Percutaneous endoscopic lumbar foraminotomy (PELF)

- Application of Repeated Foraminoplasty in Percutaneous Endoscopic Transforaminal Discectomy for Lumbar Disc Herniation Patients with Lumbar Foraminal Stenosis
- Insights on High-Value Procedures From the ISASS 4-Part Webinar Series on Current and Emerging Techniques in Endoscopic Spine Surgery Based on Surgeon Experience
- A novel endoscope-port unit for lumbar microendoscopic surgery: a single-center case series review
- The effect of large channel-based foraminoplasty on lumbar biomechanics in percutaneous endoscopic discectomy: a finite element analysis
- Percutaneous Transforaminal Endoscopic Lumbar Foraminotomy in Stable Degenerative Lumbar Isthmic Spondylolisthesis with Radicular Leg Pain: A Retrospective Study
- Transforaminal endoscopic lumbar foraminotomy for octogenarian patients
- Interventional Therapy and Surgical Management of Lumbar Disc Herniation in Spine Surgery: A Narrative Review
- The effect of annulus fibrosus incision and foraminoplasty on lumbar biomechanics in percutaneous endoscopic lumbar discectomy: a finite element analysis

Percutaneous endoscopic lumbar foraminotomy (PELF) under local anesthesia could be an efficacious surgical procedure for the lumbar foraminal stenosis treatment. This procedure may offer safe and reproducible results, especially for elderly or medically compromised patients [1)].

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.

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 PELF 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.

Characteristics

The main target of the PELF 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, Ahn et al., place the working cannula at the extraforaminal zone (more precisely, on the surface of the superior facet) and then initiate the decompression process (floating-endoscopy technique). The working field is then grad- ually changed from outside to inside the foramen as the decompression process proceeds. This floating-endoscopy tech- nique is useful for preventing neural damage or irritation. Second, 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 osteo- phyte 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), Ahn et al., 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

The most important aspect of this procedure is 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.

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 mg/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. Unlike the usual percutaneous endoscopic foraminal 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. 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, intra- foraminal 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 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. 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.

Clinical Outcome and Surgical Data

Ahn et al., 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, this series exhibited clinically significant levels of functional improvement. According to the modified MacNab criteria, the global success rate in this 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.

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.

In the current work, the PELF 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.

This data are also comparable to those of other endoscopic or minimally invasive decompression techniques.

The overall success rates of the case series ranged from 73% to 100%.

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.

Complications

Excessive manipulation or irritation of the dorsal root ganglion during foraminal decompression surgery may cause postoperative dysesthesia.

Reoperation

Case series

16 patients with coronal deformity of between 10° and 20°. All patients underwent endoscopic foraminal decompression surgery. The pre- and postoperative Cobb angle, visual analog scale (VAS), 36-Item Short Form Health Survey (SF-36), and Oswestry Disability Index scores were measured.

The average age of the patients was 70.0 ± 15.5 years (mean ± SD, range 61-86 years), with a mean followup of 7.5 ± 5.3 months (range 2-14 months). The average coronal deformity was 16.8° ± 4.7° (range 10°-41°). In 8 patients the symptomatic foraminal stenosis was at the level of the fractional curve, and in the remaining patients it was at the concave side of the main curve. One of the patients included in the current cohort had to undergo a repeat operation within 1 week for another disc herniation at the adjacent level. One patient had CSF leakage, which was repaired intraoperatively, and no further complications were noted. On average, preoperative VAS and SF-36 scores showed a tendency for improvement, whereas a dramatic reduction of VAS, by 65% ($p = 0.003$), was observed in radicular leg pain.

Patients with mild to moderate spinal deformity are often compensated and have tolerable levels of back pain. However, unilateral radicular pain resulting from foraminal stenosis can be debilitating. In select cases, an endoscopic discectomy or foraminotomy enables the surgeon to decompress the symptomatic foramen with preservation of essential biomechanical structures, delaying the need for a major deformity correction surgery [2)].

Foraminal stenosis frequently causes radiculopathy in lumbar degenerative spondylosis]]. Endoscopic transforaminal techniques allow for foraminal access with minimal tissue disruption. However, the effectiveness of foraminal decompression by endoscopic techniques has yet to be studied.

Ewins evaluated radiographic outcome of endoscopic transforaminal foraminotomies performed at L3-L4, L4-L5, and L5-S1 on cadaveric specimens. Before and after the procedures, three dimensional CT scans were obtained to measure foraminal height and area. Following the foraminotomy, complete laminectomy and facetectomy were performed to assess for dural tears or nerve root injury. L3-L4 preoperative foraminal height increased by 8.9%, from 2.12±0.13cm to 2.27±0.14cm ($p<0.01$), and foraminal area increased by 24.8% from 2.21±0.18cm(2) to 2.72±0.19cm(2) ($p<0.01$). At L4-L5, preoperative foraminal height was 1.87±0.17cm and area was 1.78±0.18cm(2). Endoscopic foraminotomies resulted in a 15.3% increase of foraminal height (2.11±0.15cm, $p<0.05$) and 44.8% increase in area of (2.51±0.21cm(2), $p<0.01$). At L5-S1, spondylitic changes caused diminished foraminal height (1.26±0.14cm) and foraminal area (1.17±0.18cm(2)). Postoperatively, foraminal height increased by 41.6% (1.74±0.09cm, $p<0.05$) and area increased by 98.7% (2.08±0.17cm(2), $p<0.01$). Subsequent inspection via a standard midline approach revealed one dural tear of an S1 nerve root. Endoscopic foraminotomies allow for effective foraminal decompression, though clinical studies are necessary to further evaluate complications and efficacy [3)].

[1)]
Ahn Y, Oh HK, Kim H, Lee SH, Lee HN. Percutaneous endoscopic lumbar foraminotomy: an advanced surgical technique and clinical outcomes. Neurosurgery. 2014 Aug;75(2):124-33; discussion 132-3. doi: 10.1227/NEU.0000000000000361. PubMed PMID: 24691470; PubMed Central PMCID: PMC4086756.
[2)]
Madhavan K, Chieng LO, McGrath L, Hofstetter CP, Wang MY. Early experience with endoscopic foraminotomy in patients with moderate degenerative deformity. Neurosurg Focus. 2016 Feb;40(2):E6. doi: 10.3171/2015.11.FOCUS15511. PubMed PMID: 26828887.
[3)]
Evins AI, Banu MA, Njoku I Jr, Elowitz EH, Härtl R, Bernado A, Hofstetter CP. Endoscopic lumbar

foraminotomy. J Clin Neurosci. 2015 Apr;22(4):730-4. doi: 10.1016/j.jocn.2014.10.025. Epub 2015 Mar 2. PubMed PMID: 25744073.