Learning Curve for Percutaneous Endoscopic Lumbar Discectomy

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Abstract

Percutaneous endoscopic lumbar discectomy (PELD) is one of the surgical options for soft lumbar disk herniation, but the learning curve is perceived to be steep. The first 51 PELD cases performed for single-level intracanalicular lumbar disk herniation causing radiculopathy by the same surgeon were prospectively studied. The patients were divided into 3 groups of 17 patients, and the PELD learning curve was assessed by evaluating operating time, failure rate, complication rate, and 1-year reherniation rate. One-year clinical success rate was assessed by telephone interviews. The herniated disk was successfully removed by PELD in 47 patients. Four patients required subsequent open discectomy due to PELD failure. There were 2 minor complications. One year after surgery, clinical success was achieved in 42 of the 47 patients in whom PELD was initially successful, and reherniation developed in 5 patients. A significant reduction in operating time was observed after 17 patients had been treated ($p = 0.0004$). No significant differences were observed in terms of either failure rate or complication rate between the 3 groups. No significant differences were observed in terms of either the clinical success rate or the reherniation rate at 1 year after surgery. The PELD learning curve seems to be stable and acceptable with proper pre-PELD training.

Key words: disk herniation, learning curve, percutaneous endoscopic lumbar discectomy

Introduction

Percutaneous endoscopic lumbar discectomy (PELD) has recently been performed as an alternative to classic open discectomy with results that are comparable to those of open discectomy.^{1,2,4,6,8,9,11,13,14,18,20,22,25,26} PELD has several advantages over open discectomy^{1,9,15,23}; PELD is usually performed under local anesthesia, postoperative pain is quite minimal, normal paraspinal structures are preserved, and the risk of postoperative epidural scar formation and instability can be minimized. However, the PELD learning curve is usually perceived to be steep.^{7,15,26} Furthermore, despite the low complication rate, major complications such as neurovascular injury, visceral injury, and/or spondylodiscitis may occur, possibly resulting from lack of skilled surgical techniques during the learning period.^{12,19,21,26}

The present study profiles the PELD learning curve of an individual surgeon not previously exposed to this procedure.

Materials and Methods

I. Patient population

The first 51 consecutive PELD procedures performed by the same surgeon (D.Y.L.) for lumbar disk herniation causing radiculopathy between November 2004 and October 2005 were prospectively studied. He had performed about 200 cases of open microdiscectomy, but had no previous experience with percutaneous endoscopic procedures. Throughout this prospective study, the indication for PELD was a single level intracanalicular soft lumbar disk herniation of the lower lumbar vertebrae, which was unresponsive to conservative therapy. Conventional open discectomy was performed in patients with hard disk herniation, foraminal and extraforaminal disk herniations, sequestered fragment, and/or severe neurological deficits. Spinal fusion was first considered in patients with spinal instability.

The 32 males and 19 females were aged 17–55 years (mean 36.4 years). Thirty-nine of the 51 patients presented with low back pain and leg pain, and 12 with leg pain only. Twelve patients also showed motor weakness on great toe dorsiflexion (power grade IV in 11 patients and III in 1 patient).

The mean duration of symptoms was 4.8 months (range 0.3–24 months). The PELD spinal levels were L4-5 in 46 patients and L5-S1 in 5 patients. All 5 patients who underwent PELD at the L5-S1 level had a low-lying iliac crest on radiography. Three patients underwent PELD for recurrent disk herniation.

The patients were divided into 3 groups of 17 patients (Group I: Cases 1–17, Group II: Cases 18–34, and Group III: Cases 35–51), and the operating time, failure rate, complication rate, 1-year clinical success rate, and 1-year reherniation rate were evaluated. Reherniation was defined as a disk herniation occurring ipsilaterally at the same level as a previously operated lumbar disk, as demonstrated on follow-up magnetic resonance (MR) imaging, with a pain-free interval after the primary discectomy of greater than 4 weeks. Clinical success rate was analyzed 1 year after surgery by telephone interview. Clinical success was defined as ≥ 2 point improvement in Visual Analogue Scale (VAS) score, $\geq 25\%$ improvement in Oswestry Disability Index (ODI) score, $\geq 50\%$ patient's subjective recovery rate, and no major complication related to the surgery.²⁴⁾ The analysis of variance (ANOVA) test, chi-square test, Kruskal-Wallis test, Wilcoxon rank sum test, and Fisher's exact test were used to compare the differences of each parameter between the 3 groups using SAS software (version 8.1; SAS Institute, Cary, N.C., U.S.A.). P values less than 0.05 were considered significant.

II. Surgical technique

Before starting this prospective study, the surgeon observed 15 PELD procedures performed by experienced surgeons and performed about 40 epidural block procedures via the transforaminal route during a 3-month training period. The surgeon also attended two PELD workshops; one with a silicon model and the other with a cadaver.

All operations followed a standard pattern suggested by the senior author.^{2,15)} The procedure was performed under local anesthesia in the prone position on a radiolucent table. Before the beginning of the procedure, patients were informed about all steps of the procedure. Patients could communicate with the surgeon during the entire procedure. The skin entry point was usually about 10–12 cm from the midline. After infiltration of the entry point with local anesthetics, an 18-gauge spinal needle was introduced under fluoroscopy guidance. The final target point of the spinal needle was the medial pedicular line on the anteroposterior image and the posterior vertebral line on the lateral image. Then epidurography was performed using contrast medi-

Fig. 1 Anteroposterior fluoroscopic image (A) showing the final target point of the initial approach step on the medial pedicular line, and lateral fluoroscopic image (B) showing the posterior vertebral line. Epidurogram (C) demonstrating the safe triangular working zone. Anteroposterior (D) and lateral (E) fluoroscopic images taken after insertion of the endoscopic cannula.

um to confirm the location of the exiting root and the traversing root. After insertion of the spinal needle into the disk, the nucleus pulposus was stained blue with 1 ml of indigo carmine. Then a guide wire was inserted through the spinal needle, the spinal needle was removed, a small skin incision was made at the entry site, a tapered cannulated obturator was inserted along the guide wire, the obturator was inserted into the disk with hammering after touching the annulus, and a bevel-ended, oval-shaped work-

Fig. 2 Preoperative (A) and postoperative (B) T₂-weighted magnetic resonance images demonstrating successful removal of the herniated disk at the L4-5 level by percutaneous endoscopic lumbar discectomy.

ing cannula was inserted into the disk along the obturator, and then the obturator was removed (Fig. 1).

The endoscope was then inserted through the cannula. The blue-stained disk was removed using small forceps and a side firing holmium yttrium-aluminum-garnet (Ho:YAG) laser using the 'in and out' technique, working from the central portion to the lateral portion of the disk space on the anteroposterior image. Targeted fragmentectomy was performed in all cases. The herniated fragment was removed, the endoscope was removed, and a sterile dressing was applied with a 1-point suture. All patients underwent MR imaging immediately after the procedure to confirm adequate decompression (Fig. 2). If the patient's symptoms had improved and adequate decompression was confirmed by MR imaging, the patient was usually discharged within 12 hours after the procedure.

Results

I. Clinical outcomes

The operating time was 30–105 minutes (mean 49.2 minutes). The herniated disks were successfully removed by PELD in 47 patients (92.2%), and all these patients showed marked improvement in their symptoms immediately after surgery. PELD failed in 4 patients (7.8%; Cases 27, 29, 33, and 41), caused by failure to remove small disk fragments located in the lateral recess in 2 patients, failure to remove a centrally protruding huge disk with a narrow base in 1 patient, and an unrecognized newly developed

migrated disk, which apparently occurred just before the operation, in 1 patient. All these 4 patients subsequently underwent open discectomy. Two minor complications (3.9%) occurred in the entire series. Case 11 complained of dyesthesia on the anterolateral thigh after the PELD procedure at the L4-5 level, which improved spontaneously 2 days after surgery. Case 22 showed pain shock during the procedure (just after annulotomy with the obturator) and was successfully managed with medical treatment. There were no significant major complications, such as neurovascular injury or significant infection.

One-year surgical outcomes were assessed in the 47 patients with initially successful PELD. The mean preoperative VAS score was 5.5 (range 5–10) and improved significantly at 1 year after surgery to 1.2 (range 0–5) ($p < 0.001$). The mean preoperative ODI score was 57.9% (range 28.9–90%) and improved significantly at 1 year after surgery to 15.9% (range 0–46.7%) ($p < 0.001$). The mean subjective recovery rate at 1 year after surgery was 80.7% (range 20–100%). Clinical success was achieved in 42 of 47 patients (89.4%), but not in Cases 5, 10, 11, 19, and 47 at 1 year after surgery. Reherniation developed in 5 patients (10.6%; Cases 5, 10, 17, 31, and 38) within 1 year after surgery. The mean interval to recurrence was 6.4 months (range 4–10 months). Two patients underwent additional surgery, open discectomy in Case 5 and repeated PELD in Case 10, and the other 3 improved after conservative treatment.

II. Learning curve

The mean age of the patients was similar in the 3 groups (ANOVA, $p = 0.20$). The sex ratio was also similar in the 3 groups (chi-square test, $p = 0.72$). The mean operating time was 62.1 minutes for Group I, 47.6 minutes for Group II, and 37.9 minutes for Group III, showing a significant difference (Kruskal-Wallis test, $p = 0.0004$). The mean operating time for Group I, which contained the earliest 17 cases, was significantly longer than those for Groups II and III (Wilcoxon rank sum test, Group I vs. II, $p = 0.02$; Group I vs. III, $p = 0.0005$; Group II vs. III, $p = 0.22$). PELD failed in 3 patients in Group II and 1 patient in Group III. There was no significant difference in the failure rates between the 3 groups (Fisher's exact test, $p = 0.31$). Minor complications occurred in 1 patient in Group I and 1 patient in Group II. There was no significant difference in the complication rates between the 3 groups (Fisher's exact test, $p = 1.0$). The 1-year clinical success rate was 82.4% for Group I, 92.9% for Group II, and 93.8% for Group III, with no significant difference (Fisher's exact test, $p = 0.51$). The 1-year rehernia-

Table 1 Summary of factors affecting the learning curve

	Case No.	Mean age (range), yrs	Male/female	Operating time (range), min	Failure rate, %	Complication rate, %	1-Year clinical success rate, %*	1-Year reherniation rate, %*
Group I	1-17	33.9 (24-52)	10/7	62.1 (30-90)	0	5.9	82.4	17.6
Group II	18-34	35.6 (18-49)	10/7	47.6 (30-105)	17.6	5.9	92.9	7.1
Group III	35-51	39.8 (15-55)	12/5	37.9 (30-60)	5.9	0	93.8	6.3
p Value		0.20	0.72	0.0004	0.31	1.0	0.51	0.60

*The 1-year clinical success rate and 1-year reherniation rate were assessed in 47 patients with initial success of percutaneous endoscopic lumbar discectomy.

tion rate was 17.6% for Group I, 7.1% for Group II, and 6.3% for Group III, with no significant difference (Fisher's exact test, $p = 0.60$). A summary of each factor concerning the learning curve is shown in Table 1.

Discussion

The surgical techniques for percutaneous endoscopic discectomy have rapidly evolved since the introduction of posterolateral percutaneous disk decompression.¹⁰⁾ The main concept of the procedure has changed from indirect decompression of the central disk to direct targeted fragmentectomy.^{2,15)} A prospective study on the surgical outcome of the first consecutive 42 patients who underwent PELD via the transforaminal route found a high failure rate of 14/42, of whom 7 patients eventually underwent re-operation (open discectomy), and 6 of these 7 patients in the first 8 months.⁷⁾ Therefore, the PELD technique has a steep learning curve, which can be overcome with training and suitable patient selection.

The present study indicated that the PELD learning curve is acceptable, with relatively low failure and complication rates of 7.8% and 3.9%, respectively, and no significant major complications. Comparison of the early, middle, and late experience groups found no significant differences in the factors concerning the learning curve except operating time. Targeted fragmentectomy was performed in all patients.

One of the most important surgical steps of PELD is the initial approach, which places the spinal needle exactly at the final target point along the optimal trajectory. The tip of the spinal needle touching the annulus should be located at the medial pedicular line on the anteroposterior fluoroscopic image and the posterior vertebral line on the lateral fluoroscopic image. Failure to place the spinal needle at the optimal target point usually results in the placement of

the endoscopic cannula at an inappropriate location, which almost always results in failure to remove the herniated disk. Another related problem is the possibility of nerve root injury during annulotomy and/or cannular insertion. If the tip of the spinal needle is exactly located at the optimal target point, the spinal needle is always located between the exiting root and traversing root, which can be confirmed by epidurography. Then, annulotomy followed by cannular insertion can be performed safely. Therefore, the surgeon should develop high needle technique before starting PELD, and so pre-PELD training was important in the stable learning curve of the present study. We recommend performing an epidural block via the transforaminal route before starting PELD, which is a very similar procedure to the initial PELD procedure step and enables beginners to develop the needle technique for PELD. Participating in PELD workshops is another way to develop needle technique and other core skills essential for PELD.

In general, correct patient selection is considered paramount to ensure satisfactory outcome after PELD. Several highly experienced endoscopic surgeons have recently expanded the indications for PELD and have reported successful results even in patients with migrated disk herniation and foraminal/extraforaminal disk herniation.^{6,16)} However, PELD surgical outcomes are affected by the surgeon's skill and personal technique in such situations.^{2,15)} Furthermore, especially for inexperienced surgeons, improper selection of patients often results in incomplete decompression and the necessity for subsequent open discectomy, and this can sometimes result in a poor surgical outcome.¹⁵⁾ Retrospective analysis of 1586 patients who had undergone PELD for intracanalicular disk herniation concluded that open surgery may be considered for herniations with high canal compromise and high-grade migrations.¹⁷⁾

In the present study, the authors adopted narrow

inclusion criteria: single-level intracanalicular soft lumbar disk herniation at the L4-5 level and L5-S1 level (with low-lying iliac crest). Patients with hard disk herniation, foraminal and extraforaminal disk herniations, sequestered fragments, severe neurological deficits, and spinal instability were excluded. The surgical outcomes of the present study were satisfactory, with an immediate success rate and 1-year clinical success rate of 92.2% and 89.4%, respectively. One notable finding in the present study is that PELD failure occurred after 26 cases were treated: 3 cases in Group II and 1 case in Group III. Although the narrow inclusion criteria were retained throughout the study, a progressive increase in the difficulty of the cases might have resulted in this phenomenon.

One of the concerns for the PELD learning curve is perioperative complication. Serious complications during the PELD learning period are rare but may lead to profound morbidity. In this regard, approaching the safe triangular zone via the optimal trajectory is of utmost importance. An inappropriate approach may increase the risk for neurovascular or visceral injury. Inadvertent contact of the spinal needle with the abdominal viscera might result in psoas abscess and/or spondylodiscitis. A case of postoperative psoas abscess with spondylodiscitis occurred after PELD.¹²⁾ The isolated organism was *Escherichia coli*, suggesting that inadvertent tap into the colon during the initial needle approach to the disk space was the cause. Meticulous preoperative planning with careful review of axial computed tomography and MR imaging is recommended. The complication rate of the present study, only 2 minor complications, is acceptable and comparable to those of experienced surgeons.^{2,26)} Temporary dysesthesia is the most commonly reported complication after PELD and is usually provoked by irritation of the exiting root or traversing root during the operation, which can be prevented by confirmation of the safe triangular working zone and careful monitoring of the patient during operation.¹⁵⁾ Pain shock, vasovagal syncope due to severe pain, can happen during PELD, especially during annulotomy and/or cannular insertion, as in our study. Nowadays, the authors prevent pain shock by additionally injecting 1 or 2 cm³ of lidocaine on the surface of the annulus just before the annulotomy.

In the present study, the 1-year reherniation rate was relatively high (10.6%). Few authors have stated concerns about reherniation after PELD.^{5,15)} In a previous study, in which experienced senior surgeons performed all procedures, the reherniation rate after PELD was 2.2% at a mean follow up of 37.2 months.¹⁵⁾ Recently, a prospective randomized study

on transforaminal posterolateral endoscopic discectomy with or without the combination of low-dose chymopapain found the endoscopy only group had a reherniation rate of 6.9%, and the combination group had a recurrence rate of 1.6% at 1-year postoperatively.⁵⁾ The relatively high reherniation rate of the present study might be attributable to targeted fragmentectomy, a concept similar to limited discectomy in conventional open discectomy. The reherniation rate in the limited discectomy group (18%) was higher than in the subtotal discectomy group (9%) at 2-year follow up.³⁾ Another influence on the 1-year reherniation rate is the learning curve. Group I, which contained the earliest 17 cases, showed a higher reherniation rate (17.6%) than Groups II (7.1%) and III (6.3%). Though statistically not significant, these results suggest that increasing experience with PELD might influence the 1-year recurrence rate.

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Commentary

The authors present their experience with percutaneous lumbar endoscopic discectomy (PLED) for treatment of soft low lumbar disc herniation. The technique is well described and the results honestly reported. In my opinion, I do not see any significant advantages of PELD over open microdiscectomy. In recent years, anesthesiological and microsurgical procedures have been improved, postoperative pain is negligible, normal structures are preserved (just temporarily shifted), scar is minimal due to accurate hemostasis, and patients can be discharged the following day. Considering that the population has been carefully and correctly selected (and therefore these are the easiest cases) I find that also the operation time is comparable or longer than microdiscectomy, and that the complication rate and re-herniation are higher using PELD. I tried myself endoscopic discectomy 15 years ago, and I went back to microsurgery. Nevertheless, I find correct that always new attempts are made to improve the surgical technique, but I do not think that this will be the solution for the majority of patients with a lumbar herniated disc.

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Recently, endoscopically visualized procedures for lumbar disk herniation have been developed. These procedures were reportedly as effective as microdiscectomy, although there is no sufficient evidence based on randomized control study. These techniques are now highlighted because of the lower invasiveness for the normal anatomy of the dorsal musculature and ligaments, and will be widely accepted among neurosurgeons.

The authors presented surgical outcomes of percutaneous transforaminal endoscopic lumbar discectomy in a case series, and the steep learning curve for this procedure. Operative time was clearly shortened by experience. This technique appears to be safe and effective for selected single level intracanalicular soft disk herniation. Low complication rate and high success rate as well as the outstanding learning curve shown in this study will encourage neurosurgeons to introduce endoscopic lumbar disk surgery. Needless to say, sufficient experience in open surgery for lumbar disk is essential to understand the anatomical structures in a limited endoscopic view field. Indeed, the author experienced 200 cases of open microdiscectomy before starting endoscopic surgery. Furthermore, as mentioned by the authors, correct selection of patients is essential to obtain good surgical outcome. Cases with far migrated disk or with pathology at L5-S1 with high-positioned pelvic crest appear not to be good candidates.

Recurrence of herniation is one of the serious problems after surgery. The authors presented lower reherniation rates in Group II or III than in Group I, though no statistical difference was proven. This implies that this complication may be lessened by im-

provement of surgical skill. I would like to know any tips to reduce recurrence of herniation, which were not mentioned in the paper. Further information in this regard will be helpful for the readers.

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The article of D. Y. Lee and S.-H. Lee describes a very important analysis of operated cases by percutaneous endoscopic lumbar discectomy (PELD). The method is firstly dependent on the indication for surgery in such cases. The inclusion criteria show an intracanalicular soft disk herniation in a single lumbar level L4-5 or L5-S1. The surgeon (D.Y.L.) has experience with open lumbar disk surgery of about 200 cases, which does not give the amount of experience that would be usual internationally. Of course the clearly defined study with the learning curve shows the advantage of using PELD. A mandatory part is to perform very exact radiographic and/or CT diagnostic. The paper does not describes exactly the endoscopic method used and the instruments. This would be important for the surgical view. Basically it is excellent that such a study has been made, showing the advantage of endoscopy use in this field.

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