Percutaneous Endoscopic Lumbar Foraminotomy: An Advanced Surgical Technique and Clinical Outcomes

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WHAT IS THIS BOX?
A QR Code is a matrix barcode readable by QR scanners, mobile phones with cameras, and smartphones. **The QR Code above links to Supplemental Digital Content from this article.**

BACKGROUND: Although several authors have reported the use of endoscopic techniques to treat lumbar foraminal stenosis, the practical application of these techniques has been limited to soft disc herniation.

OBJECTIVE: To describe the details of the percutaneous endoscopic lumbar foraminotomy (ELF) technique for bony foraminal stenosis and to demonstrate the clinical outcomes.

METHODS: Two years of prospective data were collected from 33 consecutive patients with lumbar foraminal stenosis who underwent ELF. The surgical outcomes were assessed using the visual analog scale, Oswestry Disability Index, and modified MacNab criteria. The procedure begins at the safer extraforaminal zone rather than the riskier intraforaminal zone. Then, a full-scale foraminal decompression can be performed using a burr and punches under endoscopic control.

RESULTS: The mean age of the 18 female and 15 male patients was 64.2 years. The mean visual analog scale score for leg pain improved from 8.36 at baseline to 3.36 at 6 weeks, 2.03 at 1 year, and 1.97 at 2 years post-surgery ($P < .001$). The mean Oswestry Disability Index improved from 65.8 at baseline to 31.6 at 6 weeks, 19.7 at 1 year, and 19.3 at 2 years post-surgery ($P < .001$). Based on the modified MacNab criteria, excellent or good results were obtained in 81.8% of the patients, and symptomatic improvements were obtained in 93.9%.

CONCLUSION: Percutaneous ELF under local anesthesia could be an efficacious surgical procedure for the treatment of foraminal stenosis. This procedure may offer safe and reproducible results, especially for elderly or medically compromised patients.

KEY WORDS: Endoscopic burr, Foraminal stenosis, Foraminotomy, Percutaneous endoscopic

Conventional surgical methods for lumbar foraminal or far lateral stenosis can be categorized as total facetectomy with/without fusion and facet-preserving microforaminotomy. Total facetectomy offers sufficient decompression through the nerve root course. However, this often leads to segmental instability and back pain.[1-4] A facet-preserving microdecompression technique using a paraspinal approach was reported by Reulen et al[1] in 1987 and Wiltse and Spencer[5] in 1988; this technique has since been modified by other surgeons. This technique enables direct access to a foraminal or far lateral lesion with minimal violation of the facet joint and less postoperative back pain.[6] The success rates reported for open paraspinal foraminotomy are as high as 72% to 83%,[4,7-14] and this technique has been considered the gold standard for the surgical treatment of lumbar foraminal or far lateral stenosis. However, some patients experience postoperative leg pain or dysesthesia, which are the primary causes of unfavorable outcomes.[4,7,8,10,12] Excessive manipulation of the dorsal root ganglion is thought to cause dysesthesia.[10,12] Moreover, a limited field of view in the paraspinal approach may lead to incomplete decompression.

ABBREVIATIONS: ELF, endoscopic lumbar foraminotomy; **ODI,** Oswestry Disability Index; **VAS,** visual analog scale

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To solve the above problems, various minimally invasive techniques have been developed. Some authors have reported the use of a technique known as percutaneous endoscopic foraminal discectomy and/or foraminoplasty.[15-17] However, the application of these minimally invasive techniques has been limited to foraminal soft disc herniation or concurrent mild foraminal stenosis. We reported the technique of percutaneous endoscopic lumbar foraminotomy (ELF) for L5-S1 level.[18] However, a safe approach to the stenotic foramen remains challenging, and a thorough decompression technique for hard bony stenosis has been difficult to achieve. Moreover, the practical application of this technique has been limited by its steep learning curve. We have developed a more practical form of this technique than that described in a previous study[18] and applied it not only to the L5-S1 level but also other lumbar levels. The purpose of this study was to describe this advanced ELF technique and to demonstrate the clinical outcomes.

METHODS

This longitudinal cohort study was based on 35 patients with lumbar foraminal stenosis who underwent ELF between January 2009 and September 2011. During the 2-year follow-up period, 2 patients (5.7%) were lost to follow-up. Therefore, prospective data were collected from the remaining 33 patients.

Inclusion Criteria and Outcome Evaluation

The inclusion criteria were as follows: patients with symptomatic lumbar foraminal stenosis despite more than 6 weeks of conservative treatment, including selective nerve root blockade. Radiculopathy with foraminal or extraforaminal stenosis regardless of disc herniation was confirmed by both computed tomography and magnetic resonance imaging. The radiographic indications were moderate to severe foraminal stenosis with perineural fat obliteration or nerve root collapse based on the Wildermuth grading system.[19] The exclusion criteria were intracanalicular stenosis, segmental instability, or coexisting pathological conditions such as acute inflammation, infection, and tumor.

Patient data were obtained from chart reviews and patient-based outcome questionnaires or telephone interviews. At each follow-up, the patients completed questionnaires that reflected their functional status and pain intensity. The patients' back pain and radicular leg pain levels were assessed using the visual analog scale (VAS) score. Functional status was assessed using the Oswestry Disability Index (ODI). The clinical outcomes were also assessed using the modified MacNab criteria.

Statistical Analysis

The comparison between pre- and postoperative clinical outcomes in pain and functional status was performed by using repeated-measures analysis of variance and a paired t test with Bonferroni method for adjustment of multiple comparisons. P values <.05 were considered significant.

Surgical Technique

The unique characteristic of the surgical technique in this study that distinguishes it from the standard transforaminal endoscopic discectomy technique[20-22] is the use of epidural foraminal or extraforaminal procedures, which preserve the maternal disc, as opposed to intradiscal procedures. Discectomy is optional and performed when appropriate.

The surgical process can be summarized into 3 steps: a safe extraforaminal landing, endoscopic foraminal unroofing, and sophisticated and full-scale foraminal decompression (see **Video**, **Supplemental Digital Content**, which demonstrates the 3 steps of the surgical process, http://youtu.be/aON-g_ZagqE).

Patient Preparation

As a premedication, midazolam (0.05 mg/kg) is injected intramuscularly 30 minutes before surgery. Fentanyl (0.8 μg/kg) is intravenously administered immediately before surgery, followed by additional doses as needed. The level of sedation should be titrated so that the patient is able to communicate with the surgeon during the procedure. The patient is placed in the prone position on a radiolucent table. The skin entry point is located 8 to 13 cm lateral to the midline, depending on the patient's waist size. To determine an appropriate entry point and approach angle, preoperative imaging studies and intraoperative fluoroscopy should be carefully considered.

Extraforaminal Landing

An 18-gauge spinal needle is inserted after the administration of local anesthesia (Figure 1A). Unlike the usual transforaminal endoscopic discectomy technique, the main target of this procedure is not the herniated disc fragment, but the foraminal nerve root entrapment by bony stenosis and thickened foraminal ligaments. Thus, the target point of the initial needling is the surface of the facet joint, not the intradiscal portion. The needle can be firmly engaged with the facet joint and then replaced by a guidewire. A tapered obturator is inserted over the guidewire, slid along the facet surface into the foramen using gentle manual pressure, and finally firmly engaged with the foramen. This maneuver prevents nerve root damage and enables a safe working space by pushing the exiting nerve root away from the surgical field. If the patient experiences pain during the procedure, the obturator can be placed on the surface of the superior facet. After the correct placement of the obturator in the foramen (not in the disc), a bevel-ended working cannula is introduced over the obturator and is placed on the undersurface of the facet joint. After the obturator is withdrawn, an ellipsoidal working channel endoscope is inserted. Initially, the surgeon can view the surface of the superior facet via endoscopic visualization. At this point, the direct intraforaminal placement of the working cannula or endoscope might be painful or dangerous due to nerve root injury in the stenotic foraminal space. Thus, the working cannula and endoscope should be placed outside the foramen and just contact the facet surface (floating-endoscopy technique).

Endoscopic Foraminal Unroofing

The hypertrophied part of the facet is removed using a specially designed endoscopic burr (Figure 1B). This foraminal unroofing process can be safely performed under both endoscopic and fluoroscopic guidance. In cases of osteoporosis or weak bones, a bone-removing trephine (bone reamer) can also be used to rapidly cut the facet. However, for the removal of normal bone, an endoscopic drill is safer and more effective than a bone reamer. The direction of the bone removal should be from the outside to the inside and from the inferior pedicle to the superior pedicle. The drilling should be performed until the ligamentum flavum and epidural fat begin to appear. After the hypertrophied superior facet is undercut, intraforaminal structures such as the foraminal ligament, ligamentum flavum, perineural fat covering the exiting nerve root, shoulder osteophyte, and disc surface should appear clearly. The working cannula and endoscope are now firmly engaged with the widened foraminal portion; a sophisticated exploration can now be performed. At this time, the sharp end of the
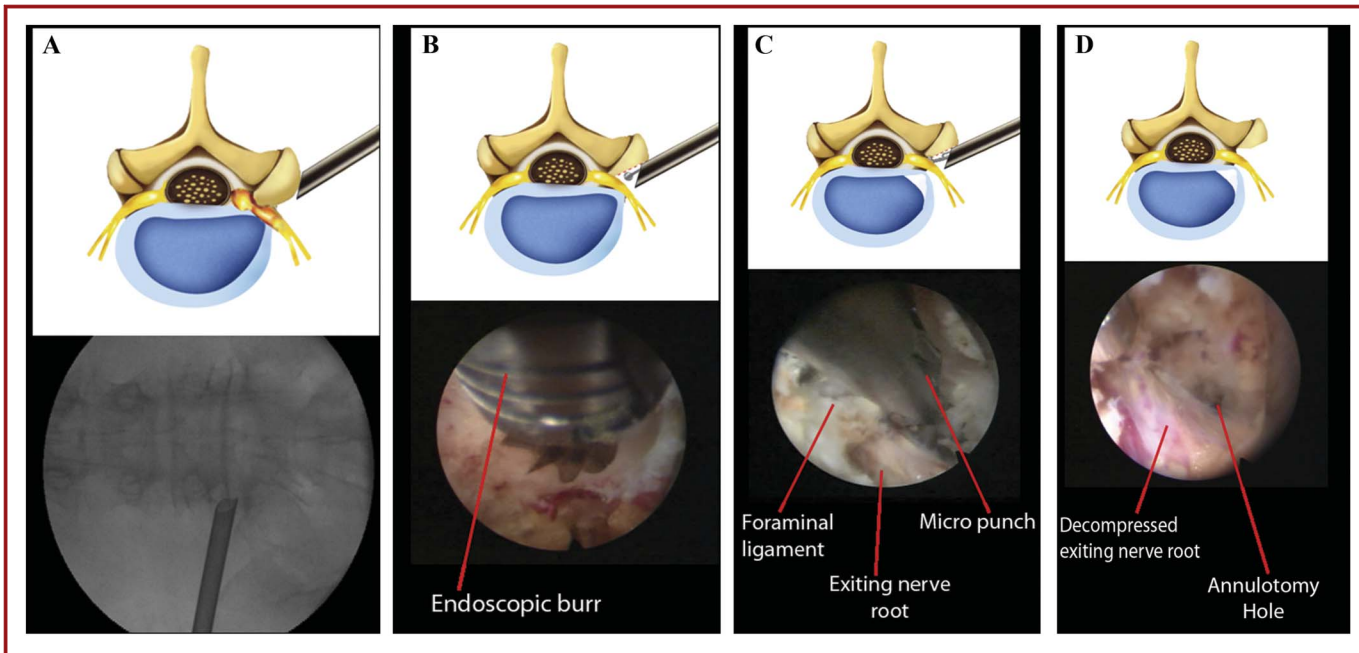
FIGURE 1. *Schematic illustrations and corresponding intraoperative fluoroscopic and endoscopic views of the surgical procedure. **A**, extraforaminal placement of the working cannula for foraminal decompression. **B**, foraminal unroofing using an endoscopic burr. **C**, sophisticated foraminal decompression using various instruments, including punches, forceps, and a laser. Note the exiting nerve root decompression using a micropunch. **D**, final view of the full-scale foraminal decompression status. Note the decompressed exiting nerve root and annulotomy site.*

bevel-ended working cannula should be positioned far from the exiting nerve root by rotating the cannula.

Full-Scale Foraminal Decompression

The hypertrophied foraminal ligament, including the ligamentum flavum and shoulder osteophyte, can be removed using various instruments (Figures 1C and 1D). Bone debris and tenacious ligaments can be removed using endoscopic graspers and punches. The redundant disc and soft tissues can be coagulated using bipolar radiofrequency. Supplementary use of a holmium yttrium-aluminum-garnet (Ho:YAG) laser may be helpful to ablate tissue debris. Any extruded disc fragments can also be removed as required. A flexible probe under both endoscopic and fluoroscopic guidance can be used to confirm the decompression. The surgeon can see and mobilize both the traversing nerve root and exiting nerve root under endoscopic visualization. The endpoint of the procedure is free mobilization of the exiting nerve root. After adequate hemostasis with a bipolar coagulator and hemostatic agent, the endoscope is withdrawn, and a sterile dressing is applied with a 1-point subcutaneous suture. The patient should be monitored for several hours if there are any postoperative problems. Patients usually undergo immediate postoperative magnetic resonance imaging and are permitted to be discharged (Figures 2 and 3).
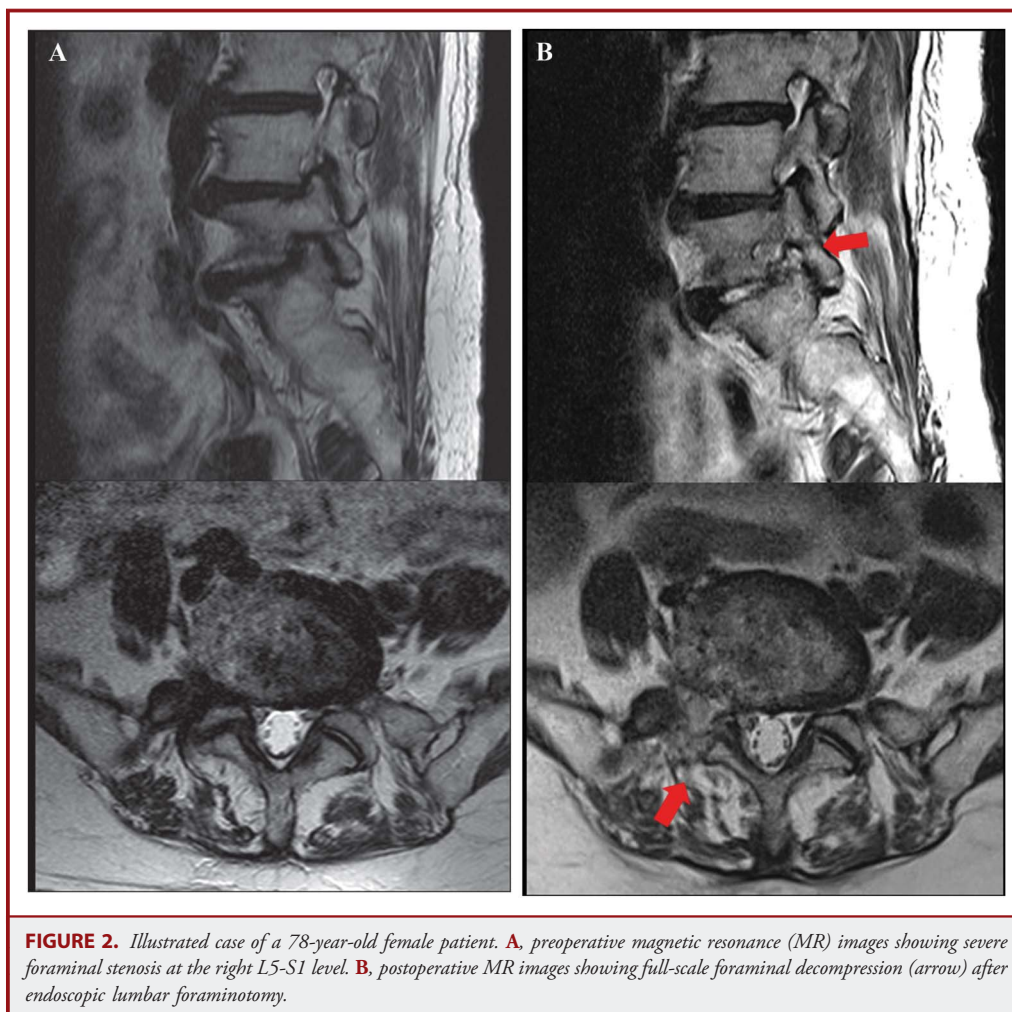
RESULTS

Demographics and Surgical Data

There were 18 women and 15 men (33 patients) with a mean age of 64.2 years (range, 27-81 years). The operated-on levels were L2-3 in 2 patients, L3-4 in 8, L4-5 in 15, and L5-S1 in 11

(36 levels). Eleven patients had a history of lumbar surgery; 5 of these patients underwent open discectomy at the same level, 2 underwent open discectomy at different levels, and 4 underwent fusion surgery at the adjacent levels. Eighteen of the 33 patients had neurological deficits in the form of muscle weakness or sensory deficits in the distribution of the affected nerve root. The mean operative time was 55.6 minutes per level (SD = 19.1 minutes; range, 35-120 minutes). The mean hospital stay after the procedure was 1.36 days (SD = 0.65 days; range, 1-4 days).

Clinical Outcomes

The mean preoperative VAS score for back pain was 5.36 (SD = 2.09). This score improved to 3.15, 2.61, 2.12, and, finally, 2.09 (SD = 1.77) at postoperative 6 weeks, 6 months, 1 year, and 2 years, respectively ($P < .001$) (Figure 4A). The mean preoperative VAS score for leg pain was 8.36 (SD = 1.32). This score changed to 3.36, 2.70, 2.03, and, finally, 1.97 (SD = 1.86) at postoperative 6 weeks, 6 months, 1 year, and 2 years, respectively ($P < .001$) (Figure 4B). The mean preoperative ODI score was 65.8% (SD = 17.4%). The mean postoperative ODI score was 31.6%, 28.0%, 19.7%, and, finally, 19.3% (SD = 16.7%) at postoperative 6 weeks, 6 months, 1 year, and 2 years, respectively ($P < .001$) (Figure 5). At the final follow-up review, the modified MacNab criteria were rated as follows: excellent in 13 patients (39.4%), good in 14 patients (42.4%), fair in 4 patients (12.1%), and poor in 2 patients (6.1%). Therefore,

FIGURE 2. *Illustrated case of a 78-year-old female patient.* **A**, *preoperative magnetic resonance (MR) images showing severe foraminal stenosis at the right L5-S1 level.* **B**, *postoperative MR images showing full-scale foraminal decompression (arrow) after endoscopic lumbar foraminotomy.*

excellent or good results were obtained in 81.8% of the patients, and the rate of symptomatic improvement was 93.9% (Figure 6). One patient who underwent ELF at the L4-5 level required subsequent open facetectomy and fusion surgery because of incomplete decompression. A hidden disc extrusion missed during an earlier endoscopic foraminotomy was found during the second surgery. Two patients experience postoperative dysesthesia in the same dermatomal distribution. Both patients required selective nerve root block and oral gabapentin medication. Their symptoms were transient and improved over a 3-month period. There were no other major complications.

DISCUSSION

History of Percutaneous Endoscopic Foraminal Decompression

Since Hijikata,[23] Onik et al,[24] and Kambin and Sampson[25] introduced the concept of posterolateral percutaneous lumbar disc decompression, several researchers have developed percutaneous endoscopic techniques for foraminal decompression. Knight et al[15,16,26] introduced laser foraminoplasty for various foraminal nerve root entrapment syndromes. They used a side-firing laser to ablate soft tissues such as foraminal ligaments and osteophytes compressing the exiting nerve root. We described an ELF technique using a bone reamer and laser.[18] Schubert and Hoogland[17] also reported the use of a bone reamer for foraminoplasty in cases of migrated disc herniation. However, the previous techniques have limited applications in definite foraminal decompression. The use of a laser is effective only for neural entrapment caused by soft tissue or fragile osteophytes. Unfortunately, the laser may be less effective and more time-consuming for severe bony stenosis. Bone reamers can rapidly cut the hypertrophied bone. However, the use of bone reamers has an inherent disadvantage: as a blind technique, it does not allow direct visual control. Some authors have reported a percutaneous endoscopic technique for foraminal/extraforaminal disc herniation.[27,28] However, their techniques can be applied only in cases of soft disc herniation, not bony stenosis of the foramen.

FIGURE 3. *Illustrated case of a 67-year-old male patient.* **A**, *preoperative magnetic resonance and computed tomography (CT) images showing severe foraminal stenosis with disc herniation and facet impingement at the left L4-5 level.* **B**, *postoperative MR and CT images showing complete foraminal unroofing and visualization of exiting nerve root after endoscopic lumbar foraminotomy.*

Characteristics of ELF

The main target of the ELF technique is lumbar foraminal stenosis that compresses the exiting nerve root by various pathologies such as hypertrophied bone and ligament, osteophytes, and/or redundant disc. Therefore, the surgeon should continually confirm the position of the exiting nerve root throughout the entire procedure. Full-scale foraminal decompression can then be performed around the exiting nerve root. A selective discectomy is optional, and the maternal disc can be preserved as required. The distinctive characteristics of this ELF technique can be summarized into 2 points: extraforaminal landing with a floating-endoscopy technique and full-scale foraminal decompression using various instruments such as a burr and punch under endoscopic vision control. First, an extraforaminal landing is one of the most important technical tips for safe foraminal decompression. The procedure begins at the safer extraforaminal zone rather than the riskier intraforaminal or intradiscal zone. In the usual transforaminal approach, the working cannula should be placed in the foraminal or intradiscal zone before the decompression process. However, the usual intraforaminal landing to the stenotic foramen may be difficult and challenging. The narrowness of the foraminal space impedes the proper placement of the working cannula and may irritate the exiting nerve root during the approach process. Therefore, severe approach-related pain or postoperative flares may occur due to nerve root irritation or injury. Instead, we place the working cannula at the extraforaminal zone (more precisely, on the surface of the superior facet) and then initiate the decompression process
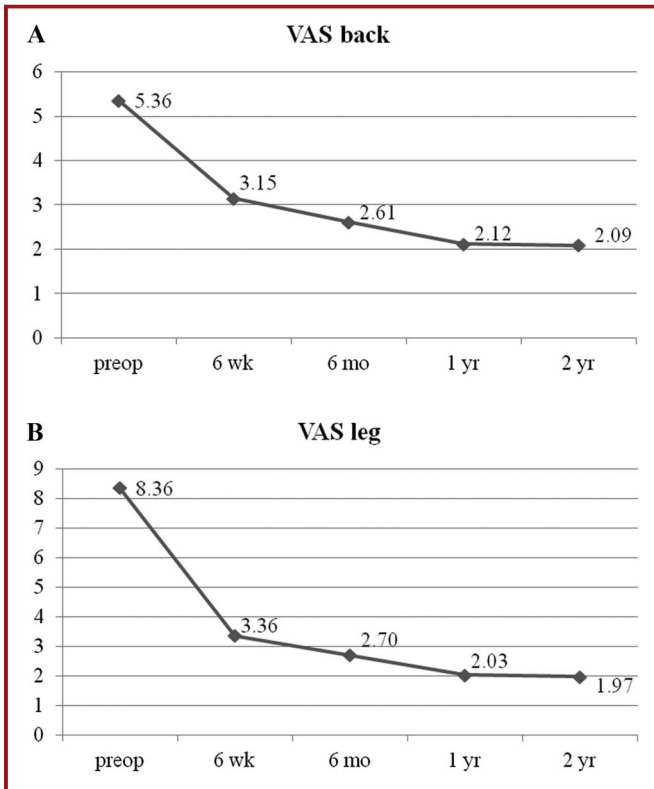
FIGURE 4. A, *Visual analog scale (VAS) pain score for back pain preoperatively (preop) and at 6 weeks, 6 months, 1 year, and the final review (2 years) post-surgery.* B, *VAS pain score for radicular pain preoperatively and at 6 weeks, 6 months, 1 year, and the final review (2 years) post-surgery.*
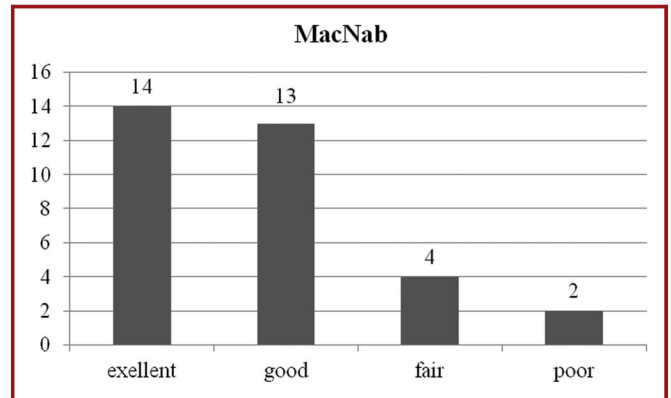

FIGURE 6. *The global outcome according to the modified MacNab criteria. Twenty-seven of the 33 patients (81.8%) experienced excellent or good results, and 31 of the 33 patients (93.9%) experienced symptomatic improvement.*

(floating-endoscopy technique). The working field is then gradually changed from outside to inside the foramen as the decompression process proceeds. This floating-endoscopy technique is useful for preventing neural damage or irritation. Second,

FIGURE 5. *Oswestry Disability Index (ODI) scores preoperatively (preop) and at 6 weeks, 6 months, 1 year, and the final review (2 years) post-surgery.*

the full-scale foraminal decompression process can be performed using various surgical instruments, such as an endoscopic burr, punch and flexible forceps, under clear endoscopic visualization, instead of using a blind bone reamer. As mentioned previously, a bone reamer can quickly cut the hypertrophied facet or osteophyte under fluoroscopic guidance. However, sculpting the bone tissue with a bone reamer is essentially a blind technique. This technique may cause unintended bleeding, inadequate bone removal, or even neural tissue damage. The use of a high-speed drill under clear endoscopic visualization enables safer and more efficacious bone removal. With the articulating bone burr (TipControl; Richard Wolf GmbH, Knittlingen, Germany), we were able to adjust the drilling direction and cover a wider working space. After the removal of the hypertrophied facet and part of the pedicle, the remaining bony shell and soft tissues can be removed via endoscopic punches, forceps, and a laser.
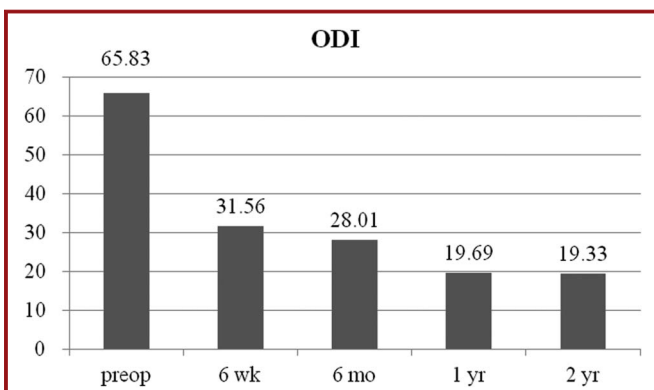
Technical Issues in Successful Decompression

We consider the most important aspect of this procedure to be identification of the location of the exiting nerve root before sophisticated decompression. The stenotic foramen is very narrow, and the exiting nerve root is subject to injury during the foraminal approach. When the working cannula is placed on the foramen, the sharp end of the bevel-ended cannula should be positioned far from the exiting nerve root by rotating the cannula. Once the working cannula is engaged around the foramen, the surgeon should locate the course of the exiting nerve root and confirm a safe working zone from the beginning of the endoscopic procedure. Another important point is that foraminal unroofing should be performed until the ligamentum flavum is exposed. It is not sufficient to remove only the lateral part of the superior facet, which exposes only a part of the exiting nerve root. The exiting nerve root should be fully decompressed from the proximal beginning point to the extraforaminal part.

TABLE 1. Comparison of Clinical Results With Conventional Open Decompression Surgery for Lumbar Foraminal Stenosis

Ref.	Year of Publication	No. of Patients	Follow-up Period	Success Rate, %	Revision Surgery, %	Complications and Residual Pain
Kunogi and Hasu[7]	1991	26	8 mo-6 y	76.9	0	2 back pain, 4 leg pain
Donaldson et al[8]	1992	25	14-54 mo	72	12	1 weakness, 1 back pain, 2 leg pain, 6 dysesthesia
Lejeune et al[9]	1994	83	2 y	76	3.6	Not applicable
Darden et al[10]	1995	25	2 y	80	4	1 deep vein thrombosis, 1 hematoma, 2 back pain, 6 dysesthesia
Baba et al[11]	1996	31	1-7.3 y	80.6	3.2	2 dysesthesia
Hodges et al[12]	1999	25	8-40 mo	76	0	Common neuropathic pain, transient
Gioia et al[13]	1999	13	4-34 mo	76.9	0	1 weakness, 2 seroma
Epstein[4]	2002	170	5 y	72.9	2.4	Not applicable
Chang et al[14]	2011	39	3-64 mo	83	5	1 transverse process fracture
Current study		33	2 y	81.8	3	2 dysesthesia, transient

Clinical Outcome and Surgical Data

We found significant improvements in both pain score and functional status at the reviews performed at 6 weeks, 6 months, 1 year, and 2 years. The mean decrease in the VAS score at the final review was 6.36 (SD = 2.19) for leg pain and 3.24 (SD = 2.02) for back pain ($P < .001$). These data indicate that this technique is efficient for decompressing the exiting nerve root, and this effect continued over a 2-year follow-up period. The mean decrease in the ODI score at the final review was 46.5 (SD = 24.2) ($P < .001$). A reduction in the ODI score of more than 20% is considered clinically relevant.[29,30] Therefore, our series exhibited clinically significant levels of functional improvement. According to the modified MacNab criteria, the global success rate in our series was 81.8%, and the symptomatic improvement was 93.9%. These outcomes are comparable to those of other published series of open decompression surgery patients (Table 1).[4,7-14] Regarding surgical data, the mean operative times reported for open foraminal decompression surgery were 65.8 to 156 minutes, and the estimated blood losses were 56 to 90 mL.[10,11,13] In the current work, the ELF procedures were performed for 55.6 minutes on average with patients under local anesthesia with negligible blood loss. Therefore, our surgical data demonstrate a relatively shorter operative time and less blood loss compared with open decompression surgery (Table 2). Our data are also comparable to those of

other endoscopic or minimally invasive decompression techniques.[16,18,26-28,31,32] The overall success rates of the case series ranged from 73% to 100%. We think that direct comparison among those studies is difficult because the type and degree of foraminal pathologies might be somewhat different. However, it would be helpful to shape the future of minimally invasive foraminal decompression techniques (Table 3).

Complications and Reoperation

Excessive manipulation or irritation of the dorsal root ganglion during foraminal decompression surgery may cause postoperative dysesthesia. The reported rates of postoperative dysesthesia or numbness after open decompression surgery are 6.5% to 24%.[8,10,11] In our series, there were 2 patients with transient postoperative dysesthesia (6.1%); this symptom subsided within 3 months. There were no other major complications in our series. Regarding the reoperation rate, the rates reported for open decompression surgery are 2.4% to 12%.[4,8-11,14] In our series, 1 (3%) of the 33 patients underwent open fusion surgery due to incomplete decompression. Therefore, our complication rate and reoperation rate are in agreement with published values for open decompression surgery (Table 1). In general, the primary advantages of endoscopic spine procedures are less traumatization and a lower complication rate.[33-35] Our surgical data and clinical

TABLE 2. Comparison of Perioperative Data With Conventional Open Decompression Surgery for Lumbar Foraminal Stenosis

Ref.	Year of Publication	No. of Patients	Follow-up Period	Operative Time, min	Blood Loss, mL	Hospital Stay, d
Darden et al[10]	1995	25	2 y	127 (70-230)	90 (negligible-320)	3.8 (1-8)
Baba et al[11]	1996	31	1-7.3 y	156 (108-198)	84 (45-190)	3-4 to ambulate
Gioia et al[13]	1999	13	4-34 mo	65.8 (45-90)	56.2 (35-70)	
Current study		33	2 y	55.6 (35-120)	Negligible	1.36 (SD = 0.65)

TABLE 3. Comparison of Clinical Results With Other Endoscopic or Minimally Invasive Foraminal Decompression Techniques[a]

Ref.	Year of Publication	No. of Patients	Follow-up	Pathology	Technique (Anesthesia)	Success Rate, %	Complications and Revision Surgery
Knight et al[26]	2001	250	30 mo	Foraminal disc disease	Endoscopic laser foraminoplasty (L)	73	1 foot drop, 1 aseptic discitis, 13 revision surgery
Ahn et al[18]	2003	12	12.9 mo	Foraminal stenosis, L5-S1	Endoscopic foraminotomy (L)	83.3	1 open surgery
Knight and Goswani[16]	2003	24	34 mo	Spondylolisthesis, isthmic	Endoscopic laser foraminoplasty (L)	79.2	2 open surgery
Jang et al[27]	2006	35	18 mo	(Extra) foraminal disc herniation	PELD (L)	85.7	6 dysesthesia, 3 open surgery
Choi et al[28]	2007	41	34.1 mo	Extraforaminal disc herniation	PELD (L)	92	3 dysesthesia, 2 open surgery
Laurysen[31]	2010	67	3.5 mo	Lateral recess and foraminal stenosis	iO-Flex (G)	All stable	7 durotomies
Yoshimoto et al[32]	2011	6	12 mo	Foraminal stenosis	MED (G)	All stable	n
Current study		33	2 y	Foraminal stenosis	Endoscopic foraminotomy (L)	81.8	2 dysesthesia, 1 open surgery

[a]L, local anesthesia; PELD, percutaneous endoscopic lumbar discectomy; iO-Flex (Baxano Inc, San Jose, California), minimally invasive decompression using a flexible microblade shaver system; G, general anesthesia; MED, microendoscopic decompression.

outcomes of endoscopic foraminotomy demonstrated considerable benefits in terms of tissue trauma.

Limitations and the Future of ELF

Although this technique has the benefits of full-scale foraminal decompression with less trauma, there are some limitations. First, there may be a learning curve for this novel technique. The use of a drill and punches under endoscopic control is unfamiliar to most spine surgeons. Second, in cases of extreme far lateral stenosis caused by hypertrophied sacral ala at the L5-S1 level, the ELF technique may still be challenging. A different approach angle and the rotation of the endoscope should be required for the removal of the sacral ala.

CONCLUSION

Endoscopic lumbar foraminotomy with patients under local anesthesia is a safe and effective technique for lumbar foraminal stenosis. This surgical technique has become more practical and standardized. Therefore, this technique may offer more reliable and reproducible results, especially for elderly or medically compromised patients.

Disclosure

The authors have no personal, financial, or institutional interest in any of the drugs, materials, or devices described in this article.

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COMMENTS

In this study, the authors describe their version of percutaneous endoscopic lumbar foraminotomy (ELF) and evaluate the outcomes and complications in 33 patients. Standard measures including VAS pain score, ODI, and the modified MacNab criteria were assessed, and outcomes were comparable to the equivalent open procedure based on the reported literature. In general, complications were low, including postoperative dysesthesia, which was attributed to the use of the floating-endoscopy technique. As with all minimally invasive procedures, the primary benefit is decreased adjacent tissue injury, which typically translates into less bleeding and a shorter hospital stay. This benefit was seen in this study with negligible blood loss and a mean stay of 2 days, which, when compared with the literature on open decompression, was an improvement. The greatest issue is that most neurosurgeons are not trained in spinal endoscopy so the learning curve involved is likely steep. Given that the outcomes seem comparable to those with the open procedure and relative benefits of percutaneous ELF (negligible vs mean <100 mL blood loss in the open cases) are not great, it remains to be seen how well this procedure will be adopted. The authors should be congratulated for describing this technique and advancing the field of minimally invasive spine surgery.

Paul Park
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The authors are to be commended for their contribution in describing a novel minimally invasive technique for lumbar foraminal decompression. This is a well-structured, nonblinded prospective study, providing level II evidence, analyzing an endoscopic extraforaminal technique for lumbar nerve root decompression in 33 patients. The clinical outcomes are impressive, and, as such, the technique appears to have merit. The results appear to be favorable compared with those of other published studies of open and minimally invasive or endoscopic decompression.

Although the clinical outcomes speak for themselves, I believe that there may be some criticism regarding the degree of foraminal decompression that is possible with this technique. The authors do provide pre- and postoperative images demonstrating a good result; however, it would be more powerful to quantify the degree of decompression for the entire cohort given that pre- and postoperative imaging was done in each case. It is my understanding that such a study is under way by this group, and I look forward to reviewing the results.

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Endoscopic lumbar procedures have appeared in the neurosurgical literature for roughly 20 years, although the mainstay of treatment has been open procedures. A not insignificant reason is that most lumbar issues can be adequately addressed via open approaches with very good results. However, a particular area of difficulty remains with foraminal stenosis as the open approaches often require significant bony resection of the facet, larger incisions for lateral exposure, and the like. This study reviews 33 patients undergoing endoscopic lumbar foraminotomy in which the clinical outcomes (VAS score, ODI score, modified McNab) were excellent with minimal complications (2 patients with transient

dysesthesia, 1 patient requiring reoperation). The authors offer a thorough explanation of the procedure, and the accompanying video demonstrates the procedure clearly. Although the study was not blinded, the results are nevertheless impressive.

The allures of percutaneous endoscopic techniques are the potential for less tissue trauma, faster recoveries, and shortened hospital stays. These endpoints will need to be compared in blinded studies to show the superiority of this application. Time will tell whether these techniques will eclipse the more standard approaches. As with all endoscopic procedures, surgeons wishing to pursue them will take on novel learning curves and therefore the benefit will need to be demonstrable to effect that change. However, for the application as described, this procedure is certainly exciting and may offer a competitive advantage to current techniques.
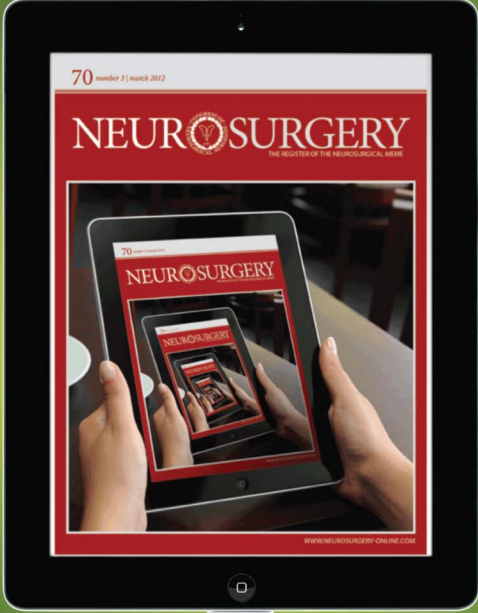
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In this nicely illustrated report, the authors describe their experience in surgically treating 33 patients with foraminal stenosis with a minimally invasive, extraforaminal approach. Their technique places the incision 8-13 centimeters off of the midline and utilizes the bony facet as a docking point during fluoroscopic positioning of a percutaneous access cannula. Favorable results were seen in over 90 percent of patients with statistically significant improvement in the VAS leg pain scores at two-year follow up. One patient required reoperation for incomplete decompression and two patients complained of postoperative dysesthesia that regressed over the course of three months.

As a practical matter, it is not clear that the described technique provides a magnitude of benefit that would prompt wide adoption by neurosurgeons who, as a group, are generally more comfortable performing surgery using the operating microscope than the endoscope. Still, the report is of interest with regard to the "outside in" description of the operative technique that emphasizes the importance of not attempting to initially place tools within the stenotic foramen that might cause neurologic injury and the use of specialized tools, the specially designed endoscopic burr in particular.

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