Learning curve of full-endoscopic lumbar discectomy

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Abstract

Purpose To report the learning curve of full-endoscopic lumbar discectomy for a surgeon naive to endoscopic surgery but trained in open microdiscectomy.

Methods From July 2006 to July 2009, 57 patients underwent full-endoscopic lumbar discectomy and 66 underwent open microdiscectomy. The clinical results were evaluated with a visual analog scale (VAS) and the Oswestry Disability Index (ODI). Spearman's coefficient of rank correlation (ρ) was used to assess the learning curves for the transforaminal and interlaminar procedures of full-endoscopic lumbar discectomy.

Results After full-endoscopic lumbar discectomy, the VAS and ODI results of the patients followed up were comparable with those of open microdiscectomy. A steep learning curve was observed for the transforaminal procedure, but not the interlaminar procedure.

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

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

Introduction

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

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

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

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

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Patients and methods

Before attempting full-endoscopic discectomy, the senior author (H-T H) observed three cases of transforaminal approach and three cases of interlaminar approach at a center respected for endoscopic discectomy, and then practiced on a cadaver at his own university.

Between July 2006 and July 2009, this surgeon performed full-endoscopic discectomy on 59 patients who suffered from buttock and leg pain due to disc herniations. The duration of pain ranged from 3 days to 3 years (mean, 335 days). All patients underwent magnetic resonance imaging (MRI) preoperatively. Two patients converted to open microdiscectomy were excluded from the following analysis. The mean age of the remaining 57 patients (38 men and 19 women) was 44.2 years. Twenty-two patients (38.5 %) underwent an interlaminar procedure, 34 (59.6 %) underwent a transforaminal procedure and one (1.9 %) underwent both. Twenty-three interventions were performed at the L5–S1 level, 33 at the L4–5 level, two at the L3–4 level and one at the L1–2 level. Two patients with 2-level herniated discs underwent 2-level surgeries (Table 1).

All operations were performed under general anesthesia. Herniated discs located at L5–S1 were treated using the interlaminar procedure. The transforaminal procedure was indicated if the herniated disc was within the spinal canal according to the criteria of Ruetten et al. [6].

In the transforaminal approach, the operation was performed with the patient lying prone. A linear skin incision, about 8 mm long, was made at the desired level. A needle (1.25 × 250 mm) was inserted posterolaterally under intraoperative fluoroscopic guidance and pointed to the desired foramen. A lead wire was inserted through the needle into the target foramen and then the needle was removed. Then a cannulated dilator (outer diameter,

6.9 mm) was inserted. At the same time, the lead wire was removed so that the dilator could be hammered into the foramen. A working sheath with a beveled opening and an outer diameter of 7.9 mm enclosing the dilator was inserted toward the foramen. The dilator was removed from the working sheath and an endoscope placed within the working sheath and moved toward the foramen (Fig. 1a). Decompression was performed while maintaining visual inspection and steady irrigation (Fig. 1b, c).

In the interlaminar approach, the patient was placed prone. An incision, about 8 mm in length, was made in the middle of the lateral edge of the interlaminar window. A 6.9 mm outer diameter dilator was inserted bluntly into the lateral edge of the interlaminar window and a working sheath with a beveled opening inserted toward the ligamentum flavum. An endoscope was inserted and the procedure continued under direct visualization with normal saline irrigation maintained at a constant rate (Fig. 2a). A lateral incision of 3–5 mm was made in the ligamentum flavum and subsequently dilated to allow access to the spinal canal. Thereafter, the beveled opening of the working sheath was placed on the herniated disc with the nerve root pushed medially (Fig. 2b, c). A long round-headed pin was used to penetrate the annulus fibrosus, then was pushed into the nucleus pulposus (Fig. 2d, e), creating a hole for annulotomy and subsequent discectomy, and allowing radiographic confirmation of the disc (Fig. 2f, g).

Blood loss, operative time, postoperative complications, reherniation and insufficient removal of herniated disc were recorded. MRI was not routinely performed in patients who had sufficient disc removal or in those without postoperative pain or nerve injury. Postoperative MRI was indicated only for those patients with postoperative pain or nerve injury. Operative results were assessed by using a visual analog scale (VAS) and the Oswestry Disability Index (ODI). All patients were assessed by the first author at 1 week and 1 month postoperatively. Follow-up at 3, 6 and 12 months and yearly thereafter was performed by a well-trained nurse under the supervision of the same surgeon.

To compare the results of full-endoscopic discectomy to open microdiscectomy, 66 patients (45 men and 21 women) with a mean age of 50.4 years who underwent open microdiscectomy performed by the same surgeon during the same period were enrolled in this study. Written informed consents were obtained from all patients.

Analysis of variance (ANOVA) was used to compare full-endoscopic discectomy with open microdiscectomy. The comparison of complications between the transforaminal approach and interlaminar approach was analyzed by Fisher's exact test. The learning curves for the transforaminal and interlaminar procedures of full-endoscopic discectomy were assessed by Spearman's coefficient of

Table 1 Summary of the procedures and level-related operative time for 57 consecutive patients who underwent full-endoscopic lumbar discectomy

Procedure	No. of cases	Op. time (min)
TF	34	
L1–2	1	78
L3–4	1	64
L3–4 + L4–5	1	170
L4–5	31	77.1 ± 43.0
IL	22	
L5–S1	22	93.7 ± 44.5
IL + TF	1	
L4–5 + L5–S1	1	180

TF transforaminal, IL interlaminar, Op operative

Fig. 1 **a** Lateral approach for the full-endoscopic transforaminal operation. Patient is placed in the prone position under a fluoroscope (triangle). The midline and cranial side are indicated by a dashed line and a star, respectively. **b** Intraoperative anteroposterior fluoroscopic

image of the transforaminal operation with working sheath (short arrow) and Kerrison punch (long arrow). **c** Intraoperative view in transforaminal approach with the traversing nerve (short arrow), and margin of the disc space (stars)

rank correlation (ρ). A positive significance level was assumed at a probability of <0.05 . Nonlinear regression analysis was applied to construct best-fit curves for data. All statistical analyses were performed using SAS version 15.0 (SAS, Inc., Cary NC).

Results

The mean follow-up period for full-endoscopic discectomy was 20.4 months (range, 12–24 months). The mean operative time was 86.5 ± 45.9 min for full-endoscopic discectomy: 77.1 ± 43.0 min for procedures at the L4–5 level and 93.7 ± 44.5 min for procedures at the L5–S1 level (Table 1). Operative blood loss was not measurable. Neither dural tear nor postoperative bleeding was encountered. Forty-seven (82.4 %) patients could ambulate without any postoperative leg pain as soon as they regained consciousness from general anesthesia. Of the remaining ten patients, four suffered from transient leg numbness which subsided within a week, four had insufficient removal of disc and two had nerve root injuries. Figure 3 summarizes the operative procedures and clinical outcomes of full-endoscopic discectomy.

Persistent symptoms after surgery were noted in four patients in whom follow-up MRI showed insufficient

removal of herniated discs: two at L4–5 and two at L5–S1. Recurrence of symptoms was noted in the two other patients who showed reherniation of the disc at 1 month and 1 year postoperatively. Microscopic revision discectomy was performed in five patients, including three with insufficient disc removal and two with reherniation. Spinal fusion was carried out in one patient with persistent back pain who had insufficient disc removal at L5–S1, although the patient's leg pain was alleviated after interlaminar approach.

Of the two patients with nerve injuries, one experienced leg numbness and weakness due to S1 root injury and had full recovery 1 month after the operation, while the other suffered from drop foot due to L5 injury and had complete recovery 2 months postoperatively.

The number of patients lost to follow-up for full-endoscopic discectomy and open microdiscectomy was 11 in each group. Among the 11 patients lost to follow-up with full-endoscopic discectomy, five did not answer the phone call, three provided the wrong phone numbers, two moved overseas, and one died in a traffic accident. After full-endoscopic discectomy, VAS and ODI scores of the 46 patients of 57 followed up decreased from 7.7 and 36 to 1.6 and 6.4, respectively, while after open microdiscectomy VAS and ODI scores of the 55 patients of 66 followed up decreased from 9.0 and 32 to 1.3 and 3.3, respectively. No significant differences were noted in a comparison of the

Fig. 2 **a** Interlaminar approach for the full-endoscopic operation. Cranial side is indicated by a star. **b** A nerve root (star) is seen before being pushed away by a working sheath (long arrow). **c** A disc (triangle) is disclosed partially when the nerve root (star) is pushed away by the working sheath (long arrow). **d** A pin (short arrow) penetrating the annulus fibrosus of the disc (triangle) with the nerve root (star) protected and mobilized by rotating the working sheath

(long arrow). **e** Only the disc (star) with the pin (short arrow) is seen in the operative field, while the nerve is fenced by the working sheath (long arrows). **f** Intraoperative lateral fluoroscopic image of the interlaminar operation with working sheath (short arrow) and Kerrison punch (long arrow). **g** Intraoperative view in interlaminar access with the ligamentum flavum (triangles), the traversing nerve (long arrow), and margin of the disc space (stars)

functional outcomes between full-endoscopic discectomy and open microdiscectomy (Table 2). In addition, complications did not differ significantly between the transforaminal and interlaminar approaches (Table 3).

After excluding the 2-level surgeries, we observed a statistically significant learning curve for the transforaminal procedure ($P < 0.001$), but not the interlaminar procedure ($P = 0.66$). The learning curve for the transforaminal procedure spanned a period of 3 years, with varying time intervals between individual operation dates. Operative time was rapidly reduced in the early phase, and then tapered to a steady state for the 33 cases receiving the transforaminal procedure (Fig. 4).

Discussion

Our initial experience with full-endoscopic discectomy showed VAS and ODI results comparable with those of open microdiscectomy. Most patients (82.4 %) could ambulate without pain immediately after recovery from general anesthesia. The improvement resulted from sufficient removal of the herniated disc, minimized traumatization and little if any blood loss. Compared to open microdiscectomy, the operative time was longer but complication and reoperation rates were similar (Table 4). The contributing factors for the longer surgery time with full-endoscopic discectomy were intraoperative bleeding which

Fig. 3 Flow chart summarizing surgical options and results of full-endoscopic lumbar discectomy

Table 2 Comparison of functional outcomes between full-endoscopic discectomy and open microdiscectomy

Outcome measure	Full-endoscopic discectomy (n = 46)	Open microdiscectomy (n = 55)	P value
Pre-OP VAS	7.65 ± 2.82	8.98 ± 1.35	n/a
Post-OP VAS	1.56 ± 2.18	1.29 ± 1.84	0.44
Pre-OP ODI	35.6 ± 10.1	31.9 ± 10.1	n/a
Post-OP ODI	6.42 ± 9.82	3.29 ± 6.94	0.17

n/a not applicable, VAS visual analog scale; ODI Oswestry Disability Index

Table 3 Comparison of complication between transforaminal and interlaminar procedures

Complication	Transforaminal (N = 34)	Interlaminar (N = 22)	P value
Nerve injury	1	1	1.0

blurred the operative field and loss of depth sensation because of the 2-dimensional vision of the endoscope. The complication occurred in the group of open microdiscectomy was a deep wound infection which was cured by debridement and 2 weeks of antibiotic therapy.

The nerve injury rate (4.3 %) was slightly higher than that reported for microscopic discectomy (0–1.7 %) [8, 9]. The two transient nerve injuries occurred in the first ten cases of full-endoscopic discectomy. One patient suffered from an L5 injury caused during insertion of the guiding needle into the target zone; the other had an S1 injury due to unintentional perforation of the ligamentum flavum by the working sheath. Both patients recovered completely during the follow-up period.

Fig. 4 Operation time plotted against time interval between 33 cases of full-endoscopic transforaminal discectomies attempted

Table 4 Comparison of operative time, blood loss, complications and reoperations between full-endoscopic discectomy and open microdiscectomy

Variable	Full-endoscopic discectomy (n = 57)	Open microdiscectomy (n = 66)	P value
Op time (min)	86.5 ± 45.9	48.1 ± 9.2	<0.01
Blood loss (ml)	Not measurable	48.9 (10–330)	n/a
Complications	2	1	0.60
Reoperations	6	4	0.51

n/a not applicable

We did not observe via the endoscope any dura tear, including in the two patients with nerve root injuries. Yeung et al. [10] reported an incidence of 0.3 % for dura tear in endoscopic excision for lumbar disc herniation. A possible reason for nerve injury without dura tear in our study is that the nerve roots might have suffered pressure injury but were not directly severed from the intraforaminal and interlaminar manipulation of the working sheath.

The reoperation rate was 13.0 %, which was slightly higher than that reported for microscopic discectomy (4.0–9.7 %) [11, 12] and endoscopic discectomy (4.2–11.0 %) [10, 13]. Our reoperative cases occurred at the beginning of the learning curve. Among the four cases with insufficient removal of a herniated disc, three had hard discs and one had downward herniation. Difficulty was confronted during endoscopic resection of the hard discs, which were not diagnosed preoperatively by MRI. Magnetic resonance

imaging alone has low accuracy for differentiating between hard and soft discs [14]. The sensitivity and specificity of hard disc diagnosis with MRI is 87 and 44 %, respectively. To improve the accuracy of diagnosis, one should consider together patient age, MRI and computed tomography (CT). Computed tomography scanning should be performed in cases of high probability of hard calcified disc with low signal intensity on all MRI sequences [15].

Disc reherniation was observed in two cases (4.4 %), a rate comparable to that reported for microscopic discectomy (2.0–4.5 %) [1, 11]. Most patients after lumbar discectomy are restricted in their activities for some time by discomfort and medical advice and advised to restrict weight-bearing activities or bending over for several weeks or months [16–18]. However, the optimal time of restrictions and the clinical benefit of such restrictions remain unknown [19].

Two patients were converted to microscopic discectomy. The conversion rate was 3.4 %. Lee et al. [20] reported a similar learning curve for percutaneous endoscopic lumbar discectomy. It was reported that percutaneous endoscopic lumbar discectomy failed in 4 of 51 patients, resulting in a conversion rate of 7.8 %. In our study, the reason for conversion in the first patient was scarring of the epidural space caused by previous surgery, which made endoscopic surgery difficult. In the second patient, the interlaminar window was smaller than the outer diameter of the working sheath, which impeded passing the working sheath through the ligamentum flavum.

The transforaminal procedure requires less operative time than the interlaminar procedure. Lee et al. [20] observed a significant reduction in the operative time after the 17th patient was treated by percutaneous endoscopic lumbar discectomy. In our study, the asymptote of the learning curve for the transforaminal approach occurred around the 10th case based on the operative time, resulting in a steep learning curve, which represents the rapid acquisition of skills and a good thing for a beginner [21]. Based on this experience, we recommend transforaminal approach for those beginning full-endoscopic lumbar discectomy.

We have not yet overcome the learning curve for the interlaminar procedure. Choi et al. [22] recommended supervision by an experienced surgeon in the initial ten cases to overcome the learning curve for the interlaminar procedure at L5–S1. Surgeons should gain adequate experience by starting with simple cases first, in which no serious problems are anticipated from the anatomic conditions [6].

An advantage of percutaneous endoscopic lumbar discectomy is that local anesthesia can be used as was described by Choi et al. [22]. The benefits of local anesthesia are reduced morbidity compared with general anesthesia and the ability of surgeons to continually communicate with the patient, thus avoiding the risk of nerve damage during

insertion of the working sheath [20, 22]. However, the complications associated with local anesthesia in performing percutaneous endoscopic lumbar discectomy include posterior neck and thoracic back pain, headache, and even unconsciousness. These complications are not uncommon because of high cervical epidural pressure on meninges due to massive amounts of saline irrigation fluid [23].

Patients benefit from a surgeon having gone through his or her learning curve. Minimal instrumentation and injury to the ligamentum flavum is a potential benefit of endoscopic discectomy. About 5–12 % of failed back syndrome is caused by epidural fibrosis in patients who underwent lumbar disk surgery [24]. Reduced trauma to the ligamentum flavum appears to limit epidural fibrosis [25]. In standard open microscopic discectomy, about the same amount of the ligamentum flavum is removed as with laminotomy. However, in the interlaminar approach of full-endoscopic discectomy, the ligamentum flavum is incised transversely to only 3–5 mm, allowing insertion of an endoscope. In the transforaminal approach, there is no need to open the ligamentum flavum. In terms of the cost/benefit ratio, the full-endoscopic discectomy cost less with a ratio of 0.89 compared with open microdiscectomy, and the number of days of hospitalization was fewer in full-endoscopic discectomy with a ratio of 0.31 compared with open microdiscectomy.

A limitation of this study was the high number of patients lost to follow-up, which may complicate analysis of the outcomes. This loss is an inherent shortcoming of a retrospective cohort study. Indeed, a prospective controlled study can provide more detailed information without the loss of follow-up of patients. However, this study may prove valuable in assessing risk versus benefit of full-endoscopic lumbar discectomy.

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