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ORIGINAL ARTICLE

Learning Curve of Microendoscopic Discectomy for the Treatment of Lumbar Disc Herniation

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KEYWORDS
Microendoscopic discectomy;
Learning curve;
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Minimally invasive spine surgery

Abstract
Objective: To evaluate the learning curve of the Microendoscopic Discectomy (MED) for the treatment of lumbar disc herniation.
Material and methods: Prospective observational clinical study of 120 patients operated by MED technique. The learning curve was assessed using surgery time, complication rate and conversion rate. The relief of pain, improvement of functional status and patient satisfaction were also assessed. The follow-up time after surgery was 5 years in all cases.
Results: The duration of surgical operating time decreased over the course of the study to stabilise around 62-69min. There were complications in 14 patients (11.7%), the most frequent of which was incidental durotomy (3 cases, all during the learning curve period). There were six (5%) conversions to open discectomy (4 patients in the first 30 cases). After this stage, conversion to open procedure was exceptional and there were no complications related to technique. The MED is a predictable and safe procedure that can treat all types of herniated discs through an 18 mm incision without detaching the muscles, providing similar results to those obtained with conventional techniques, as it is based on the same surgical principles.

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PALABRAS CLAVE
Discectomía microendoscópica;
Curva de aprendizaje;
Hernia discal lumbar;
Cirugía mínimamente invasiva de columna

Curva de aprendizaje de la discectomía microendoscópica para el tratamiento de la hernia discal lumbar

Resumen

Objetivo: Evaluar la curva de aprendizaje de la Discectomía Microendoscópica (MED) para el tratamiento de la hernia discal lumbar.

Material y métodos: Estudio clínico observacional prospectivo de 120 pacientes intervenidos mediante técnica MED. La curva de aprendizaje se determinó atendiendo a la duración del procedimiento, las complicaciones y la tasa de conversión a cirugía abierta. Además se cuantificó el alivio del dolor, la mejoría del estado funcional y el grado de satisfacción del paciente, con un seguimiento de 5 años en todos los casos.

Resultados: La duración de la intervención fue disminuyendo a lo largo de la serie para estabilizarse en torno a 62-69 min después de los primeros 48 procedimientos. Se presentó alguna complicación en 14 pacientes (11,7%) la más frecuente fue el desgarro dural (3 casos, todos durante el proceso de aprendizaje de la técnica). En 6 ocasiones (5%) fue preciso reconvertir el procedimiento a técnica abierta (4 de ellos en los primeros 30 casos de la serie).

Discusión y conclusiones: El periodo de aprendizaje de la MED abarcó entre 30-48 procedimientos. Superada esta etapa, fue excepcional la conversión a técnica abierta y no se produjeron complicaciones relacionadas con la técnica. La MED es un procedimiento predecible y seguro que permite tratar todo tipo de hernias discales a través de una incisión de 18 mm sin seccionar ni desinsertar la musculatura, y que ofrece unos resultados equiparales a los obtenidos con técnicas convencionales debido a que se basa en sus mismos principios quirúrgicos de descompresión radicular.

Introduction

Surgery of herniated lumbar disc pathology has evolved in the last few decades toward the use of less invasive techniques. As a general principle, these new techniques should maintain the efficacy of the procedure while decreasing approach-related morbidity.

Ever since Caspar[1] developed the microsurgical technique (microdiscectomy) using a microscope in 1977, this procedure has been gaining acceptance and many authors today consider it to be the gold standard for the surgical treatment of herniated lumbar disc pathology.

In the last several decades, new techniques have been developed based on the use of an endoscope such as the one developed by Destandau[2] that, using the interlaminar route by means of a small incision, makes it possible to perform the discectomy and root release under endoscopic control with a surgical technique that is basically similar to the one used in open surgery.

In 1997, Foley and Smith[3,4] adapted Wiltse's paraspinal transmuscular approach[5] to access the interlaminar space and perform a discectomy with endoscopic control by means of a tubular retractor separating the muscle fibres without severing or detaching them. According to the opinion of several authors,[6] the most promising of the new methods of minimally invasive posterior approach that have emerged in recent years in the area of microendoscopic discectomy (MED) is that of Foley and Smith, since it enables resection of the emergent disc fragments in the canal and release of the nerve root when the hernia is associated with stenosis of the lateral recess secondary to bone hypertrophy through an incision of less than 2 cm. We have been using the MED technique at our centre for several years now; not only for disc surgery, but also to treat segmental lumbar stenosis of the lateral recess,[7,8] and even to release a lumbar root compressed by other more uncommon pathologies such as a intraspinal synovial cyst.[9]

The process of acquiring the necessary skills to carry out a new technique is translated into a learning curve,[10] which can be defined as the graphic representation of the relation between experience with a new procedure or technique and an outcome variable, such as surgical time, complication rate, hospital stay, or mortality.[10,11] It is generally acknowledged that there is higher morbidity[12] during the learning process of a new technique, which is worth bearing in mind, since it is often not mentioned when publishing the results obtained.

Several different parameters have been used to quantify the learning curve in surgery. Surgical time is one of the most widely used, as it decreases as skills improve; however, other variables have also been contemplated such as the complication rate, bleeding, length of hospitalization, and the frequency with which conversion to an open procedure becomes necessary.[13-16] Moreover, there is a series of subjective components involved that are hard to quantify, although they are no less important (the surgeon's convenience and speed, determination of movements, familiarity with the new procedure, ease with which the anatomic dissection can be carried out) that improve as the surgical skill is acquired.

The aim of this work is to determine the learning curve of MED for the treatment of herniated lumbar disc pathology.

Material and methods

A prospective, observational, clinical study was conducted on a series comprising the first 120 patients to undergo surgery for herniated lumbar disc pathology at the Orthopaedic Surgery and Traumatology Department at the University of Vigo Hospital Complex (Meixoeiro) between March, 1999, and April, 2003, using the MED technique by means of an 18 mm tubular retractor. The MED technique was performed in substitution of conventional open discectomy.

All the interventions were performed by the same surgical team made up of 2 orthopaedic surgeons (RCM and MHB), both acting either as the surgeon or assistant. For this reason, a single learning process for this team and the complete series of patients was studied. Both surgeons had previous experience in open lumbar discectomy and in arthroscopic surgery.

Prior to beginning to use the technique, the surgeons attended 2 surgical sessions conducted by an expert surgeon, as well as a training session on an artificial model and 2 sessions on a cadaver, in order to become familiarized with the visualization of the surgical anatomy using the tubular retractor.

Inclusion criteria: 1. Patients with a diagnosis of disc herniation of the lumbar canal (contained, non-contained, sequestered, or foraminal), who met indication criteria for surgical treatment as defined by the American Association of Orthopaedic Surgeons[17] (radicular lumbalgia sciatica extending distally to the knee; signs of root involvement with or without neurological impairment; absence of significant response to suitable conservative treatment lasting a minimum of three weeks; clinical-topographic correlation between the hernia and the radicular pain confirmed by imaging studies). 2. Patients who, having met the previous criteria except for the minimum conservative treatment period, presented progressive motor impairment.

Exclusion criteria: 1. Massive disc herniation with *cauda equina* syndrome. 2. History of prior surgery at the same level and on the same side. 3. Patients with clinical picture consisting predominantly or solely of lumbalgia, and few or no root symptoms. 4. Associated congenital lumbar stenosis. 5. Lumbar spondylolisthesis at the same level as the hernia. 6. Other causes of vertebral instability, considering unstable any lumbar segment exceeding 4 mm of translation and/or 11 degrees of rocking on the functional X-rays.[18]

Recording of variables: A database was created using the Excel program (Version 2003 Microsoft Corporation) which included patients' demographic characteristics (sex, age, occupation), diagnosis-related variables (type and location of the hernia, associated pathology, duration of symptoms), pre-operative assessment of the clinical situation (intensity of pain according to the Visual Analogue Scale and degree of disability following the Oswestry Disability Index - ODI), and the physical examination (signs of radicular tension and motor and sensory status). Data related to the surgery (surgical time, intra-operative findings, complications, and hospital stay) were recorded, as well as variables having to do with the patients' clinical situation at the 2-month and 1-year check-ups and at a final check-up after 5 years, at which time a survey of patient satisfaction[19] was also conducted and the incidence of re-interventions and return to the workplace noted. The criterion applied was to consider that the reduction or improvement in the ODI score following vertebral surgery must be at least 15 points in order to consider it not only statistically significant, but also clinically relevant. The outcomes obtained were classified as excellent or good, fair, and poor following MacNab's criteria[20] as modified by Turner.[21]

In line with the work by Nowitzke,[13] the learning curve of the technique was determined by assessing the presentation of complications related to the procedure, how long the surgery lasted (decrease in the surgical time throughout the course of the study - *mean and median* - until asymptote was reached) and the rate of reconversions to open surgery.

Although all the patients were monitored for 5 years, in the case of those who required additional surgery during this 5-year period, the final check-up was considered to be the one prior to the second surgery.

A statistical analysis was performed using SPSS software, version 15.0 for Windows. A univariate analysis was conducted to describe the sample (mean and standard deviation for quantitative variables and frequencies for categorical variables), and a bivariate analysis to analyze the relations existing between the variables of interest. Contrast tests were performed to determine the existence of significant differences among the variables studied. Parametric tests were used for the quantitative variables (Student's t, Student's t for paired data). Qualitative variables were compared by means of Pearson's X^2 test, using Fisher's exact test when necessary (expected frequency in cells<5). Following the international consensus, a statistically significant association has been considered when the p value is less than 0.05. In the event that a test turns out to be statistically significant, the clinical significance has been established by the magnitude of the mean effect, with a 95% confidence interval. A Pearson's correlation analysis was performed to establish the relation between the duration of surgery and the time elapsed since the implementation of the technique. In order to determine the "learning time" or the time at which the skill is achieved and after which there is no significant reduction in the surgical time, curve fitting regression models were created.

The tracing of the learning curve was performed using the Cartesian method (the successive exposures in a learning series [patients who underwent surgery using the MED technique] were placed on the X-axis, the duration of the surgical intervention on the Y- axis. Joining up the centres of the data distributed on the XY plane defined the curve).[11]

The patients were informed of the risks inherent to the surgery and the characteristics of the endoscopic surgical technique and signed the corresponding informed consent.

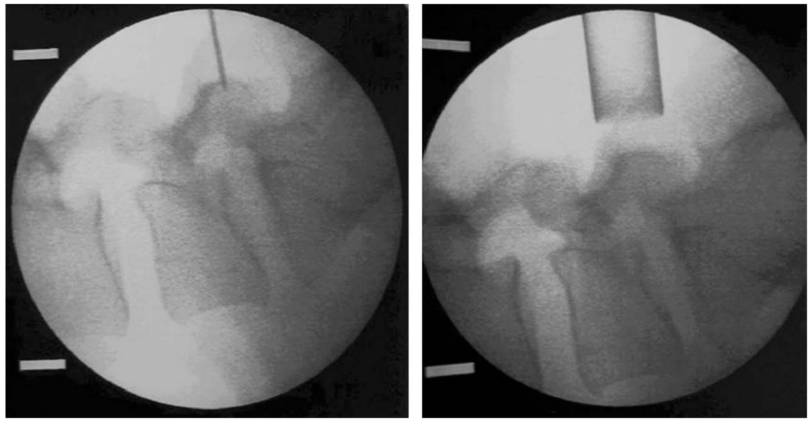

Figure 1 Introduction of the Kirschner wire under fluoroscopic guidance.

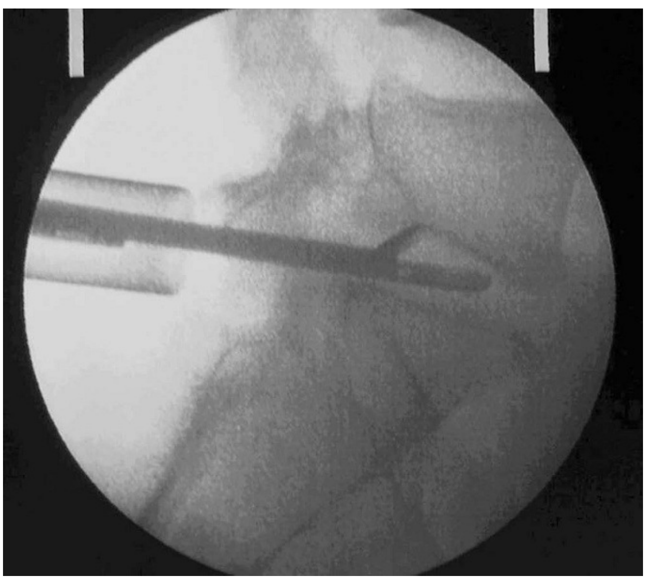

Figure 2 Resection of disc material by means of the tubular retractor.

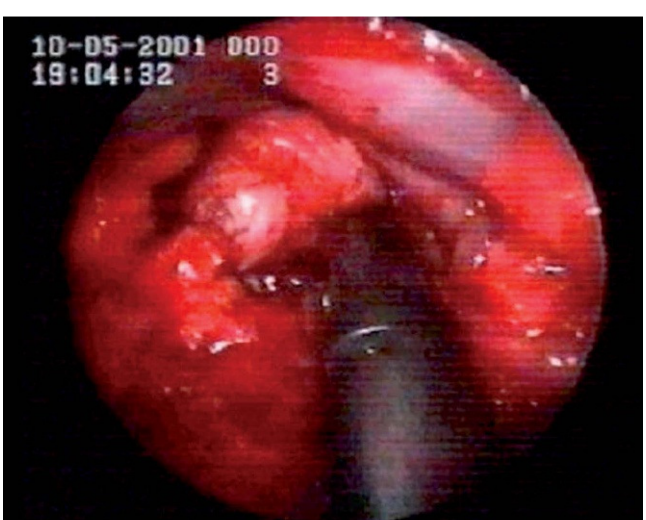

Figure 3 Extruded herniated disc in the vertebral canal. To the right, dural sac and root.

Surgical technique: METRx instrumental (Medtronic Sofamor Danek, Memphis, TN) was used to perform the discectomy and decompress the nerve root under endoscopic control according to the technique described by Foley.[3] A longitudinal incision is made 18 mm to 20 mm from the midline; a Kirschner wire is directed toward the inferior aspect of the superior lamina and metal cannulae are slid on top of the guide wire that dilate the muscle fibres without severing them (fig. 1) in order to enable an 18 mm tubular retractor to be passed for the introduction of a light source and an optical scope connected to a camera. The discectomy is performed under endoscopic control on a video screen (figs. 2 and 3). If necessary, disc fragments that have emigrated outside of the spinal canal can be removed or the lateral recess recalibrated by resecting osteophytes or hypertrophic ridges of the joints inside the spinal process to complete the radicular release. The patient can walk the same afternoon of the operation and, if there is adequate pain control, can leave hospital the next day.

Results

The mean age of the patients was 41.3 years (±11.2) (range 20-72); 65 were male (54.2%) and 55, female (45.8%). The type of hernia was: contained in 56 cases (46.6%), non-contained in 33 (27.5%), sequestered in 27 (22.4%), and foraminal in 4 (3.3%). Prior to surgery 21 patients (17.5%) presented mild or moderate motor impairment; 32 patients (26.7%) had dysaesthesias, and 14 patients (11.7%) suffered from hypoaesthesias (table 1).

The level affected was L5-S1 in 65 patients (54.2%), L4-L5 in 50 cases (41.7%), L3-L4 in 4 cases (3.3%), and in one case there was a ipsilateral two-level hernia (L4-L5 and L5-S1) (0.8%). In 56 cases (46.7%) the right side was affected and the left side was affected in 64 (53.3%) of the patients. The mean duration of the intervention, from the beginning until closure of the incision, was 74.1 min (±29.9).

The mean post-operative stay was 1.9 (±1.5) days. Seventy-two patients (60%) were released from hospital in the morning of the day following surgery, i.e. within the first 24 hours, counting the length of hospital stay in these patients as 1 day. One patient was released on the same day of surgery.

The mean VAS value for the lower limbs went from 7.9 (±1.2) prior to the intervention to 1.2 (±1.4) two months later, 1.2 (±1.6) at the 1-year time point, and 1.7 (±2.2) 5 years after the surgery. The mean value of the lumbar VAS went from 4.6 (±2.5) before the intervention to 1.9 (±1.7) at two months, 2.3 (±4.2) at the 1-year time point, and 2.6 (±2.2) at 5 years. The mean pre-operative Oswestry Disability Index (ODI) was 69.6 points (±14.1). After the intervention, the ODI score fell to the following mean values: 2 months after surgery 14.3 (±10.9), at the 1-year point 10.9 (±11.9) and at 5 years 16.7 (±16.5) ($p<0.05$ in all cases) (table 2). Clinically relevant improvement in the ODI (reduction of more than 15 points) occurred at 2 months in 115 patients (95.8%), at the 1-year point in 116 patients (96.7%) and in the final check-up at 5 years in 109 patients (90.8%). The subjective satisfaction of patients[19] with respect to their surgery was positive in 95% of cases at the final follow-up.

Table 1 Clinical findings on pre-operative examination

Pre-operative examination	Nº of cases	Percentage (%)
Lasègue		8.3
Negative	10	32.5
<45.°	39	59.2
>45.°	71	67.5
Achilles reflex		13.3
Normal	81	19.2
Diminished	16	94.2
Absent	23	5.0
Patellar reflex		0.8
Normal	113	
Diminished	6	
Absent	1	
Muscle strength		
Mild motor impairment (4/5)	18	15.0
Moderate motor impairment (3/5)	3	2.5
Sensory alteration		
Dysaesthesias	32	26.7
Hypoaesthesias	14	11.7

Complications: Some type of complication arose in 14 patients (11.7%). The most common one was dural tears or punctures in 5 cases (4.2%), 3 of which required conversion to an open procedure for suturing, whereas in the 2 remaining cases, it was a puncture of the dura mater with the guide wire (table 3). The only case of deep vein thrombosis occurred in a 68-year old diabetic patient who had been confined to bed for 2 weeks prior to the surgery because of the intensity of his pain. No complication caused mortality and, in all cases, recovery was spontaneous or following the corresponding medical treatment, with the exception of one case of paresis of the extensor muscles in the foot that required transposition of the tendons. There were no cases of excessive bleeding or need for transfusions. On 2 occasions (1.7%), the initial approach performed was at the wrong level (cases 106 and 119). In both cases, the level was corrected intra-operatively after radioscopic verification and the endoscopic procedure continued without complication.

Conversion of the technique to open surgery: In 6 patients (5%), the endoscopic surgery had to be converted to an open technique (table 3). Four of them (dural tears and technical difficulties due to associated stenosis) presented in the first 30 cases. In the next 90 patients of the series, it was only necessary to convert to an open technique on 2 occasions; both of them due to problems with the instrumentation: due to a clamp breaking in the disc space and because of inadequate visualization due to deterioration of the scope. In no case was it necessary to resort to open surgery because of bleeding in the surgical field.

Table 2 Statistical analysis of the reduction in lower limb VAS, lumbar VAS and ODI following surgery. Student's t test for paired data

Test of related samples	Related differences					Sig. (bilateral)
	Mean	Standard desviation	Standard error of the mean	95% Confidence Interval for the difference		
				Inferior	Superior	
Par 1 LL VAS Pre-op at 2 m	6.6	1.7	0.160	6.3	7.0	0.000
Par 2 LL VAS Pre-op at 1 year	6.7	1.8	0.171	6.4	7.0	0.000
Par 3 LL VAS Pre-op at 5 years	6.1	2.3	0.216	5.7	6.6	0.000
Par 4 Lumbar VAS Pre-op at 2 m	2.6	3.0	0.281	2.1	3.2	0.000
Par 5 Lumbar VAS Pre-op at 1 year	2.3	4.9	0.448	1.4	3.2	0.000
Par 6 Lumbar VAS Pre-op at 5 years	1.9	3.3	0.304	1.3	2.5	0.000
Par 7 ODI Pre-op at 2m	55.4	18,0	1.649	52.2	58.7	0.000
Par 8 ODI Pre-op at 1-yr	58.9	18.8	1.723	55.4	62.3	0.000
Par 9 ODI Pre-op at 5-years	52.9	21.5	1.964	49.0	56.8	0.000

LL VAS: lower limb pain according to the Visual Analogue Scale. Lumbar VAS: lumbar pain according to the Visual Analogue Scale. ODI: Oswestry Disability Index. Pre-op: prior to surgery. 2 m: 2-month check-up. 1-yr: 1-year check-up. 5-years: 5-year check-up.

Table 3 Intra-operative and post-operative complications throughout the series and conversion to open surgery

Case nº	Intra-operative complications	Post-operative complications	Conversion to open surgery
Nº 3		Transient paresis	
Nº 6	Dural tear		YES
Nº 7			YES Technical difficulties
Nº 18	Dural puncture	Early recurrence of hernia	
Nº 27	Dural tear		YES
Nº 29	Dural tear		YES
Nº 56		Transient paresis	
Nº 61	Dural puncture		
Nº 83	Material breakage		YES
Nº 96		Paresis	
Nº 101		Discitis	
Nº 104	Partial injury to a root		
Nº 105		Transient paresis	
Nº 107		Venous thrombosis	
Nº 116			YES Deterioration of optics

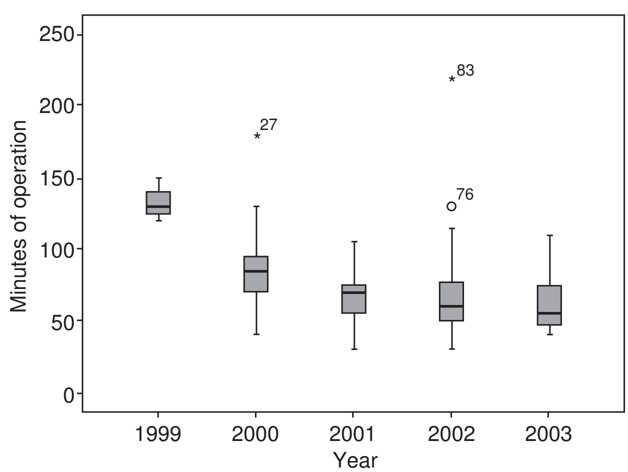

Figure 4 Evolution of surgical time.

Duration of surgery: There was a gradual reduction in surgical time over the course of the 4 years during which the patients underwent surgery, from 133 min in the first 5 cases, operated on in 1999, to 83 min in the following 29 cases operated on in 2000; the duration stabilized at values that varied between 69 and 62 min in the years 2001-2003. The median of surgical time gradually decreased each year, although in 2002 the mean went up slightly because of the existence of one case (number 83) that took a very long time because a discectomy clamp broke in the disc space and finally conversion to an open technique was needed to remove it (fig. 4).

In figure 5, the columns represent the duration of surgery in minutes for the 120 procedures making up the series, sorted by date, and outcomes in boldface refer to the 6 cases that required conversion to an open surgical technique due to the development of the complications specified above.

In red, the cases of conversion to open surgery.

The analysis of Pearson's correlation reveals that there is a significant negative association ($p<0.001$) between the duration of surgery (in minutes) and the time elapsed (in months) since implementation of the technique.

To estimate the "learning time" or time at which the skill is achieved and after which there is no significant reduction in surgical time, the curve fitting regression model (fig. 6).

From the different curves, we can infer that the learning time, in which the line is parallel to the time axis from the time when the technique started to be used, is between 24 and 30 months, which in our series, is equal to the first 48 procedures for the set of the 2 surgeons who comprised the surgical team treating all the patients.

No statistically significant differences were seen between lumbar pain, lower limb pain, and ODI scores at any of the follow-up visits among the first 48 cases (learning curve) and the subsequent 72 cases in the series ($p>0.05$).

Discussion

The learning curve represents an obstacle for many surgeons who feel comfortable using the open procedures with which they obtain good results and who do not want to increase the risk of complications or of achieving worse outcomes that the introduction of a new technique entails. The risk/benefit ratio should be considered when bringing any new technology on board, beginning with analyzing the corresponding learning curve.

No significant complications were observed in our series in relation with the technique. The most important ones were the 3 dural tears that required suturing by open surgery and the breakage of a discectomy clamp inside the disc space. The absence of serious complications during the learning process allows us to state that MED is a safe procedure.

The ascertainment of the procedure's safety and overcoming the learning curve should be pre-requisites for any prospective, randomized evaluation comparing it with conventional techniques.[13]

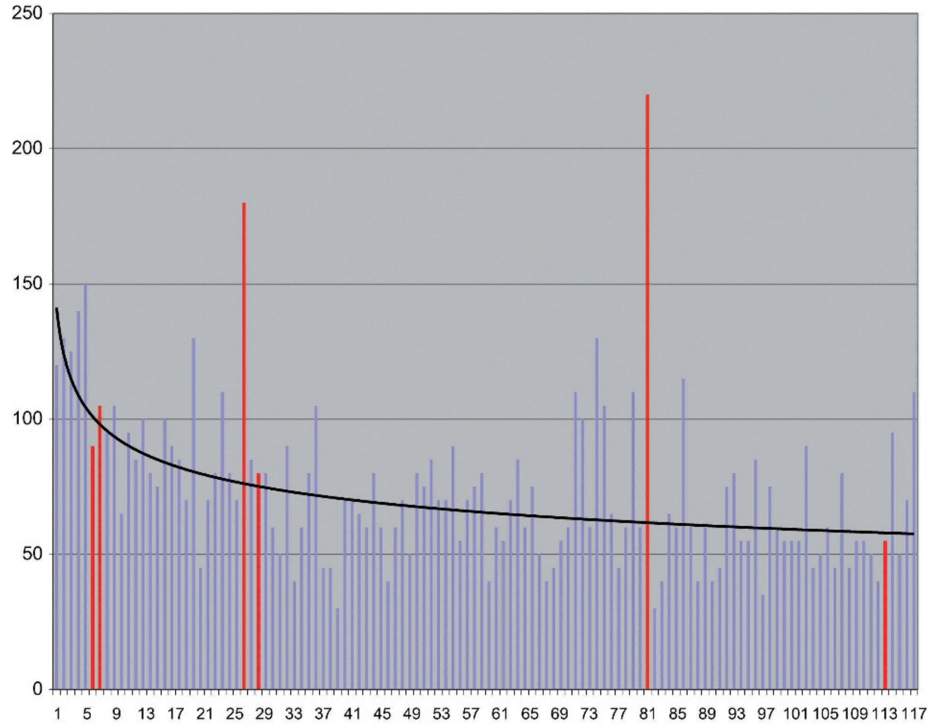

Figure 5 Duration in minutes of all the procedures making up the series.

The initial approach at the wrong level is of particular note, since most authors do not record it with the use of conventional techniques, whereas Schoeggl[22] estimates that it occurs in 3.8% of the cases. In our series, we have made a wrong initial approach on 2 occasions (1.7%). In both cases the level was corrected during the same intervention after radioscopic verification and the endoscopic procedure continued as usual. These 2 episodes were not related to the learning curve, but rather occurred in cases numbers 106 and 119, when the technique had already become routine to us and fewer radioscopic verifications were conducted during the surgery.

The duration of the surgery decreased significantly during the first cases in the series and the evolution of surgical time can be illustrated by a descending curve whose asymptote is reached at around 48 procedures. We also saw that the main intra-operative complications took place in the first 30 patients, which means that they can be related to the difficulties inherent to a surgery that is a highly demanding in technical terms.

We believe, in accordance with what other authors such as Wu et al.[23] state, that it is essential for the surgeon to have prior experience in open disc surgery before starting to use the endoscopic technique (this author estimates that this experience should cover no fewer than 100 open procedures). Practice with an artificial model and on cadavers to become familiarized with the use of the endoscope and with the surgical anatomy can be useful, particularly if the help of another surgeon already experienced in the technique is not available.

When starting to use an endoscopic procedure, it may sometimes be necessary to convert to an open approach due to technical difficulties, bleeding, or inadequate visualization of the structures. For this reason, the rate of conversion to open surgery is also an important indicator for the learning curve. In our series, conversion was performed on 6 occasions (5%): in cases n. 6, 7, 27, 29, 83, and 116. As we have seen, 4 of them were among the first 30 patients, whereas the last two were due to instrumentation issues (a clamp broke and the scope became deteriorated). When on occasion there was excessive bleeding that hindered endoscopic visualization, electrocoagulation with a bipolar clamp or compression on the vessel in question

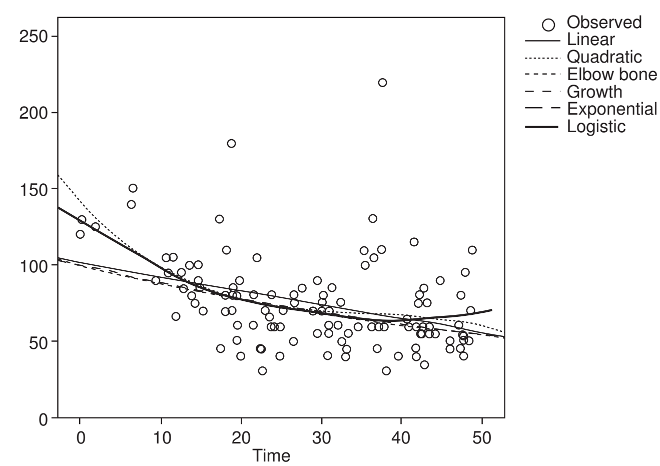

Figure 6 Curve fitting estimation of learning time. X-axis: time since introduction of the technique in months. Y-axis: duration of surgery in minutes.

with a small lens introduced through the working channel was always capable of overcoming the problem. The quality of visualization of the neural structures with the MED technique has been excellent at all times and was only an issue in the case in which the scope had deteriorated.

We can conclude that as of procedure nº 30, both surgeons together reached a plateau in the learning curve and the need to convert to open surgery was rare, while the mean duration of surgery was around 60 min, without any complications of interest, although the asymptote in the curve of decreasing surgical time is reached at around 48 cases. A figure of between 30 and 48 cases can therefore be considered to be the number of procedures needed to reach optimal skill with this procedure.

Nowitzke[13] arrives at a similar conclusion; in his work to determine the learning curve of the MED technique, he observed that the surgeon needed to convert the technique to an open technique on 3 occasions during the first 7 cases and in none of the following 28. Assessing this datum together with the reduction in surgical time and the complication rate, this author established the learning curve at approximately 30 procedures.

Despite the differences observed with respect to surgical time, complications, and conversion to open surgery during the learning curve, this did not translate into any statistically significant difference in the remaining cases in the series regarding lumbar pain, lower limb pain, functional capacity (ODI) scores at any of the clinical follow-up visits (at 2 months, one year, and 5 years); consequently, in our series, the learning curve did not affect the outcomes obtained with the surgery.

Conclusions

In our experience, the MED learning curve consists of about 30-48 procedures for a 2-surgeon team with experience in vertebral surgery and in arthroscopic techniques.

The clinical outcomes in this work were unaffected by the learning curve.

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