de la cirugía mínimamente invasiva. Se piensa que una de las razones por las que su aceptación mundial no ha sido la esperada sea por la percepción de una larga curva de aprendizaje. Se trata de un diseño de estudio multicéntrico basado en encuestas para identificar la percepción de la curva de aprendizaje necesaria para procedimientos endoscópicos de columna, aplicado a cirujanos de columna de América Latina, buscando evaluar las diferentes variables que influyen en la percepción de la curva de aprendizaje. Métodos: Se envió un cuestionario de 23 ítems centrado en la demografía, la experiencia y la educación sobre la cirugía endoscópica a todos los cirujanos registrados en la base de datos de AO Spine LATAM (un grupo de especialidad dentro de la Fundación AO). El análisis de se realizó con base a las respuestas proporcionadas. Resultados: 296 miembros (de 1164 miembros activos de AOSpine) respondieron la encuesta. El 54,73% de los encuestados piensa que la mejor manera de aprender la técnica es una combinación de Observership con un cirujano experto, taller de cadáveres o modelos, y operar con un experto. La mayoría de los encuestados coinciden

Study conducted by the Hospital Israelita Albert Einstein, Department of Orthopedics and Traumatology, Spine Group, São Paulo, SP, Brazil.
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en que 26 es el promedio de cirugías necesarias para dominar el abordaje interlaminar o el abordaje transforaminal. Conclusiones: La curva de aprendizaje percibida por los cirujanos de columna, está por debajo de lo reportado en la literatura, tanto para interlaminar como transforaminal. Endolif resultó el procedimiento menos realizado. ***Nivel de Evidencia I; Investigaciones de Muestras Aleatorias (o censos) Locales y Actuales.***

Descriptores: *Procedimientos Quirúrgicos Mínimamente Invasivos; Curva de aprendizaje; Percepción; Endoscopía.*

INTRODUCTION

Full endoscopic spine surgery has become a very attractive surgical technique for spine surgeons worldwide, as it represents the minimally invasive surgery concept in its full meaning. When learning a new procedure, performance tends to improve with experience. Measures of learning related to a surgical technique fall into two categories: measures of surgical process and measures of patient outcome.[1] Surgical process measures include operative factors such as operative time and blood loss. Patient outcomes include postoperative factors such as analgesia requirement, transfusion requirement, length of stay in intensive care, length of stay in hospital, morbidity, and mortality rates. Process outcomes are generally easier to analyze and, therefore, more commonly used. However, they are only indirectly related to patient outcomes.[1]A learning curve shows the rate of improvement in performing a task as a function of time (or number of repetitions of the task at hand).[2-4] The learning curve in minimally invasive surgery (MIS) is multifactorial and controversial.[5-9]

The major concerns regarding full endoscopic surgery include a steep learning curve, fear of failure, complications, and recurrence after surgery, particularly if the surgeon is in his junior stage. There are no guidelines or gold standards on how to learn full endoscopic surgery.[2,3] Open midline lumbar discectomy is a procedure familiar to most spine surgeons and results in good outcomes. However, open surgery often requires muscle retraction, dural sac, and nerve retraction. This can cause instability and scarring of the epidural space, which can become clinically symptomatic in 10% of patients or more.[4]

A steep learning curve is often considered a complicated and slow process since it is a "steep climb upward" that requires much effort. However, a steep learning curve is a good thing, considering that with a few procedures, the surgeon or learner can acquire enough experience and rapidly master the technique.[1,10]

The objective of this study is to comprehend, based on the experience of Latin American spine surgeons, the best way to start the full endoscopic surgery learning curve.

MATERIALS AND METHOD

The authors created and consented to a 23-item questionnaire on demographics, experience, and education regarding full endoscopic spine surgery. The questionnaire was sent to all AO Spine LATAM database registered spine surgeons. It is divided into three sections, and the surgeon's background formation, experience, and perspective toward full endoscopic spine surgery and its modalities are analyzed.

The AOSpine database includes surgeons from their first years of practice to experts and seniors and covers all countries in Latin America.

This study was carried out by AOspine Latam and supported by the MISS Study Group.

The survey, in Spanish and Portuguese, was sent electronically to all active members, 1164 spine surgeons, in March 2022.

Ethical registration was not required due to the anonymous nature of the survey conducted with AO Spine LATAM members. (Appendix 1)

Statistical Analysis

According to the different factors under study, statistical analysis of the survey responses was done using the non-parametric Mann-Whitney or Kruskal-Wallis tests, as appropriate. The use of non-parametric tests is due to the breach of the necessary assumptions to carry out parametric tests. P values < 0.05 were considered statistically significant. The analyses were carried out with the Minitab 19 software. On the other hand, the graphs were made with RStudio, version 1.4.1106.

Continuous variables were summarized by their mean and Standard Deviation (SD). Categorical variables were summarized as absolute numbers and as a percentage of the N = 296 total subjects.

Ethical registration was not required due to the nature of the survey, which collected information anonymously from members of AO Spine LATAM.

RESULTS

Out of the 296 participants, the mean age was 45, with an average of 14 years of experience, as shown in Table 1. We found a 60-vs 40 percent of endoscopic practitioner vs nonpractitioner relation among surveyed surgeons.

Table 1. Continuous variables description. Its median describes each of the continuous variables of the sample, the Standard Error of the Median (SEM), the minimum value (Min), the first quartile (Q1), the median, the third quartile (Q3), and the maximum value (Max). Those values under Q1 represent 25% of the data, while those less than Q3 represent 75% of the values. N = Number of individuals answered.

Variable	N	Median	SEM	SD	Min	Q1	Median	Q3	Max
Age (years)		44,848	0.59	10,146	26	37	43	52	76
Experience (years)	296	14,162	0.707	12,159	0	5	11	20	100
How many surgeries do you think you should perform to:									
Master the transforaminal endoscopic technique?		26.9	1.16	19.89	0	12	20	30	100
Master the interlaminar endoscopic technique?		26.74	1.23	21.2	0	10	20	30	100
How many surgeries do you think you need to perform to go:									
From soft tissue transforaminal (disc) to foraminoplasties?	296	22.86	1.06	18.28	0	10	20	30	100
From performing soft tissue interlaminar (disc) to decompressions for stenosis?		27.52	1.24	21.32	0	12	20	35	100
From lumbar transforaminal to thoracic transforaminal?		35.95	1.52	26.09	0	18	30	50	100
How many surgeries do you think you should perform to start performing endoscopy fusion (ENDOLIF)?		37.09	1.59	27.35	0	19	30	50	100
How many additional surgeries do you have to perform to master the technique compared to surgery under a microscope or microdiscectomy?		23.4	1.08	18.6	0	10	20	30	100

The countries with the highest response were Brazil and Mexico, with 103 and 68, respectively; Central America was the region with fewer responders. Spine surgeons answered mainly; 75% and 65% of the surveyed were Orthopedic surgeons vs. 35% Neurosurgeons, as shown in Table 2.

The highest percentage of responders were junior surgeons (less than five years of professional practice as spine surgeon) with 27.7% of responders, followed by 25.68% of sub-senior surgeons (10-15 years of professional practice as spine surgeon), 23.65% of senior surgeons (more than 15 years of professional practice as spine surgeon) and for last 22.97 middle experienced surgeons (5-10 years of professional practice as spine surgeon) as shown on Table 3.

75% of the responders (222) were spine surgeons, followed by 16.55% of Orthopaedics surgeons or Neurosurgeons with no further spine training, with a professional practice composed of public and private medicine in its majority (61.5%).

The majority of the responders (70%) have had contact with full endoscopic spine surgery either as an observer or with workshops and feel more comfortable with both transforaminal (62%) and interlaminar (62%) discectomy and less comfortable with endoscopic fusion procedures (5%). Even though most of them (69%) answered that they do not have an expert to help them with their learning curve, they believe that the best way to learn is through a sum of observership with an expert, cadaveric or model workshop, and having the support of an expert during the beginning of the learning curve. The least useful was the expert Observership alone.

When asked what the main limitation to starting endoscopic procedures or techniques (more than one option possible) was, 63% answered a lack of training, followed by a lack of financial resources. The long learning curve was a concern for 20%, and only 6% considered that the technique was not superior, hence worth the migration to endoscopic techniques, as shown in Table 4.

Responders perceived that 26-27 full endoscopic spine surgeries are needed to master either the transforaminal or interlaminar endoscopic approaches. (Table 1)

Table 2. Categorical variables description. Each of the categorical variables of the sample is described by the number of individuals who choose the different options.

Variable	Subcategory	Count	Percentage (%)
Country (by regions)	North	84	28.38
	Central	42	14.19
	Brazil	103	34.8
	South	67	22.64
Specialty	Neurosurgeon	106	35.81
	Orthopedist	190	64.19
Experience	Junior	82	27.7
	Middle	68	22.97
	Senior	70	23.65
	Subsenior	76	25.68

Table 3. Categorical variables description. Each of the categorical variables of the sample is described by the number of individuals who choose the different options.

Variable	Subcategory	Count	Percentage (%)
Had contact with camera-assisted surgery? (arthroscopic or endoscopic)	No	142	47.97
	Yes	154	52.03
Do you perform facet or selective root blocks in your practice?	No	38	12.84
	Yes	258	87.16
Have you performed or performed lumbar endoscopic surgery?	No	121	40.88
	Yes	175	59.12
Have you had contact with endoscopic lumbar spine surgery? (Observership or workshop)	No	62	20.95
	Yes	234	79.05

DISCUSSION

This survey addressed spine surgeons from Mexico, Central America, and South America with diverse cultural and professional backgrounds, training levels, and attitudes toward full endoscopic spine surgery.

Our survey had a fairly good number of respondents (n=296) from most of our region's countries, giving our study an acceptable regional representative value.

Full endoscopic spine surgery has been around for a while. Still, it hasn't even been accepted by the spine surgery community, and one of the reasons is the long, challenging, and even dangerous learning curve surgeons imagine it has. The literature varies widely, from Morgenstern's paper, which says that an average of 70 cases are needed to master the transforaminal technique, to Hsien-Ta Hsu et al.[4], who says that around the 10th case, the surgeon learns how to do full transforaminal endoscopic spine surgery, guiding us to believe that a bigger, multicentric and focused study based on education, experience, and evidence was needed.

Our study considers the opinions and experiences of a diverse group of spine surgeons from different regions in Latin America to provide an objective pathway to achieving an efficient learning curve in full endoscopic spine surgery.

So far, the learning curve for Endoscopic Interlaminar Lumbar Discectomy (EILD) is longer than for Open Lumbar Microdiscectomy (OLM).[2] However, the learning curve of PEILD was not as difficult as those of other minimally invasive spine surgeries, and the operation time of EILD was significantly shorter than that of OLM. Moreover, the safety and efficacy of EILD were similar to OLM, with comparable failure, complication, and recurrence rates.[2]

The majority of our responders (75%) are spine surgeons (orthopedic surgeons or neurosurgeons with further training in spine pathologies) with some training or exposure to video-assisted surgery and fluoroscopic procedures, which are thought to give the surgeon an edge in anatomic orientation and surgical equipment handling, making the learning curve somewhat more friendly.

59% of the Respondents haven't done a full endoscopic spine procedure. Based on our results, we think this is because, even though most have been exposed to observerships with experts and cadaveric or model workshops, 69% don't have an expert available to help them at the beginning of their learning curve.

A higher percentage of responders answered having prior experience with endoscopic or arthroscopic surgery and currently performing facet or selective nerve block (which can relate to a surgeon feeling comfortable with video-assisted surgery and fluoroscopic anatomy of the spine), as shown in Table 3.

The wide variety of information regarding the learning curve needed to master these techniques can be misleading and, to one point, limit the technique's adoption into general spine surgery practice. More than 70% of responders recognized that indications for surgery would increase with more expertise in endoscopic techniques. Surgeons recognize the advantages endoscopic surgery provides; the only thing limiting them is the intricate learning curve thought to be needed to manage these procedures.

62% of Surgeons felt comfortable with transforaminal and interlaminar endoscopic disc decompression for the same. According to the literature available, the learning curve for the transforaminal approach was steep and easy, while the learning curve for the interlaminar approach was flat and hard to master.[4] Choi et al.[11] recommended supervision by an experienced surgeon in the initial ten cases to overcome the learning curve for the interlaminar procedure at L5–S1. But our results state a different reality. This can be related to the fact that most of the responders to our survey had some previous exposure or training in video-assisted surgery fluoroscopic facet block and selective nerve block or had some exposure to endoscopic surgery during their basic training as spine surgeons.

Managing disc disease by endoscopic surgery seems to be more accepted by spine surgeons than bony decompression in all of its modalities, but no specification was made as to what restrains

Table 4. Statistical tests to compare the different variables. The table shows the comparisons between the different variables. Non-parametric tests (Kruskal-Wallis, Mann-Whitney) were performed. P-values less than 0.05 were considered statistically significant and highlighted in red. Refs: DF: Degrees of freedom; W-value: Mann-Whitney statistic; H-statistic: Kruskal Wallis statistic.

How many surgeries do you need to master:	Variable	DF	H-value/W value	p-value	Test
Transforaminal endoscopic technique	Age (ranges)	2	3.59	0.166	Kruskal-Wallis
	Country (Region)	3	2.47	0.48	Kruskal-Wallis
	Specialty	-	15,608.5	0.85	Mann-Whitney
	Experience	3	1.48	0.687	Kruskal-Wallis
	Position	3	2.08	0.557	Kruskal-Wallis
	Professional practice	2	0.18	0.915	Kruskal-Wallis
	Have you had contact with camera-assisted surgery? (arthroscopic or endoscopic)	-	22,138	0.149	Mann-Whitney
	Do you perform facet or selective root blocks in your practice?	-	6316	0.168	Mann-Whitney
	Have you performed or performed lumbar endoscopic surgery?	-	17,119	0.236	Mann-Whitney
	Have you had contact with endoscopic lumbar spine surgery? (Observership or workshop)	-	9,069	0.817	Mann-Whitney
	Do you have someone to help you in your learning curve, in your center, or a proctor of endoscopic surgery?	-	25,771	0.911	Mann-Whitney
	Do you think the indication for surgery increases with expertise in endoscopy techniques?	-	15,206	0.242	Mann-Whitney
	In your experience, do you perceive difficulty in accessing this technology?	-	17,859.5	0.572	Mann-Whitney
Interlaminar endoscopic technique	Age (ranges)	2	2.95	0.229	Kruskal-Wallis
	Country (Region)	3	4.26	0.235	Kruskal-Wallis
	Specialty	-	14,954	0.261	Mann-Whitney
	Experience	3	1.32	0.725	Kruskal-Wallis
	Position	3	2.33	0.506	Kruskal-Wallis
	Professional practice	2	0.32	0.852	Kruskal-Wallis
	Have you had contact with camera-assisted surgery? (arthroscopic or endoscopic)	-	22,985	0.009	Mann-Whitney
	Do you perform facet or selective root blocks in your practice?	-	6217	0.24	Mann-Whitney
	Have you performed or performed lumbar endoscopic surgery?	-	17,592.5	0.601	Mann-Whitney
	Have you had contact with endoscopic lumbar spine surgery? (Observership or workshop)	-	8,881.5	0.584	Mann-Whitney
	Do you have someone to help you in your learning curve, in your center, or a proctor of endoscopic surgery?		26,037	0.631	Mann-Whitney
	Do you think that with expertise in endoscopy techniques, the indication for surgery increases?		14,697	0.67	Mann-Whitney
	In your experience, do you perceive difficulty in accessing this technology?		18,430.5	0.819	Mann-Whitney
Endoscopy fusion (ENDOLIF)	Age (ranges)	2	2.44	0.295	Kruskal-Wallis
	Country (Region)	3	15.47	0.001	Kruskal-Wallis
	Specialty		15,940.5	0.777	Mann-Whitney
	Experience	3	2.11	0.55	Kruskal-Wallis
	Position	3	3.07	0.381	Kruskal-Wallis
	Professional practice	2	5.44	0.066	Kruskal-Wallis
	Had contact with camera-assisted surgery? (arthroscopic or endoscopic)		21,044	0.954	Mann-Whitney
	Do you perform facet or selective root blocks in your practice?		5,478.5	0.738	Mann-Whitney
	Have you performed or perform lumbar endoscopic surgery?		16,179	0.013	Mann-Whitney
	Have you had contact with endoscopic lumbar spine surgery? (Observership or workshop)		7,598.5	0.007	Mann-Whitney
	Do you have someone to help you in your learning curve, in your center, or a proctor of endoscopic surgery?		23,955.5	0.016	Mann-Whitney
	Do you think that with expertise in endoscopy techniques, the indication for surgery increases?		14,905.5	0.467	Mann-Whitney
	In your experience, do you perceive difficulty in accessing this technology?		18,801.5	0.459	Mann-Whitney

	Variable	DF	H-value/W value	p-value	Test
How many additional surgeries do you think you have to perform to	Age (ranges)	2	0,44	0,804	Kruskal-Wallis
	Country (Region)	3	1.44	0.695	Kruskal-Wallis
	Specialty		16,004.5	0.708	Mann-Whitney
	Experience	3	0.27	0.966	Kruskal-Wallis
	Position	3	4.46	0.216	Kruskal-Wallis
Master the technique compared to surgery under a microscope or microdiscectomy?	Professional practice	2	0.39	0.824	Kruskal-Wallis
	Had contact with camera-assisted surgery? (arthroscopic or endoscopic)		21,751	0.364	Mann-Whitney
	Do you perform facet or selective root blocks in your practice?		6,623	0.045	Mann-Whitney
	Have you performed or perform lumbar endoscopic surgery?		18,197	0.751	Mann-Whitney
	Have you had contact with endoscopic lumbar spine surgery? (Observership or workshop)		9,068.5	0.817	Mann-Whitney
	Do you have someone to help you in your learning curve, in your center, or a proctor of endoscopic surgery?		25,420.5	0.708	Mann-Whitney
	Do you think that with expertise in endoscopy techniques, the indication for surgery increases?		14,795.5	0.569	Mann-Whitney
	In your experience, do you perceive difficulty in accessing this technology?		18,236.5	0.968	Mann-Whitney
How many surgeries do you think you need to perform to go:	**Variable**	**DF**	**H-value/W value**	**p-value**	**Test**
From soft tissue transforaminal (disc) to foraminoplasties?	Age (ranges)	2	0.24	0.888	Kruskal-Wallis
	Country (Region)	3	0.39	0.942	Kruskal-Wallis
	Specialty		16,792.5	0.134	Mann-Whitney
	Experience	3	0.81	0.847	Kruskal-Wallis
	Position	3	3.72	0.294	Kruskal-Wallis
	Professional practice	2	1.29	0.524	Kruskal-Wallis
	Had contact with camera-assisted surgery? (arthroscopic or endoscopic)		20,464	0.395	Mann-Whitney
	Do you perform facet or selective root blocks in your practice?		6,722	0.027	Mann-Whitney
	Have you performed or perform lumbar endoscopic surgery?		18,840	0.225	Mann-Whitney
	Have you had contact with endoscopic lumbar spine surgery? (Observership or workshop)		9,576	0.535	Mann-Whitney
	Do you have someone to help you in your learning curve, in your center, or a proctor of endoscopic surgery?		25,360.5	0.647	Mann-Whitney
	Do you think that with expertise in endoscopy techniques, the indication for surgery increases?		14,744.5	0.621	Mann-Whitney
	In your experience, do you perceive difficulty in accessing this technology?		18,211.5	0.941	Mann-Whitney
From performing soft tissue interlaminar (disc) to decompressions for stenosis?	Age (ranges)	2	1.6	0.45	Kruskal-Wallis
	Country (Region)	3	6.97	0.073	Kruskal-Wallis
	Specialty		15,953.5	0.763	Mann-Whitney
	Experience	3	4.69	0.196	Kruskal-Wallis
	Position	3	2.88	0.411	Kruskal-Wallis
	Professional practice	2	0.45	0.799	Kruskal-Wallis
	Had contact with camera-assisted surgery? (arthroscopic or endoscopic)		19,937.5	0.116	Mann-Whitney
	Do you perform facet or selective root blocks in your practice?		6,002	0.464	Mann-Whitney
	Have you performed or perform lumbar endoscopic surgery?		17,840	0.859	Mann-Whitney
	Have you had contact with endoscopic lumbar spine surgery? (Observership or workshop)		8,717.5	0.412	Mann-Whitney
	Do you have someone to help you in your learning curve, in your center, or a proctor of endoscopic surgery?		24,058.5	0.024	Mann-Whitney
	Do you think that with expertise in endoscopy techniques, the indication for surgery increases?		14,471	0.924	Mann-Whitney
	In your experience, do you perceive difficulty in accessing this technology?		18,551	0.693	Mann-Whitney

From lumbar transforaminal to thoracic transforaminal?	Age (ranges)	2	0.82	0.662	Kruskal-Wallis
	Country (Region)	3	16.29	0.001	Kruskal-Wallis
	Specialty		15,509.5	0.743	Mann-Whitney
	Experience	3	3.89	0.274	Kruskal-Wallis
	Position	3	4.64	0.2	Kruskal-Wallis
	Professional practice	2	3.18	0.204	Kruskal-Wallis
	Had contact with camera-assisted surgery? (arthroscopic or endoscopic)		21,273.5	0.8	Mann-Whitney
	Do you perform facet or selective root blocks in your practice?		5542	0.838	Mann-Whitney
	Have you performed or perform lumbar endoscopic surgery?		16,270	0.019	Mann-Whitney
	Have you had contact with endoscopic lumbar spine surgery? (Observership or workshop)		8,052	0.053	Mann-Whitney
	Do you have someone to help you in your learning curve, in your center, or a proctor of endoscopic surgery?		24,115.5	0.029	Mann-Whitney
	Do you think that with expertise in endoscopy techniques, the indication for surgery increases?		14,727	0.64	Mann-Whitney
	In your experience, do you perceive difficulty in accessing this technology?		18,804	0.457	Mann-Whitney

them from venturing into treating bony decompression (if it was the fear of using a power drill, or Kerrison Rongeurs near nervous structure from an endoscopic approach or other motive).[12]

Imprecise anatomic orientation and manipulation inside the spinal canal are key factors in the steep learning curve that the full endoscopic interlaminar approach is thought to have. Obtaining microsurgical experience, attending workshops, and suitable patient selection can help shorten the learning curve and decrease complications.[13]

Another result that matches the current literature is that surgeons don't feel comfortable incorporating endoscopic spine fusion into their practice or find it proficient (only 5% of responders). As shown in Table 1, surgeons' perception of the number of surgeries needed to master each one of the endoscopic techniques is not far from what is stated in the literature, with the perception that endoscopic spine fusion is the technique that requires more surgeries to master it.

The main limitation we found in our study is related to the fact that it is a survey-based analytical study. Heterogeneity in clinical practices among centers may be a major confounding factor in interpreting the results.[14]

Overall, we recognized that this survey is no substitute for large prospective trials, but it gives us a clear view of the perception of the learning curve needed to learn and master full endoscopic spine surgery; it gives us a view of where these techniques stand and what is limiting spine surgeons from incorporating endoscopic techniques into their practice, which seems to be mainly the lack of training in these modalities.

Another highlight of our survey that has not been explored deeply in previous literature is the learning curve for surgeons already familiar with basic endoscopic spine surgeries, such as soft tissue transforaminal surgeries and interlaminar decompression, that wanted to incursion into endoscopic spine surgery of higher complexity such as foraminoplasties, canal stenosis decompression, thoracic transforaminal surgery, and endoscopic fusion. As stated in Table 1, our survey revealed that 22-23 endoscopic transforaminal disectomies were a reasonable number of surgeries before starting with foraminoplasties. 27-28 soft tissue interlaminar decompression was a reasonable number of surgeries before starting stenosis decompression surgery. The two procedures that our survey responders considered needed more experience were thoracic transforaminal decompression (35-36 lumbar transforaminal surgeries must be done before trying it) and endoscopic fusion for our responders 37 endoscopic spine surgeries must be done before doing this technique (Table 1). The number of procedures mentioned for each technique was the same, independent of the years of experience of the responders.

CONCLUSION

Several factors influence the perception of the learning curve regarding endoscopic spine surgery. We learned that spine surgeons, both the most experienced and the less experienced, perceive that the best way to learn full endoscopic spine surgery with an efficient learning curve is the summation of an observership, cadaveric or model workshop, and having an expert present while performing the first cases; we recommend spine surgeons to follow this path. The mean number of surgeries needed to feel competent in endoscopic spine surgery is 26 for disc or decompressive surgeries. It stands out that Endolif was the procedure with the least surgeons feeling competent or comfortable performing rather than cervical endoscopic spine surgery.

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REFERENCES

1. Benzel EC, Orr RD. A steep learning curve is a good thing! Spine J. 2011;11(2):131-2. http://dx.doi.org/10.1016/j.spinee.2010.12.012.
2. Son S, Ahn Y, Lee SG, Kim WK. Learning curve of percutaneous endoscopic interlaminar lumbar discectomy versus open lumbar microdiscectomy at the L5-S1 level. PLoS One. 2020;15(7):e0236296. http://dx.doi.org/10.1371/journal.pone.0236296.
3. Kim M, Lee S, Kim HS, Park S, Shim SY, Lim DJ. A Comparison of Percutaneous Endoscopic Lumbar Discectomy and Open Lumbar Microdiscectomy for Lumbar Disc Herniation in the Korean: A Meta-Analysis. Biomed Res Int. 2018;2018:9073460.
4. Hsu HT, Chang SJ, Yang SS, Chai CL. Learning curve of full-endoscopic lumbar discectomy. Eur Spine J. 2013;22(4):727-33.
5. Sharif S, Afsar A. Learning Curve and Minimally Invasive Spine Surgery. World Neurosurg. 2018;119:472-8. https://doi.org/10.1016/j.wneu.2018.06.094.
6. Lee CW, Yoon KJ, Kim SW. Percutaneous endoscopic decompression in lumbar canal and lateral recess stenosis – The surgical learning curve. Neurospine. 2019;16(1):63-71.
7. Sun B, Wu H, Xu Z, Lu J, Wang Y, Zhang K, et al. Is selective nerve root block necessary for learning percutaneous endoscopic lumbar discectomy: a comparative study using a cumulative summation test for learning curve. Int Orthop. 2020;44(7):1367-74.
8. Morgenstern R, Morgenstern C, Yeung AT. The Learning Curve in Foraminal Endoscopic

Discectomy: Experience Needed to Achieve a 90% Success Rate. SAS J. 2007;1(3):100-7. http://dx.doi.org/10.1016/S1935-9810(07)70054-3.
9. Jaffe TA, Hasday SJ, Knol M, Pradarelli J, Quamme SRP, Greenberg CC, et al. Safety considerations in learning new procedures: a survey of surgeons. J Surg Res. 2017;218:361-6. http://dx.doi.org/10.1016/j.jss.2017.06.058.
10. Ruetten S. The Full-endoscopic Interlaminar Approach for Lumbar Disc Herniations. In: Mayer, HM (eds). Minimally Invasive Spine Surgery. Berlin: Springer; 2006. https://doi.org/10.1007/3-540-29490-2_38. p. 346-55.
11. Choi G, Lee SH, Raiturker PP, Lee S, Chae YS. Percutaneous endoscopic interlaminar discectomy for intracanalicular disc herniations at L5-S1 using a rigid working channel endoscope. Neurosurgery. 2006;58(Suppl 1):59-68.
12. Wang B, Lü G, Patel AA, Ren P, Cheng I. An evaluation of the learning curve for a complex surgical technique: The full endoscopic interlaminar approach for lumbar disc herniations. Spine J. 2011;11(2):122-30. http://dx.doi.org/10.1016/j.spinee.2010.12.006.
13. Hopper AN, Jamison MH, Lewis WG. Learning curves in surgical practice. Postgrad Med J. 2007;83(986):777-9. doi:10.1136/pgmj.2007.057190.
14. Youseff N, Reinhart K, Sakr Y. The pros and cons of multicentre studies. Neth J Crit Care. 2008;12(3):120-2.

Appendix 1.

Survey
Country of Origin: _____ Age: _____
Basic Studies O Neurosurgeon O Orthopedist
Current Position O Resident O Specialist (Without a formal training in Spine Surgery) O Spine Surgery Fellow O Spine Surgeon
Years of Experience: _____
Type of Practice O Public O Private O Mixed (Both Private and Public).
Did you have contact with camera-assisted surgery during your training as a resident or specialist? (arthroscopic or endoscopic) O Yes O No
Do you perform facet or selective nerve root blocks in your practice? O Yes O No
Have you performed or are you performing lumbar spine endoscopic surgery? O Yes O No
Have you had contact with lumbar spine endoscopic surgery? (Observership or workshop) O Yes O No
How many surgeries should you perform to master the transforaminal endoscopic technique? _____
How many surgeries should you perform to master the interlaminar endoscopic technique? _____
What is the best way to learn a new surgical technique? O Cadaveric or model workshop O Observership with an expert surgeon O Observership + cadaveric workshop O Perform the surgery with the support of an expert. O All of the above.

How many surgeries do you need to perform to master the technique compared to microdiscectomy?
How many surgeries do you think you should do to go from soft tissue transforaminal (disc) to foraminoplasty?
How many surgeries do you think you should do to go from soft tissue interlaminar (disc) to decompression due to stenosis?
How many surgeries do you think you should do to go from lumbar transforaminal to thoracic transforaminal?
How many surgeries should you do to start performing endoscopic fusion (ENDOLIF)?
Which of the following surgical techniques do you perform that you feel comfortable with or that you consider you have mastered? Several possible options. O Lumbar transforaminal (disc) O Lumbar transforaminal (foraminoplasty) O Lumbar interlaminar (disc) O Lumbar interlaminar (lumbar stenosis) O Thoracic transforaminal O Endoscopic Fusion (ENDOLIF) O Posterior cervical O Anterior cervical
Do you have someone in your center or practice to help you with endoscopic surgery? O Yes O No
*Do you have someone technically proficient to help you? A Proctor, for example. O Yes O No
*Do you think mastering endoscopic surgery increases the indication for surgery? O Yes O No
*What is your main limitation to perform endoscopic surgery? O Lack of financial resources O Lack of training in endoscopic surgery O I don't think it is superior to other techniques O The learning curve is very long for the benefits it brings.
* In your experience, do you perceive a difficulty in accessing this technology? O yes O No