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Original Article

Introducing Interlaminar Full-Endoscopic Lumbar Diskectomy: A Critical Analysis of Complications, Recurrence Rates, and Outcome in View of Two Spinal Surgeons' Learning Curves

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Abstract

Background and Study Objective Interlaminar full-endoscopic diskectomy is a minimally invasive surgical alternative to microdiskectomy for the treatment of lumbar disk herniation. The authors analyze their surgical results and learning curves during and after the introductory phase of this surgical technique.

Patients and Methods We present a case review of 76 patients operated on using interlaminar full-endoscopic diskectomy. We retrospectively analyzed two spinal surgeons' learning curves in terms of operation time with respect to intraoperative blood loss, conversion rates, complications, infections, length of hospitalization, need for rehabilitation, recurrence rates, pain intensity, and opioid use. Patients' functional status and Health-related Quality of Life were assessed by follow-up questionnaires for 47 patients, using the North American Spine Society Score and the Short Form 12 in addition to long-term pain intensity, work capacity, and patient satisfaction with the operation.

Results A steady state of the learning curve (operation time) of an experienced spinal surgeon was reached after 40 cases. Supervision by a more experienced surgeon can shorten the learning curve. The rate of conversions (10%), complications (5%), and recurrent lumbar disk herniations (28%) did not negatively affect the long-term outcome in patients operated on before and after the learning phase. Patient satisfaction was high.

Conclusions The rate of conversions, complications, and recurrent lumbar disk herniations compared with microdiskectomy combined with the challenging learning curve should be considered before surgeons adopt this procedure. Supervision by an endoscopically experienced spinal surgeon during the introductory phase is highly advisable.

Keywords
- full-endoscopic lumbar diskectomy
- learning curve
- minimally invasive
- percutaneous endoscopic lumbar diskectomy
- recurrence rate

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Introduction

Microdiskectomy (MD) has become the gold standard for the surgical treatment of lumbar disk herniation (LDH). Endoscope-assisted transforaminal (TF) and interlaminar (IL) approaches evolved at the end of the twentieth century, the latter having been first introduced by Foley and Smith in 1997.[1] Since then, many authors[2–4] have reported mixed results in terms of complications and recurrence rates, and they describe a shallow learning curve as the pivotal point for the introduction of endoscope-assisted IL diskectomy. The spectrum of minimally invasive lumbar surgery was further widened with the advance of the full-endoscopic technique[5,6] (also labeled percutaneous endoscopic lumbar diskectomy), which does not require the use of a tubular retractor. Interlaminar full-endoscopic diskectomy (IL FED) has been assessed in retrospective[7–10] and prospective trials,[5,6,11–14] of which only one featured a control group.[12]

At our institution we perform ~ 500 microdiskectomies for LDH per year. Surgeon 1 (J-Y.F.) began performing IL FED in selected cases of LDH in 2007 and was followed 1 year later by surgeon 2 (H.R.). Both surgeons participated in a training course for full-endoscopic diskectomy prior to clinical application.

We analyzed the surgical results in view of the two surgeons' individual learning curves. The following two hypotheses were tested: (1) Surgeon 2 has a faster learning curve than surgeon 1 because he is supervised by experienced surgeon 1; (2) significantly more conversions, complications, and recurrences occur before a steady state of the learning curve is reached.

Patients and Methods

Patient Population and Follow-Up

All consecutive patients ($n = 76$) who were operated on by surgeon 1 ($n = 53$) and surgeon 2 ($n = 23$) using IL FED between April 2007 and April 2012 were reviewed with respect to operation time in minutes (primary end point) and the following secondary end points: intraoperative blood loss in milliliters, conversion from IL FED to MD, complications, infections, length of hospitalization in days, need for rehabilitation, recurrence rates, leg and back pain pre- and postoperatively measured with the visual analog scale (VAS), and opioid use. In addition to this retrospective data collection, all patients who underwent successful IL FED without conversion were asked to fill out a mailed questionnaire. The questionnaire assessed current leg and back pain, opioid use, and work capacity. The functional status was assessed with the validated German version of the North American Spine Society (NASS) outcome assessment.[15] The Short Form 12 (SF-12) questionnaire[16] was used to assess Health-related Quality of Life (HrQoL). Patients were also asked whether they would have the same operation performed again, provided they had the same outcome. The need for revision surgery for recurrent LDH at the same level confirmed by magnetic resonance imaging (MRI) was asked for to record any revision surgeries performed at different institutions that would otherwise be unnoticed. We defined recurrent LDH as new radicular pain, irrespective of the length of the precedent pain-free interval, corresponding to radiologically evident nerve root compression by extruded disk material on the same side and level as the index procedure.

All retrospective variables were compared between the patients who underwent IL FED before (group 1; $n = 43$) and after (group 2; $n = 25$) a steady state of the surgeon's learning curve (determined by the operation time) was reached. The same analysis was performed for HrQoL and long-term pain intensity for those patients who returned the questionnaire. Patients scheduled for IL FED who were intraoperatively converted to MD were taken into consideration for the analysis of possible complications only, but excluded from analysis of other secondary endpoints.

Ethical Considerations

Written informed consent was requested from all included patients. The study was approved by the Cantonal Ethics Committee St. Gallen, Switzerland (Clinical Trails Unit [CTU] protocol 12/35).

Inclusion and Exclusion Criteria

All included patients had predominant radicular leg pain unresponsive to conservative therapy with or without neurologic deficits corresponding to a single-level nonsubluxed posterolateral disk herniation of either level L4–L5 or L5–S1. Diagnosis was confirmed by MRI in all cases. Exclusion criteria were any kind of previous lumbar surgery (except diagnostic/therapeutic epidural infiltrations), LDH of any level other than L4–L5 or L5–S1, multilevel LDH, foraminal or extraforaminal LDH, lumbar stenosis, lumbar instability, and advanced degeneration of the involved segments.

Surgical Technique

An overview of the surgical instruments used for IL FED is given in ►**Fig. 1** and an intraoperative ►Video 1 is available at http://www.neurochirurgie.kssg.ch/home/unser_fachbereich/unser_angebot/wirbelsaeulen_chirurgie/lumbale_diskushernie.html. Surgery was performed under general anesthesia in the knee-chest position. A < 10-mm-long skin incision was made ~ 1 cm lateral to the midline. Under anteroposterior and lateral fluoroscopy, a dilator aiming at the inferior edge of the superior lamina was advanced (►**Fig. 2A**). Once placed at the superior border of the interlaminar window, an oblique cannula was inserted over the dilator (►**Fig. 2B**). The dilator was removed, the 30-degree working endoscope (Richard Wolf GmbH, Knittlingen, Germany) inserted, and the ligamentum flavum was identified, irrigated, and bluntly perforated using a dissector (►**Fig. 2C**). Bipolar diathermy was used to cauterize epidural veins and fat blocking the view (►**Fig. 2D**). Under constant irrigation and protection of the nerve root with the beveled cannula, the sequester was mobilized with a blunt hook (►**Fig. 2E**) and removed in one piece or in fragments with a rongeur (►**Fig. 2F**) while leaving the intervertebral disk space untouched. After thorough inspection for any remaining disk material or bleeding, the cannula was removed and the skin closed.

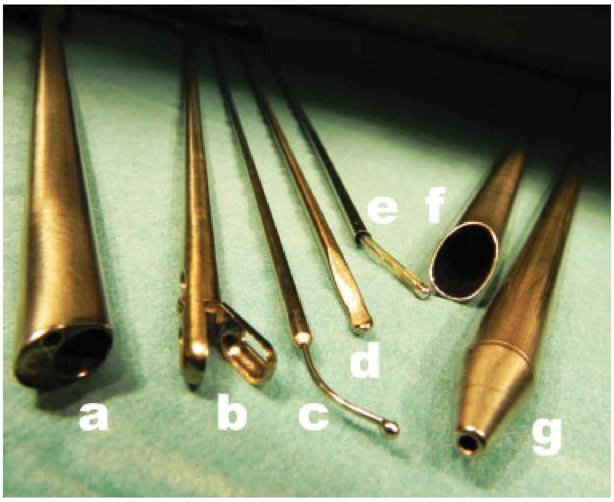

Fig. 1 Overview of the surgical instruments used for interlaminar full-endoscopic diskectomy: (a) 30-degree working endoscope (Richard Wolf GmbH, Knittlingen, Germany); (b) rongeur; (c) blunt hook; (d) dissector; (e) bipolar diathermy; (f) oblique cannula; (g) dilator.

Video 1

Procedural key steps of interlaminar full-endoscopic diskectomy. Online content including video sequences viewable at: www.thieme-connect.com/products/ejournals/html/10.1055/s-0035-1570343.

Statistical Analysis

The two spinal surgeon's learning curves were established by the statistician of the local Clinical Trials Unit using a nonparametric monotone (antitonic) regression (monoreg function from the package fdrtool[17,18]). This regression technique fits horizontal line segments to specific sections of the data, requiring that each line be as low or lower than previous line segments. The primary end-point analysis was performed in the R programming language (v.3.0.1).[18]

The secondary end points were compared using the Mann-Whitney *U* test for continuous variables or the chi-square test for dichotomized or ordinal variables, as appropriate. The SF-12 outcomes were compared with normative data of German patients with and without lumbar back pain.[16]

Analysis of secondary outcomes was performed with SPSS v.19.0. A p value < 0.05 was considered statistically significant.

Results

Patient Characteristics

A total of 76 patients were identified who had received IL FED surgery at our institution. After the exclusion of eight patients who were converted from IL FED to MD intraoperatively, a total of 68 patients were asked to participate in the study. Of those, 47 returned their mailed questionnaire for the long-term clinical outcome analysis. Time of follow-up ranged from 1 to 6 years (mean: 3.4 years, ranging from 1.1 to 6.1 years).

Baseline data of included patients (►**Table 1**) such as sex, age, level, and side of LDH were equally distributed between patients of group 1 and group 2 (patients who underwent

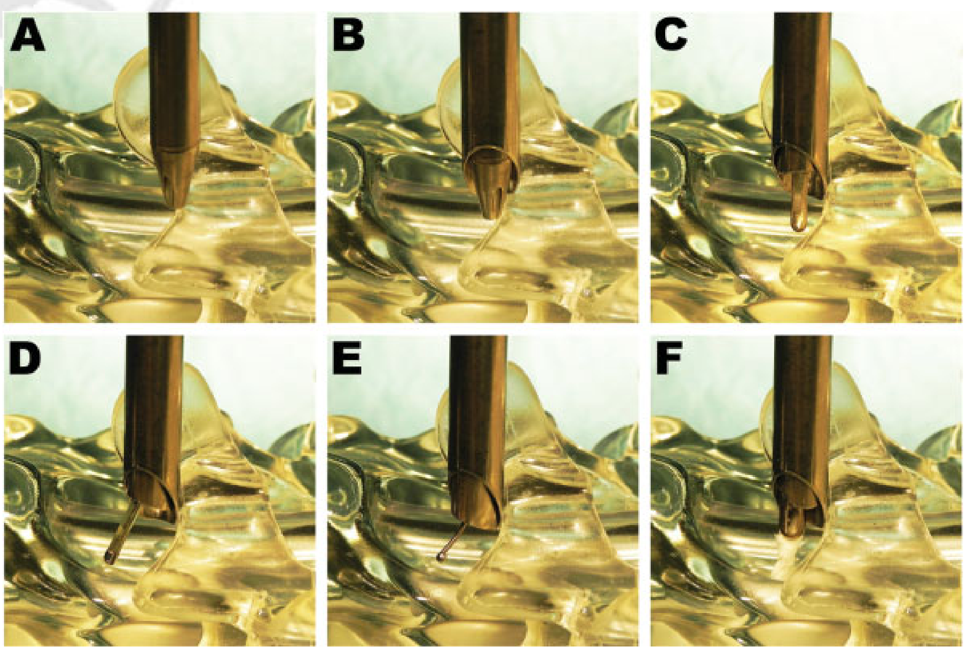

Fig. 2 Procedural key steps of interlaminar full-endoscopic diskectomy (detailed description in the text). (A) Advancing the dilator toward the inferior edge of the superior lamina. (B) Positioned at the superior border of the interlaminar window, an oblique cannula is inserted over the dilator. (C) Dilator removal, insertion of a 30-degree working endoscope (Richard Wolf GmbH, Knittlingen, Germany) and blunt perforation of the ligamentum flavum. (D) Bipolar diathermy. (E) Sequester mobilization. (F) Sequester removal.

Table 1 Patients' preoperative characteristics

		Group 1 $n = 43$		Group 2 $n = 25$		Σ $n = 68$		p value
Sex (%)	Female	15	(35)	10	(40)	25	(37)	0.795
	Male	28	(65)	15	(60)	43	(63)	
Age, y	Mean ± SD	38.5 ± 10.8		40.7 ± 11.1		39.3 ± 10.9		0.571
	Range	17.2–62		24.7–58.8		17.2–62		
Level (%)	L4–5	3	(7)	4	(16)	7	(10)	0.409
	L5–S1	40	(93)	21	(84)	61	(90)	
Side (%)	Right	11	(26)	12	(48)	23	(34)	0.069
	Left	32	(74)	13	(52)	45	(66)	
Pain duration, d)	Mean ± SD	98.5 ± 108.4		135.6 ± 138.7		112.2 ± 120.8		0.265
	Range	5–360		4–360		4–360		
VAS leg	Mean ± SD	4.5 ± 2.6		4.4 ± 2.6		4.5 ± 2.5		0.858
VAS back	Mean ± SD	2.1 ± 1.9		2.3 ± 2.6		2.2 ± 2.1		0.875
Opioid use (%)		14	(33)	13	(52)	27	(40)	0.131

Abbreviations: SD, standard deviation; VAS, visual analog scale.

surgery before and after a steady state of the learning curve was reached). An overall preponderance of left-sided LDH in male patients was noted.

Analysis of the Primary End Point

Operation Time

All patients originally scheduled for IL FED ($n = 76$) were taken into consideration. Surgeon 1 reached an average operation time of 42.7 minutes after 40 operations (including five patients who were converted to MD intraoperatively). Surgeon 2 had a shorter learning curve, reaching an average of 47.3 minutes after 16 operations (including two patients who were converted to MD intraoperatively) (►**Fig. 3**). Operation time decreased significantly for both surgeons with 65.5 ± 26.5 minutes before and 47.2 ± 17.9 minutes after a steady state of the learning curve was reached ($p = 0.001$; ►**Table 2**).

Analysis of the Secondary End Points

Perioperative Parameters, Conversions, Complications, and In-Patient Follow-Up

Blood loss was negligible and similar between both groups ranging between none and a maximum of 10 mL (►**Table 2**). No patient required a blood transfusion or a drain. Six patients of surgeon 1 and two patients of surgeon 2 were intraoperatively converted from IL FED to MD due to complications ($n = 3$), surgeon's uncertainty ($n = 3$), or technical difficulties ($n = 2$) (►**Table 3**). Thus conversion rate was 10.5%. Comparing the conversion rates before (group 1) and after (group 2) a steady state of the learning curve was reached, no significant difference was shown ($p = 0.704$). In addition to the complications that led to conversions, one small dural tear, which did not require repair and was without consequences for the patient, was documented in group 2. Thus there were four complications (5%) with no group differences ($p > 0.99$). Further difficulties encountered during IL FED leading to prolonged operation times are listed in ►**Table 3**. Among these were reduced visibility, orientation loss, demanding anatomical obstacles (e.g., hypertrophied facet joints) during the surgical approach, and one technical problem with the endoscope. No infections were registered. The postoperative hospitalization time was 3 ± 1.3 days on average with no group differences ($p = 0.712$; ►**Table 2**). Only one patient was discharged to rehabilitation due to persistent leg paresis.

Recurrences

Postoperative MRI was not routinely performed, but always in cases of recurrent radicular pain. Radiologically confirmed recurrent LDH was demonstrated in 19 patients (28%); five of these had more than one recurrence. There was no significant difference with respect to the incidence of LDH recurrence before (14 patients in group 1) and after (5 patients in group 2) a steady state of the learning curve was reached ($p = 0.401$; ►**Table 2**). The majority ($n = 10$) occurred within 4 weeks after the initial operation. Sixteen patients had revision surgery either using IL FED ($n = 6$) or MD ($n = 10$). Three of the latter operations were performed at another neurosurgery clinic. Of note, 50% of all recurrent LDH were treated surgically within 4 weeks after symptom onset; one patient was revised endoscopically on the first postoperative day. Finally, one patient required a lumbar disk prosthesis due to diskopathy after 15 months, and another patient underwent lumbar spine fusion after 4 years.

Pain

The intensity of leg and back pain on postoperative day 1 and 2, as well as for follow-up, was equal between both study groups (p values in ►**Table 2**). Although 40% of the patients were on opioid medication preoperatively, only

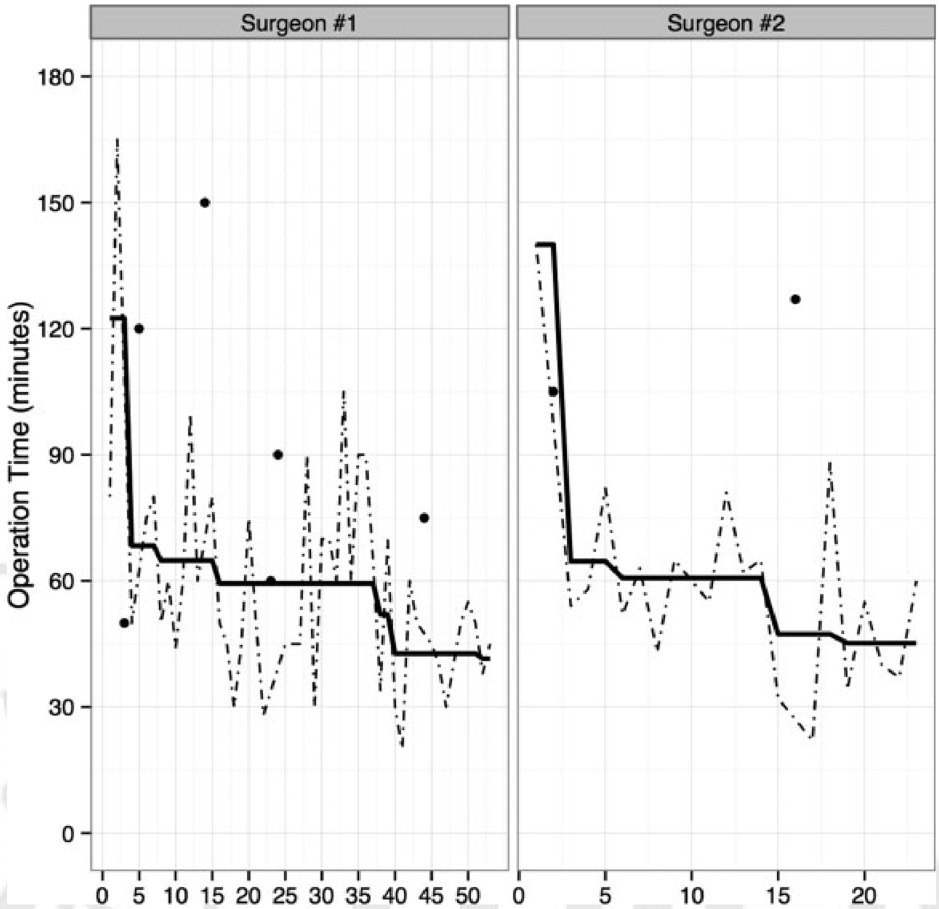

Fig. 3 Average operation time becomes an asymptote with 42.7 minutes after 40 operations (35 interlaminar full-endoscopic diskectomy [IL FED] plus 5 conversions to microscopic diskectomy [MD]) for surgeon 1 and 47.3 minutes after 16 operations (14 IL FED plus 2 conversions to MD) for surgeon 2. The unconnected dots represent converted patients, which count as operative case numbers but are omitted for the analysis of the operation time.

one patient required them at the time of follow-up. It should be noted that one patient in group 1 completed his follow-up questionnaire while he was suffering from severe pain (VAS 10/10) due to a recurrent LDH. Nevertheless, he was included in the analysis.

HrQoL and Working Capacity

The NASS pain/disability score (1.96 ± 1.07) and NASS neuro score (2.33 ± 1.25) showed no significant difference among patients in both groups ($n = 47$) at the time of follow-up (►**Table 2**). The same held true for the SF-12 mental component summary (MCS) (55.38 ± 6.95) and SF-12 physical component summary (PCS) (47.77 ± 10.12) (►**Table 2**).

Only three patients had a reduced working capacity at the time of follow-up. One further patient was on maternity leave; two patients were retirees.

Patient Satisfaction

Most of the patients (81%) said that they would certainly (73%) or probably (8%) choose the same operation again, provided they had the same outcome. Among those were eight patients with a recurrent LDH. Only 11% were unsure, 3% said that they probably would, and 5% said that they would certainly decide against surgery (►**Fig. 4**).

Discussion

We analyzed the introduction period of IL FED into a neurosurgical department with a spinal focus. The learning curves demonstrate a total number of ~ 40 procedures needed for an experienced spinal surgeon (surgeon 1) to reach a steady-state operation time (42.7 minutes) without internal supervision (►**Fig. 3**). In addition to professional courses, supervision by an experienced colleague shortens the learning curve: Surgeon 2, who was supervised by surgeon 1, reached a similar operation time of 47.3 minutes after only 16 procedures (►**Fig. 3**).

Our data indicate that the total incidence of difficulties and complications encountered is higher during the learning phase for both surgeons. The mid- to long-term clinical outcome of the patients operated on during that period, however, was not negatively affected as compared with those operated on thereafter.

Learning Curve

IL FED was previously shown to be associated with a significant learning curve.[5,7,9,11–14] It is well known from minimally invasive surgery training that the learning phase can be shortened and complications be reduced when surgeons

Table 2 Perioperative parameters and follow-up

			Group 1 $n = 43$	Group 2 $n = 25$	Σ $n = 68$	p value
Operation time, min		Mean ± SD	65.5 ± 26.5	47.2 ± 17.9	58.8 ± 25.2	0.001
		Range	28–165	20–90	20–165	
Blood loss, mL		Mean ± SD	2.6 ± 2.6	1.8 ± 2.9	2.3 ± 2.7	0.075
		Range	0–10	0–10	0–10	
Postoperative hospitalization, d		Mean ± SD	3 ± 1.3	2.8 ± 1.2	3 ± 1.3	0.712
		Range	2–7	2–6	2–7	
Recurrent LDH (%)			14 (33)	5 (20)	19 (28)	0.401
Early		(< 4 wk)	6	4	10 (53)	0.303
Late		(> 4 wk)	8	1	9 (47)	
Revision surgery (%)			11 (26%)	5 (20%)	16 (24)	0.768
Early		(< 4 wk)	6	4	10 (63)	0.608
Late		(> 4 wk)	5	1	6 (37)	
Outcome: Pain						
VAS leg	POD1	Mean ± SD	1.1 ± 1.3	2.0 ± 1.9	1.4 ± 1.6	0.048
	POD 2	Mean ± SD	1.3 ± 1.8	1.2 ± 1.4	1.2 ± 1.7	0.916
	Follow-up[a]	Mean ± SD	2.1 ± 2.9	1.9 ± 2.4	2.0 ± 2.7	0.940
VAS back	POD 1	Mean ± SD	0.7 ± 1.1	1.4 ± 1.5	1 ± 1.3	0.252
	POD 2	Mean ± SD	0.4 ± 0.7	0.7 ± 0.8	0.5 ± 0.7	0.397
	Follow-up[a]	Mean ± SD	2.5 ± 2.8	1.9 ± 2.0	2.3 ± 2.6	0.605
Opioid use		Follow-up[a]	1	0	1	n/a
Outcome: Life quality and work capacity						
NASS Pain/Disability[a]		Mean ± SD	1.92 ± 1.03	2.03 ± 1.16	1.96 ± 1.07	0.682
		range	1–5.18	1–5.36	1–5.36	
NASS Neuro[a]		Mean ± SD	2.36 ± 1.34	2.27 ± 1.08	2.33 ± 1.25	0.891
		range	1–5.17	1–4.16	1–5.17	
SF-12 MCS[a]		Mean ± SD	55.66 ± 6.05	54.82 ± 8.7	55.38 ± 6.95	0.99
		range	42.28–64.9	34.86–67.09	34.86–67.09	
SF-12 PCS[a]		Mean ± SD	47.46 ± 11.22	48.38 ± 7.75	47.77 ± 10.12	0.492
		Range	19.93–58.38	31.24–55.91	19.93–58.38	
Reduced work capacity[a]			2	1	3	NA

Abbreviations: LDH, lumbar disk herniation; MCS, mental component summary; NA, not applicable; NASS, North American Spine Society; PCS, physical component summary; POD, postoperative day; SD, standard deviation; SF-12, Short Form 12; VAS, visual analog scale.
[a]Missing data: Only 47 of 68 patients returned their follow-up questionnaire.

are supervised by a more experienced colleague.[2] Longer operation times in our series were mainly caused by difficulties with the anatomical orientation. This was found to be most challenging in the early stages of IL FED introduction. Apart from the new adoption of the two-dimensional endoscopic view, the correct and safe identification of the ligamentum flavum was a major hurdle in the beginning. It appears white under endoscopic view, rather than yellow with direct visualization or when using the operative microscope. Degenerative changes can become obstacles to the approach for beginners and led to conversion to MD in one case in our series (►**Table 3**). Computed tomography (CT) might be useful to assess for facet joint hypertrophy in elderly patients while there is no rationale for an age cut-off per se in performing IL FED. CT could also help to exclude disk herniation calcifications in patients with long-standing pain; size of disk herniation does not predict the success of the operation from our experience. Prior to booking a case for IL FED, measuring the size of the interlaminar window on preoperative X-rays is advisable. Over the course of time, we became less reluctant to operate on patients with more challenging anatomy including concomitant minor spinal stenosis.

Table 3 Difficulties encountered during interlaminar full-endoscopic diskectomy in a series of 76 analyzed cases

Surgeon 1					
Case	Sex	Age, y	Level/Side	Difficulty/Complication	Conversion
2	Male	23	L5–S1 left	Orientation loss because ligamentum flavum could not be identified	No
3	Male	20	L5–S1 right	Less sequester found than expected. MD did not find any remaining sequester	Yes
5	Male	22	L5–S1 right	LDH not visible with endoscope	Yes
14	Male	57	L5–S1 left	No visibility due to excessive bleeding (200 mL). Nerve root S1 could not be mobilized	Yes
15	Male	44	L5–S1 right	Reduced visibility due to extraspinal muscle bleeding	No
23	Male	60	L5–S1 left	Dural tear	Yes
24	Male	49	L5–S1 right	Could not identify ligamentum flavum	Yes
28	Male	54	L5–S1 right	Challenging anatomy due to facet joint hypertrophy	No
33	Female	48	L5–S1 left	Endoscopic malfunction	No
44	Female	76	L5–S1 left	LDH could not be mobilized	Yes
Surgeon 2					
Case	Sex	Age, y	Level/Side	Difficulty/Complication	Conversion
2	Male	48	L5–S1 right	Two dural tears	Yes
16	Male	57	L5–S1 left	No sequester found. MD did not find any sequester.	Yes
18	Female	37	L4–L5 right	Reduced visibility due to diffuse bleeding from bony structures	No
21	Male	58	L5–S1 right	Small dural tear	No

Abbreviation: LDH, lumbar disk herniation; MD, microscopic diskectomy.
Note: Eight cases led to intraoperative conversion from interlaminar full-endoscopic diskectomy to MD.

Similar to endoscope-assisted learning curve assessments[2,4] other authors have analyzed their learning progress in IL FED using the operation time as a primary end point. Ruetten et al[12] described a steady state of the learning curve after $\sim$ 30 cases. Xu et al[13] noted an average operation time of 102 minutes for cases 1 to 12, and 57 minutes for cases 25 to 36. Likewise, it took Wang et al[11] on average 108 minutes to operate on cases 1 to 10, and 43 minutes for cases 21 to 30. Yadav et al[14] reported that the average operation time for the first 25 cases (135 minutes) could be halved in the last 350 cases (68 minutes). Because of this relatively long learning phase, IL FED is highly debated among specialists in spinal surgery. The introduction of new techniques associated with shallow learning curves, but without clear superiority over the so-called gold standard treatments should be questioned, and assessments of learning curves considered as critical.[19]

Our opinion is that an endoscopic training course is mandatory to maximize patient safety at the beginning of the learning curve. Ideally, a spinal surgeon well experienced with endoscopic lumbar diskectomy assists a learner until the steady state of the learning curve is reached.

Conversions and Complications

Similar to operation time, a learning curve can be established by the number of conversions and complications. Two conversions took place in the early phase of a series of 36 full-endoscopic operations where difficulties when passing the working sheath through the interlaminar space were ecountered.[13] Misplacement of the working portal as well as variations of the nerve root origin were deemed responsible for a high conversion rate of 10% by Wang et al.[9] In a previous learning curve evaluation, the same author[11] counted two conversions, and with respect to complications, one dural tear in the first 10 cases, and only one additional complication (dural tear) in the following 20 cases. Yadav et al[14] found one conversion, six dural tears, one nerve root injury, and two facet joint injuries to take place in the initial 50 cases in a large series of 400 patients. Similarly, Hsu et al[7] recognized a significant rate of complications in terms of nerve injuries in the initial phase (2 of the first 10 patients) of their full-endoscopic series with 22 IL and 34 TF approaches. It must be emphasized that there is no need for dural repair in FED surgery. Sencer et al[20] reported six dural tears in 163 FED cases, and no attempt to repair was made in five cases. In one

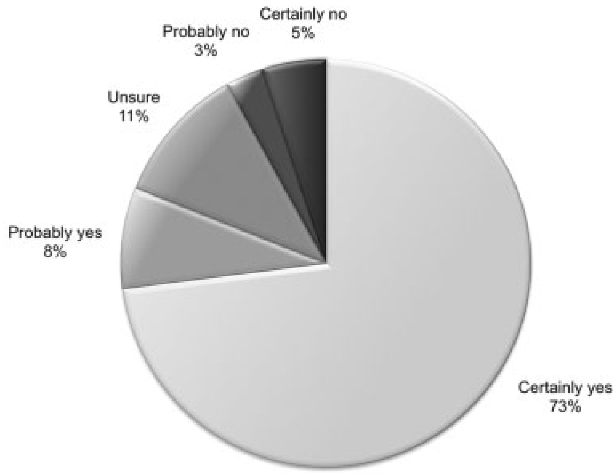

Fig. 4 Patient satisfaction with the operation: "Provided you had the same outcome, would you have the same operation performed again?"

case an open cerebrospinal fluid fistula with a complicated postoperative course was related to their attempt to perform an open microscopic repair, and the authors recommended to refrain from such attempts. Whereas at the beginning of the learning phase (surgeon 1, case 23, and surgeon 2, case 2) we converted to an open procedure, we later changed our management with this complication (surgeon 2, case 21; no conversion) and registered no sequelae.

In agreement with previous literature and clinical studies of endoscope-assisted diskectomy,[2,21] almost all conversions (7/8) and complications (3/4) in the current study occurred before the steady state of the learning curve was reached, although this was not statistically significant. Again, these findings reflect the surgeons' anatomical uncertainty at the beginning of their learning path using IL FED. Overall, our 5% complication rate after IL FED was close to the 4% complication rate normally observed after MD.[22] As a merit of the minimally invasive technique, we observed less blood loss (2.3 ± 2.7 mL) compared with MD (79 ± 119 mL[22]), as well as reduced scarring with surgical revision after IL FED as previously highlighted by Ruetten et al.[5,6,12]

Recurrences

The rate of recurrent LDH requiring revision surgery after IL FED varies greatly in the literature. For an experienced surgeon it was found to be 5.7% and thereby equal[12] to or even lower[23] than the open procedure. However, in one prospective study[13] with a follow-up of 1 to 1.5 years and another long-term follow-up study,[11] the recurrence rates were reported to be nil. A high revision surgery rate of 13% due to recurrence or insufficient removal was found in two studies.[7,10] Hsu et al[7] noted that these took place predominantly at the beginning of the learning phase, but the authors did not separate their data for the IL FED and TF FED approach. In the literature of endoscope-assisted diskectomy, a significant higher recurrence rate as compared with MD was reported by Teli et al.[3]

Our follow-up interval was significantly longer (mean: 3.4 years, ranging from 1.1 to 6.1 years) as compared with most studies for FED. Taking into account the progressive natural course of degenerative lumbar disk disease, our recurrence rate can be expected to be higher. Also, preoperative selection bias of younger individuals (mean: 39.3 ± 10.9 years, ranging from 17.2 to 62 years) might have negatively skewed our recurrence rate. Patients between the ages of 35 and 49 years are known to have a higher cumulative risk of multiple reoperations after lumbar diskectomy of 17.1% at 3-year follow-up.[24] Because the time and age factors alone, however, cannot account for the high rate of LDH recurrence (28%) and revision surgery (24%), other explanations have to be considered.

In contrast to MD, where the intervertebral disk space can be inspected thoroughly and a partial enucleation performed, we only removed the loose sequester at the early stage of IL FED surgery. Any possibly remaining loose disk material might have been left in the intervertebral space. As more experience was gained and more instruments were introduced, a better exploration of the site may have led to a more rigorous resection, resulting in fewer recurrent LDHs after a steady state of the learning curve was reached (group 2). Indeed, our data indicate that most of the recurrent LDHs (14 of 19) were documented for patients in group 1. Due to the small patient sample in group 2, this did not reach statistical significance.

A further explanation for our high recurrence rate could be the earlier mobilization of patients due to less wound pain in the immediate postoperative period after IL FED compared with MD. The body of literature[25,26] on minimally invasive endoscope-assisted diskectomy highlights the advantage of reduced tissue trauma by measuring a reduced cytokine response or creatine phosphokinase as surrogate markers. Endoscope-assisted[25] and full-endoscopic[9] surgery for LDH resulted in a shorter hospital stay. Likewise, our endoscopically operated patients were discharged earlier (3 ± 1.3 days) than patients after MD (6.3 ± 2.1 days[22]). Whether earlier mobilization or discharge contributed to more recurrent LDHs observed within the first 4 weeks after the index procedure remains speculative.

The time span between onset of recurrent radicular pain and decision for revision surgery was relatively short in our patient cohort. As shown in ►**Table 2**, 63% of all revision surgeries took place within 4 weeks after symptom onset, with one patient even revised on the first postoperative day. Because we used a new type of operation that involves less postoperative pain, we might have been more attuned to the signs of postoperative pain, which likely resulted in faster diagnosis and revision surgery. Possibly a significant proportion of our patients experiencing recurrent sciatica might in fact be due to residual disk material (i.e., insufficient sequestrectomy) rather than a real recurrent LDH. In any case, nonoperative management of recurrent sciatica was recommended as first-line therapy to all of these patients.

Contrary to MD where a dorsal decompression is done by flavectomy, laminotomy, and undercutting, thus creating more space for the nerve root, in IL FED only the ligamentum flavum is perforated. Thus even a small recurrent LDH could likely cause more nerve root compression in post–IL FED patients than in post-MD patients, possibly resulting in more rapid and severe development of radicular pain.

Outcome

Despite the fact that a quarter of our patients after IL FED had to undergo revision surgery, we found short to long-term clinical outcomes and patient satisfaction to be similar to those observed after MD. Mean postoperative and follow-up VAS pain levels were low for both leg and back pain, independent from the surgeon's experience (►**Table 2**). Of 47 patients returning the follow-up questionnaire, only one patient required opioid analgesics, and three patients stated that their ability to return to work was reduced. NASS for pain and neurogenic symptoms and function were not significantly different between patients operated on before and after a steady state of the learning curve was reached (►**Table 2**). Likewise, in both groups fair HrQoL outcomes were obtained with mean SF-12 PCS of 47.77 ± 10.12 and MCS of 55.38 ± 6.95. These values are within the range of values obtained from the general German-speaking population.[16]

Study Limitations

Our study consisted of only two surgeons, limiting the generalizability of our data. Further limitations are the retrospective design, the possible selection bias, and the heterogeneity of patient characteristics, as well as the lack of a control group. However, the confounding factors were equally distributed between both study groups. The follow-up period was significantly longer in patients of group 1 compared with patients of group 2. For the long-term secondary end-point analysis we could only use data of 47 out of 68 patients due to loss of follow-up.

Conclusion

IL FED provides good short- and long-term outcome in terms of pain and HrQoL. The advantages are less intraoperative blood loss, shorter hospitalization times and a high patient satisfaction with only minimal wound pain thanks to its minimally invasive nature.

We recommend considering the shallow learning curve and mentoring by an IL FED experienced spinal surgeon initially. By virtue of the high number of recurrences, a randomized clinical trial comparing IL FED with MD should be conducted. Further technological development might also improve the feasibility of IL FED in the future.

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