Endoscopic interlaminar lumbar discectomy: How to decrease the learning curve

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ABSTRACT

Background: Herniated lumbar disc is a common cause of lumbosacral pain. Endoscopic interlaminar lumbar discectomy (ILD) is a well-established technique that provided comparable results to micro-discectomy. The aim of the study is to describe the learning curve of endoscopic ILD and explore measures that could improve effectiveness and decrease blood loss and operative time with accumulation of reasonable experience.

Methods: This retrospective cohort study included 65 patients presenting with symptomatic herniated lumbar disc who underwent endoscopic ILD. Patients were divided into two groups: Group I (standard technique) and Group II (modified technique). Collected data included patients' age, gender, preoperative manifestations, visual analog score (VAS) for pain, Oswestry Disability Index (ODI), disc level, operative time, intraoperative blood loss, complications, and follow-up data at 1, 6, and 12 months postoperatively. Primary outcomes included total operative time, amount of intraoperative blood loss, and post-operative improvement in pain. Secondary outcomes included intraoperative complications, rate of conversion to open surgery, and recurrence.

Results: Post-operative VAS and ODI improved significantly in both groups. Mean total surgical time and intraoperative blood loss were significantly lower in Group II compared to Group I (P < 0.001). The learning curves for operative time and intraoperative blood loss were shallow in Group I, and almost flattened in Group II. Complications were recorded in only three cases, and no symptomatic recurrences were reported.

Conclusion: The learning curve of endoscopic ILD was shallow with standard technique, indicating difficulties in mastering the procedure. The proposed modified technique helped reaching the required level of proficiency in the early phase of the curve, providing a significant reduction in operative time and blood loss, with comparable effectiveness and safety as the standard technique.

Keywords: Disc herniation, Interlaminar discectomy, Learning curve, Neuroendoscopy

INTRODUCTION

Disc prolapse of the lumbosacral region is one of the most commonly encountered conditions in neurosurgery. Surgical management largely contributes to alleviation of symptoms in selected indicated patients. However, surgical intervention has been associated with scarring of the epidural space in approximately 10% of patients. This complication may evolve during operative steps, including dural sheath retraction and occasional partial resection of lamina and facet joints.

The introduction of endoscopy into surgical fields provided a means for less invasive techniques, allowing better visualization of the surgical field, smaller incisions, paraspinal
muscle splitting, and shorter hospital stays. Two main endoscopic techniques of discectomy have been developed: The interlaminar lumbar discectomy (ILD) and the transforaminal approaches. Each technique has its own advantages and drawbacks. The interlaminar approach provided superior results in discs that are calcified, herniating, migrating, or recurrent as well as in cases of foraminal stenosis.

Although microscopic discectomy is still the gold standard technique for surgical management of disc prolapse, endoscopic techniques are promising alternatives that are increasingly used and provided comparable results to microsurgery. Endoscopic techniques require a certain amount of experience that can be gained by performance of the procedure on convenient number of patients, a process known as the learning curve.

During an early phase of learning curve, improvement in performance is observed with increased number of performed surgeries. A plateau phase then follows where the procedure is well mastered by the surgeon and higher number of performed cases will result in minimal change in quality of performance. The number required to reach the plateau phase differs from one procedure to another, and it is affected by the surgeon's prior experience in similar techniques.

Despite being a well-established technique, few studies assessed the learning curve of ILD, and most of them provided controversial reports. The present study was conducted to describe the learning curve of endoscopic ILD and to explore measures that could improve effectiveness and decrease both blood loss and operative time with the progress of experience.

MATERIALS AND METHODS

Surgical technique

In the current study, patients were divided into two groups according to the chronological order of the surgery. Group I was operated upon using the standard technique of endoscopic ILD, while a modified technique was used in Group II.

All patients were operated on using the EasyGo® endoscopic system (Karl Storz company, Tuttlingen, Germany) under general anesthesia with local lidocaine infiltration. All patients in Group I were positioned prone on Wilson frame. After initial sterilization of the skin, a spinal needle was inserted in place to confirm the level under fluoroscopic guidance [Figure 1a]. No specific medications to reduce the intraoperative bleeding were used in Group I. Surgical draping was done and skin incision 2 cm paramedian and 0.5 cm away from the midline was performed. Incision of the lumbar fascia was followed by local infiltration with lidocaine. Muscle splitting was achieved using successive tubular dilators of the system till reaching the target interlaminar space, which was confirmed by intraoperative fluoroscopy [Figure 1b and c].

The technique time-consuming steps were: Necessity to rongeur more from lamina to obtain full view of the nerve displaced by the offending disc, troublesome epidural bleeding requiring frequent suctioning, and necessity to introduce the least instrument set to keep the working channel less crowded. In Group II, these issues were overcome by (1) keeping the patient at knee-chest position with hip flexed to widen the interlaminar space and posterior disc height; (2) intravenous infusion of the anesthetic medication dexmedetomidine HCL (Precedex®), an α2-adrenergic receptor agonist with a clinically proven effect (26) in reduction of intraoperative bleeding, (aiming to reduce epidural bleeding); and (3) rotation of the lensecope 180 degrees in the working sheath to obtain both better view of the nerve root and more space for surgical instruments [Figure 1d and e].

Data collection

The patients’ data were thoroughly reviewed. The collected data included patients’ age, sex, presenting manifestations, preoperative levels of visual analog score (VAS) for pain, and Oswestry Disability Index (ODI) as well as level of the herniated lumbar disc. In addition, operative details, including total operative time, the amount of intraoperative blood loss, and complications, were recorded. Data of follow-up at 1, 6, and 12 months postoperatively were recorded. Data of follow-up at 1, 6, and 12 months postoperatively were collected as regard VAS, ODI, and symptomatic recurrence.
Drilling of the lower part of upper lamina was done to fashion a keyhole corridor to access the root and corresponding disc. Ligamentum flavum was resected to reveal the nerve root that was retracted medially, and disc removal with rongeur was accomplished by standard methods [Figure 2a-h].

Outcomes

The primary studied outcomes included total operative time, amount of intraoperative blood loss, post-operative pain decline, and post-operative MRI [Figure 2d and h]. The pre- and post-operative VAS and ODI scores were used for pain functional assessment. The studied secondary outcomes included intraoperative complications, rate of conversion to open surgery, and symptomatic recurrence during 12-month follow-up.

Statistical analysis

Data were analyzed using the Statistical Package for the Social Sciences software, version 26.0. Qualitative variables were represented as number and percentage and associations were tested using Pearson’s Chi-square test for independence, Fisher’s exact test, or Fisher-Freeman-Halton exact test as appropriate. All quantitative variables followed normal distribution. They were summarized as means and standard deviations, and differences between the groups were assessed using independent samples t-test. Pearson’s correlation was conducted to examine relationship between experience and outcome measures. Multiple regression analysis was conducted to examine the effects of the disc level and the surgical technique on the total surgical time and intraoperative blood loss. P < 0.05 was adopted for significant results.

RESULTS

The mean age was 42 ± 9 years in Group I and 43 ± 8 years in Group II with no significant difference (P = 0.608). In both groups, male patients outnumbered the female patients (63.6% vs. 36.4% in Group I; and 62.5% vs. 37.5% in Group II), with no significant difference (P = 0.924). Motor weakness and radicular pain were the most common manifestations in both groups. Group I had significantly higher percentage of patients with motor weakness than Group II (100% vs. 84.4%, respectively; P = 0.024). On the other hand, Group II had a significantly higher percentage of patients with radicular hypoesthesia (81.3% vs. 54.5%, respectively; P = 0.021). The mean preoperative VAS was similar in the two groups (VAS = 7 ± 1, P = 0.681). There was no significant difference in pre-operative pain ODI between the two groups (P = 0.318). Nearly half the cases in Group I had disc prolapse at L5-S1 level, while nearly half the cases in Group II had disc prolapse at L4-5 level, with no significant difference (P = 0.179) [Table 1].

The mean total operative time was significantly lower in Group II compared to Group I (50 ± 4 vs. 68 ± 13 min, respectively; P < 0.001). Moreover, the mean amount of intraoperative blood loss was also significantly lower in Group II compared to Group I (42 ± 7 vs. 50 ± 10, respectively; P < 0.001). Wound infection was encountered in two cases in Group I and only one case in Group II (P = 1.000).

Follow-up of patients showed an improvement in VAS and ODI scores at 6 months and further decrease at 12 months in the two groups. However, no significant difference was detected between the two groups at 1, 6, or 12 months postoperatively (P > 0.05). No recurrences were detected in patients during the follow-up period of 12 months [Table 2].

[Table 3] shows the degree and strength of correlation between surgical team experience (number of operated
cases) and operative and post-operative outcomes. There was a strong, significant, negative correlation ($r = -0.909$, $P < 0.001$) between the number of patients and the total time of surgery in Group I (i.e., time decreased with increased number of patients). The correlation between surgical team experience and surgical time in Group II was weak and non-significant ($r = -0.236$, $P = 0.193$), indicating that increased number of cases did not affect the surgical time in this group. A moderate, significant, and negative correlation existed between the number of patients and amount of intraoperative

![Figure 2](image)

Figure 2: Same patient (a) pre-operative axial MRI showing left L5S1 herniated disc. (b) Intraoperative image with endoscope sheath position as shown in Figure 1d, the dissector is gently retracting the S1 root (white arrowhead) and passed underneath the remaining part of ligamentum flavum (white arrow). (c) Camera-lens complex in contralateral position [as shown in Figure 1e] showing full root path (white arrowhead) after annular incision and removal of the disc (black arrowhead). (d) Postoperative MRI is revealing adequate disc removal. Images are for another patient. (e) Axial MRI is showing L4-5 left herniated disc. (f) The L5 nerve root (white arrow) is retracted to reveal subradicular disc herniation (black arrow). (g) The nerve root (white arrow) is kept in retraction by cottonoid, followed by annulotomy and removal of the herniated disc by rongeur (curved white arrow). (h) Post-operative MRI is confirming the success of the procedure.

| Parameters                     | Groups                        | P-value |
|--------------------------------|-------------------------------|---------|
| **Patients' characteristics**  |                               |         |
| Age (years)                    | Mean±SD (range)               |         |
| Group I (n=33) (%)             | 42±9 (25–57)                  | 0.608   |
| Group II (n=32) (%)            | 43±8 (25–58)                  |         |
| Gender                         |                               |         |
| Female                         | 12                            | 0.924   |
| Male                           | 21                            |         |
| Motor weakness                 |                               |         |
| Absent                         | 33                            | 0.238   |
| Present                        | 0                             |         |
| Present                        | 33                            | 0.024*  |
| Radicular hypoesthesia         |                               |         |
| Absent                         | 15                            | 0.021*  |
| Present                        | 18                            |         |
| Radicular pain                 |                               |         |
| Absent                         | 18                            | 0.261   |
| Present                        | 15                            |         |
| Pre-operative VAS              | Mean±SD (range)               |         |
| Group I (n=33) (%)             | 7±1 (5–9)                     | 0.681   |
| Group II (n=32) (%)            | 7±1 (5–9)                     |         |
| Pre-operative pain ODI         | Mean±SD (range)               |         |
| Level                          |                               |         |
| L3-4                           | 70±6 (60–85)                  | 0.318   |
| L4-5                           | 13                            |         |
| L5-S1                          | 19                            | 0.179   |

n: Number, SD: Standard deviation, VAS: Visual analog score, ODI: Oswestry disability index, N/A: Non-applicable, *Significant at $P<0.05$
blood loss in Group I ($r = -0.712, P < 0.001$) and Group II ($r = -0.432, P = 0.013$). A moderate correlation was noted also between experience and post-operative VAS at 1 month in Group II only ($r = -0.407, P = 0.021$). Other correlations between VAS and ODI scores with number of patients were weak and non-significant ($P > 0.05$). The learning curves for surgical time were shallow in Group I, but almost flattened in Group II [Figure 3]. On the other hand, the learning curves for intraoperative blood loss were shallow in both groups [Figure 4].

[Table 4] shows the results of multiple regression analysis that examined the effects of disc level and operative technique on total operative time and intraoperative blood loss. The modified operative technique was significantly ($P < 0.001$) associated with reduced operative time and blood loss, whereas disc level had no significant impact on them ($P > 0.05$).

**DISCUSSION**

The ILD has been shown to be an effective and safe surgical remedy for herniated lumbar disc.\textsuperscript{[24,26,28,29]} Few studies addressed the learning curve of the procedure. Moreover, some studies included patients undergoing either ILD or transforaminal discectomy.\textsuperscript{[16,30]} The present study was conducted to explore measures that could improve effectiveness and decrease blood loss and operative time with improvement of experience.

The mean operative time in our series was 68 ± 13 min in Group I and was reduced in Group II to 50 ± 4 min. This indicates that the measures adopted in the modified technique helped in reduction of the required time for ILD. These results were supported also by conducting multiple regression analysis that showed a significant association of the modified technique with operative time and intraoperative blood loss, regardless of the level of disc.

The operative time in both groups was shorter than that reported by Wang et al.,\textsuperscript{[35]} which was 107.9 ± 20.8 min in the first ten cases and 68.5 ± 14.9 min in the second ten cases, but was closer to the third ten cases in their study (43.2 ± 12.7 min). Xu et al.,\textsuperscript{[36]} reported similar durations to Wang et al.,\textsuperscript{[35]} with mean operative times of 102.7 ± 17.2, 65.4 ± 11.5,
and 57.4 ± 7.6 min in their sample of 36 patients who were divided chronologically into three groups. Hsu et al.\textsuperscript{[16]} also reported a longer operative time of 86.5 ± 45.9 min in their series of endoscopic discectomy. However, this duration was for patients undergoing either transforaminal or interlaminar procedures, and the authors did not report operative time for each procedure. The mean operative time in Group II in the present study reached nearly the mean operative time described for open microdiscectomy that was 48.1 ± 9.2 min.\textsuperscript{[16]}

The amount of intraoperative blood loss has not been assessed by most previous studies that evaluated the learning curve of ILD. Intraoperative blood loss was reduced from 50 ± 10 ml in Group I to 42 ± 7 ml in Group II. Xu et al.\textsuperscript{[36]} found a significant decrease in blood loss from 70.6 ± 20.5 ml in the first 11 patients to 54.6 ± 7.6 ml in the second 11 patients. However, further decrease in their third group was slight (53.8 ± 13.3 ml).

Our results showed that increased experience of the surgical team (with the increased number of operated cases) was significantly and strongly correlated with decrease in the mean total operative time in Group I and the mean amount of intraoperative blood loss in Groups I and II. However, surgical team experience did not correlate significantly with operative time in Group II. It seems that the modified technique enabled the surgical team to attain the required level of proficiency faster, so the plateau of the learning curve was reached early. Consequently, further operated cases did not add significantly to the performance of the team and resulted in non-significant correlation with operative time in Group II.

The severity of pain decreased considerably at 6 and 12 months following surgery. Pre-operative VAS of about 7 ± 1 decreased to 2 ± 1 and 1 ± 1 at 12 months postoperatively in Groups I and II, respectively. Moreover, the mean pre-operative ODI score decreased from 70 ± 6 and 68 ± 8 in Groups I and II, respectively, to reach 16 ± 7 and 14 ± 5 at 12 months postoperatively. These findings indicate that both techniques were comparable in terms of pain control and functional outcome. Hsu et al.\textsuperscript{[16]} reported similar

| Table 4: Multiple regression analysis of the effects of experience (number of cases) and disc level on total operative time and intraoperative blood loss. |
|---|---|---|---|---|---|---|
| Model | Independent variables | Unstandardized coefficients | t | P-value | 95.0% Confidence interval for B |
| | | B | SE | | Lower bound | Upper bound |
| Total | Constant | 88.607 | 6.835 | 12.963 | <0.001* | 74.944 | 102.271 |
| operative | Disc level | -0.686 | 2.020 | -0.340 | 0.735 | -4.724 | 3.351 |
| time | Technique (standard vs. modified) | -18.375 | 2.434 | -7.548 | <0.001* | -23.241 | -13.509 |
| Intraoperative | Constant | 65.209 | 6.223 | 10.478 | <0.001* | 52.768 | 77.649 |
| blood loss | Disc level | -2.228 | 1.839 | -1.212 | 0.230 | -5.905 | 1.448 |
| | Technique (modified vs. standard) | -9.082 | 2.216 | -4.097 | <0.001* | -13.512 | -4.651 |

B: Regression coefficient, SE: Standard error, *Significant at P<0.05
decline in VAS (from 7.7 ± 2.8 to 1.6 ± 2.2) and ODI scores (from 35.6 ± 10.1 to 6.4 ± 9.8) in patients undergoing endoscopic discectomy. These results are also comparable to the improvement achieved by open microdiscectomy.\(^{16}\) Similarly, Sencer et al.\(^{30}\) reported a significant decrease in VAS and ODI scores at 12 months postoperatively. Moreover, Xu et al.\(^{16}\) reported a reduction in VAS scores in their patients at 3 months postoperatively.

No specific intraoperative complications were detected in our series, and conversion to open surgery was not mandated in any of our patients. A diversity of reported complications of endoscopic ILD includes unintended durotomy with potential pseudomeningocele, meningitis, and discitis.\(^{8,33,40}\) The only post-operative complication encountered in our series of patients was wound infection reported in three cases; the rate of which did not differ significantly between the two studied groups. No recurrences were observed during the follow-up period of 12 months in any of our patients. Our findings are supported by those of Xu et al.\(^{16}\) whose series of patients did not encounter any significant post-operative complications or recurrences. Wang et al.\(^{35}\) also did not encounter recurrences in their series. On the other hand, Hsu et al.\(^{16}\) reported nerve injury in one case out of the 22 cases that underwent ILD in their study. Sencer et al.\(^{30}\) reported unintended durotomy 5.8% of their patients during the early phase of learning. The recurrence rate reported by other studies ranged from 3.3% to 4%\(^{8,11,18,21,36}\)

In the present study, the learning curve of endoscopic ILD for operative time in Group I and intraoperative blood loss in Groups I and II was gradual rather than steep, which agrees with the findings of the previous studies reporting endoscopic ILD as a challenging procedure that requires practicing to be mastered. The plateau for the curve of operative time was reached in Group I approximately after the 25th case, which is close to the number of patients (30 patients) recommended for passing the early phase of learning curve in endoscopic procedures.\(^{5,30}\) Meanwhile, the plateau was not clear for intraoperative blood loss in Groups I and II, and a higher number of cases was likely required to reach it, [Figure 4]. The amount of blood loss in all cases was relatively small, with the largest amount (80 ml) being at the start of the learning curve. On the other hand, the learning curve for operative time in Group II was nearly flattened, with little change in the length of operative time among the cases. The early phase merged into the plateau which was reached earlier than Group I, approximately after the 15th case, [Figure 3].

A steep learning curve means that the procedure can be mastered after a relatively small number of patients. In this case, the first phase of the curve is short and gives way abruptly to the second phase. In a shallow curve, the first phase is prolonged and gradually merges into the second phase. Therefore, a shallow learning curve indicates that improvement of performance is gradual, and reaching the plateau phase where the procedure is mastered requires practicing on a large number of cases.\(^{4}\) Hsu et al.\(^{16}\) reported that the learning curve of endoscopic transforaminal discectomy was steep and easy to master, while the interlaminar procedure was flat and hard to master. On the other hand, Wang et al.\(^{35}\) reported that the learning curve of surgical time in their series of 34 patients was relatively steep. Xu et al.\(^{16}\) also reported a steep learning curve for operative time, but a shallow curve for intraoperative blood loss.

Surgeons performing the procedure during the first phase of the learning curve are susceptible to experience difficulties, resulting in increased risk of complications during this stage and longer operative time than open surgery.\(^{6,18,33,37}\) However, once this phase is overcome by gaining experience, the procedure is accomplished in a shorter time. To reach the second phase smoothly, it is recommended to gain more experience with the procedure, by attending workshops, and performing more cases.\(^{35}\)

The interpretation of the learning curve in literature is variable. This could be attributed to the previous experience of surgeons with endoscopic or microscopic procedures and variable levels of herniated disc. Unfortunately, the details of the previous experiences of the surgical teams with endoscopic procedures or open discectomy were not reported by the previous studies to allow comparisons and test this hypothesis. Only Xu et al.\(^{16}\) mentioned having experience with microscopic surgeries.

The present study had points of strength, including a convenient sample size of patients who underwent endoscopic ILD at different disc levels. However, larger sample size is required to describe the learning curve for intraoperative blood loss.

**CONCLUSION**

In conclusion, the learning curve of endoscopic ILD was shallow with standard technique, indicating difficulties in mastering the procedure and the need of practice on a relatively larger number of patients. Meanwhile, the proposed modified technique helped reaching the required level of proficiency in the early phase of the curve, providing significant reduction in operative time and blood loss, with comparable effectiveness and safety as the standard technique.

**Declaration of patient consent**

Institutional Review Board permission obtained for the study.
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Conflicts of interest
There are no conflicts of interest.

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