14 Neural Foramen Decompression Using Transforaminal Access

Yong Ahn

14.1 Introduction

The clinical importance of lumbar foraminal or far-lateral stenosis is that it may be a candidate for surgery because it may cause greater intractable pain and disability than central or intracanal stenosis [1]. Moreover, focal compression of a single dorsal root ganglion in the neuroforamen can be treated effectively by decompression surgery at the critical point. The current gold standard surgical technique for lumbar foraminal or far-lateral stenosis is open paraspinal facetectomy with or without fusion [2]. However, there may be some drawbacks of this technique based on the extent of facetectomy. Excessive facetectomy may cause postoperative instability or the addition of unnecessary fusion surgery. Excessive irritation of the dorsal root ganglion may also cause considerable postoperative dysesthesia [3, 4]. In contrast, facet-sparing foraminal decompression may result in incomplete decompression. Therefore, an alternative minimally invasive surgical technique that preserves segmental stability and achieves complete decompression is required. Transforaminal percutaneous access to the foraminal zone is theoretically ideal to achieve this goal in terms of the angle of the approach and minimal tissue trauma. Recently, percutaneous endoscopic lumbar foraminotomy (PELF) has been emerging as a minimally invasive surgical option for lumbar foraminal stenosis. Remarkable technical advancement of endoscopes and surgical instruments makes this procedure practical. The objective of this chapter is to describe the cutting-edge technique of PELF.

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14.2 History of Endoscopic Foraminal Decompression

Over the 40-year history of percutaneous endoscopic spine surgery, development of the PELF technique was relatively late because of the irony of the transforaminal approach. In fact, foraminal decompression is more difficult than intracanal decompression. Therefore, practical PELF techniques did not begin to appear in the literature until the late 1990s. The first generation of PELF occurred during the age of the laser. Knight et al. published an endoscopic laser foraminoplasty technique for various foraminal nerve root entrapment syndromes [5–7]. The basic concept of foraminoplasty is reshaping the foramen by ablating hypertrophied osteophytes and ligaments using a side-firing laser under direct endoscopic visualization. The second generation of PELF occurred during the age of the bone trephine. Ahn et al.

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described a PELF technique using a bone reamer and laser [8], while Schubert and Hoogland also reported the use of a bone reamer for foraminoplasty [9]. Lasers are effective for neural entrapment caused by soft tissue or fragile osteophytes. However, they may be less effective for harder bone tissue. The use of a bone trephine also has inherent risks, such as bone bleeding and neural injury, because it is a blind technique without any direct visual control. The third generation of PELF occurred during the age of the endoscopic burr and endopunch. Specially designed endoscopic burrs and endopunches enable safer and more effective full-scale foraminal decompression [10–13].

14.3 Indications

The clinical indications for PELF are as follows: (1) presence of radicular pain due to lumbar foraminal or extraforaminal stenosis, (2) intractable pain despite more than 6 weeks of conservative treatment including extensive physical therapy and medications, and (3) transient pain-relieving effect with selective nerve root block. The radiographic indications are moderate to severe foraminal or extraforaminal stenosis with perineural fat obliteration or nerve root collapse on magnetic resonance imaging (MRI) and computed tomography (CT) [12–15]. In cases of mild foraminal stenosis suspicious of dynamic foraminal stenosis, PELF can be considered if the index foramen is confirmed as the pain source by selective root block or nerve stimulation. This procedure is contraindicated for patients with intracanalicular stenosis, definitive segmental instability, or other pathologic conditions, such as inflammation, infection, or tumor.

14.4 Surgical Technique

The standard surgical procedure is composed of three stages [12, 13]: first, transforaminal percutaneous access of the working channel endoscope (Fig. 14.1) into the foraminal pathologies (foraminal endoscopic landing); second, endoscopic foraminal unroofing and resection of the hypertrophied superior articular process (SAP) using specially designed surgical instruments (Fig. 14.2) including an endoscopic burr and endopunches (bony decompression); and finally, full-scale foraminal decompression and release of the exiting nerve root using fine instruments (Fig. 14.2) including forceps and radiofrequency (soft decompression). The patient is placed in the prone position with the hip and knee flexed on a radiolucent table. The procedure is performed under local anesthesia with conscious sedation. The patient is injected with midazolam (0.05 mg/kg) intramuscularly and fentanyl (0.8 μg/kg) intravenously. The sedative amounts are then adjusted during the procedure. Preoperative antibiotics (usually 1.0 g cefazolin) are given before surgery.

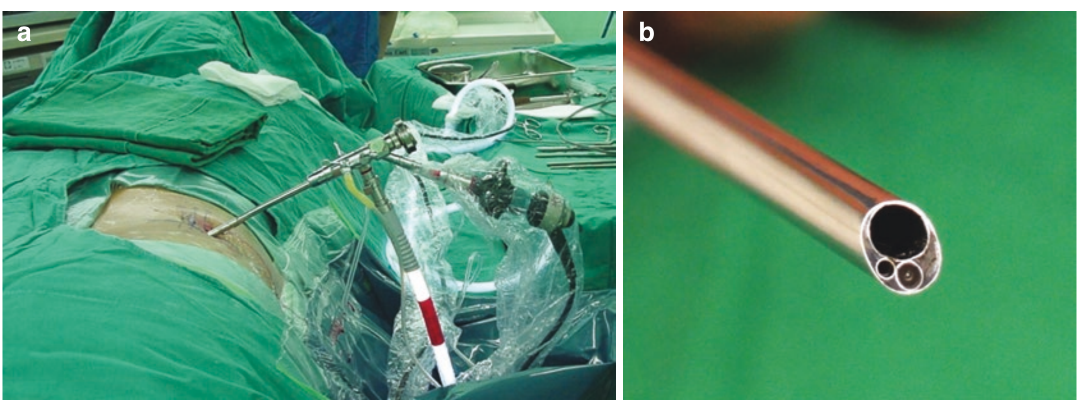

Fig. 14.1 Working channel endoscope for percutaneous endoscopic lumbar foraminotomy. (**a**) Intraoperative view. (**b**) Top view. Note the angled optic system, irrigation channel, and bigger working channel

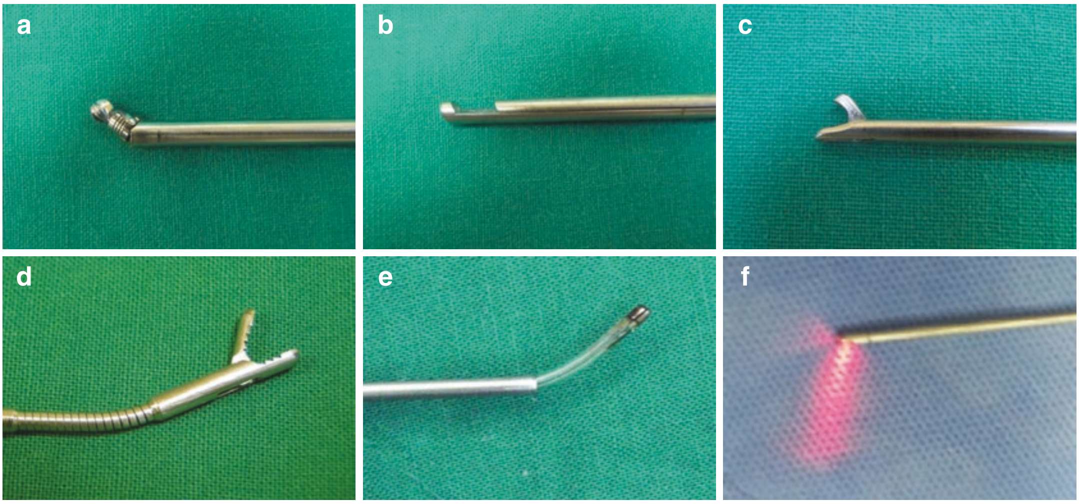

Fig. 14.2 Surgical instruments of percutaneous endoscopic lumbar foraminotomy. (**a**) Articulating bone burr can remove wide range of bone tissues. (**b**) Endopunch can remove bone and pathologic tissues under endoscopic control. (**c**) Micropunch can precisely resect hypertrophied bone and ligaments. (**d**) Steerable and curved forceps can reach a remote site and decompress lesions around the corner of the endoscopic field. (**e**) Curved radiofrequency coagulator is used to coagulate or ablate soft tissues. (**f**) Side-firing laser is used to ablate pathologic tissues in a delicate manner while protecting normal tissues

14.4.1 Percutaneous Foraminal Approach

The key point of this step is safe foraminal landing of the working cannula while protecting the exiting nerve root. In most cases of lumbar foraminal stenosis, the safe triangular zone is relatively narrow and there is higher risk of exiting nerve root injury during the approach. Therefore, extraforaminal landing is safer than direct transforaminal landing. The skin entry point of the approach needle is typically located 8–13 cm lateral from the midline. It can be adjusted according to the patient's body size and the target point under biplanar fluoroscopic guidance. The target point of the initial needle placement is the undersurface of the SAP or caudal endplate of the disc. The needle is then replaced by a guidewire, followed by the introduction of a tapered obturator over the guidewire into the foraminal space. The obturator should be advanced with gentle rotation to protect the exiting nerve root. Once the obturator is firmly engaged in the foramen without exiting nerve root irritation symptoms, a bevel-ended working cannula is introduced over the obturator with the sharp end directed toward the opposite side of the exiting nerve root. The working cannula is then opened to the foraminal zone and the proper working space for endoscopic decompression can be secured (Fig. 14.3a).

14.4.2 Endoscopic Foraminal Unroofing

After the working cannula is placed in the proper position, a working channel endoscope is introduced. The surgeon can see the undersurface of the hypertrophied SAP, thickened foraminal ligaments, and inflamed exiting nerve root. The first step of foraminal decompression is undercutting of the hypertrophied SAP using an articulating endoscopic bone burr (TipControl; Richard Wolf, Knittlingen, Germany) and endopunches under direct endoscopic visualization (endoscopic foraminal unroofing). The articulating bone burr is useful to remove a wide range of bone in the endoscopic visual field (Fig. 14.2b). The endopunches are used to remove bone shell after using the burr (Fig. 14.2c). This unroofing process in which the burr and endopunches are used alternately is very safe because the neural tissue can

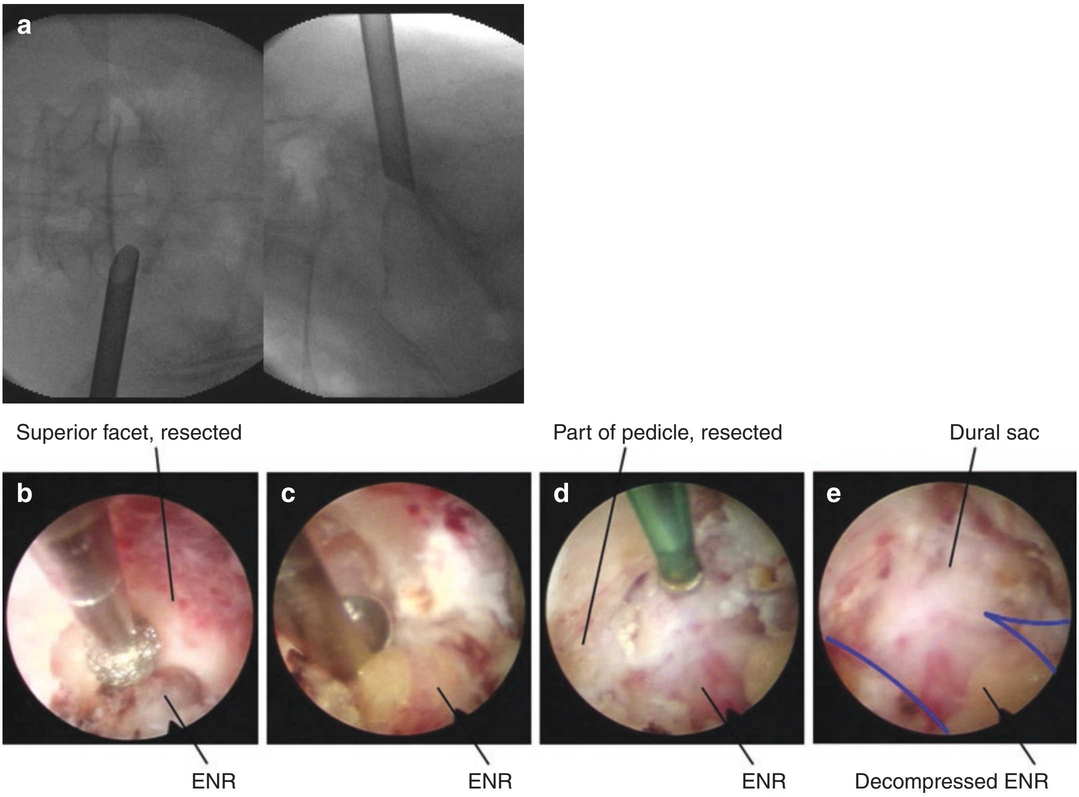

Fig. 14.3 Intraoperative pictures of the operative procedure at the left L5-S1 level. (**a**) Extraforaminal landing for foraminal decompression. Note the placement of the working sheath avoiding the exiting nerve root (ENR). (**b**) Foraminal unroofing by using a burr under endoscopic control. Hypertrophied superior facet and a part of the pedicle can be removed until the ligamentum flavum is exposed. (**c**) Full-scale foraminal decompression by using endoscopic punches, forceps, and supplementary tools. Ligamentum flavum and remaining bone can be removed and the ENR is gradually released. (**d**) ENR should be entirely decompressed from the proximal end to the exit zone. Note the probe indicates the proximal end of the nerve root. (**e**) Endpoint of the procedure. Note the ENR and dural sac are adequately released and freely mobilized

be protected by the ligamentum flavum and perineural fat under clear endoscopic visualization. This process is gradually proceeded from outside to inside and from caudal to rostral until the ligamentum flavum and proximal part of the exiting nerve root are exposed.

14.4.3 Full-Scale Foraminal Decompression

After foraminal unroofing is completed, the intraforaminal structures, such as the thickened ligamentum flavum, foraminal ligaments, perineural fat, compressed exiting nerve root, shoulder osteophytes, and disc surface, can be observed. The precise location of the exiting nerve root and dural sac should always be confirmed and protected during the entire procedure. The ligamentum flavum and foraminal ligaments compressing the nerve roots are removed using micropunches and endopunches. As dorsal decompression is performed, the dural sac and exiting nerve root are gradually exposed. Thereafter, the ventral structures, such as shoulder osteophytes and redundant disc, can also be decompressed. Curved probe and flexible forceps help to decompress a wide range of foraminal pathologies (Fig. 14.4d). Bipolar radiofrequency with a curved tip is essential to ablate soft tissue

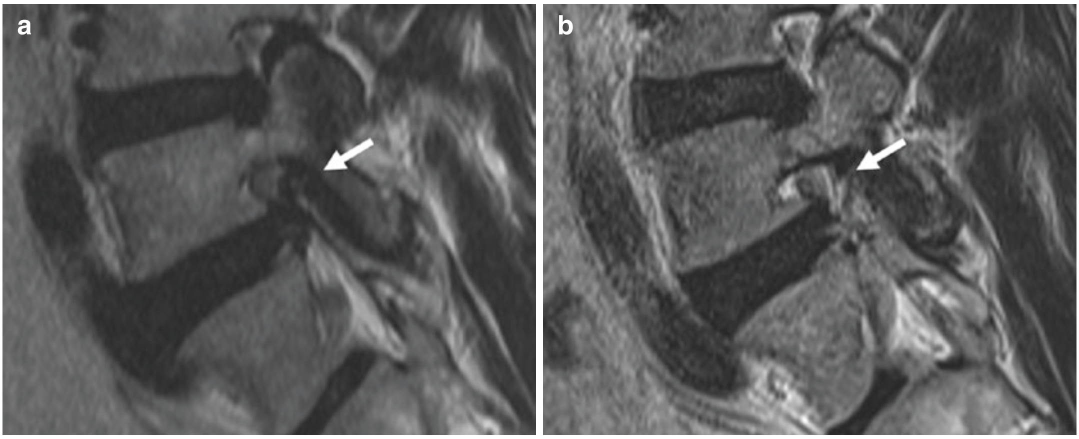

Fig. 14.4 Illustrated case of a 53-year-old female patient. (**a**) Preoperative MR image showing severe foraminal stenosis (arrow) at L5-S1 level on the left side. (**b**) Postoperative MR image showing full-scale foraminal decompression (arrow) after percutaneous endoscopic lumbar foraminotomy

debris and to control bleeding during the procedure. Supplementary use of a side-firing Ho:YAG laser is optional but may be helpful to ablate soft tissue and bone debris. The endpoint of the procedure is free mobilization and release of the exiting nerve root. The exiting nerve root should be released throughout the entire course from the proximal axilla portion to the distal exiting zone (full-scale foraminal decompression, Fig. 14.3e).

After confirming the endpoint of the procedure and adequate hemostasis, the endoscope and working cannula are withdrawn and sterile dressing is applied with a one-point subcutaneous suture. The patient should be observed for 3 h for any postoperative complications and permitted to go home after 24 h (Figs. 14.4 and 14.5).

14.5 Outcomes

Since Ahn [8] introduced endoscopic lumbar foraminotomy using a bone trephine, there have been some clinical studies on the advanced technique of PELF. The techniques commonly use a bone trephine or endoscopic burr for foraminal decompression under direct endoscopic control. Supplementary use of a laser may enhance the efficiency of the technique [12]. The clinical success rate of PELF varies from 71% to 95% [9, 10, 12, 16–18]. PELF is especially effective for geriatric patients [11] and for postsurgical foraminal stenosis or failed back surgery syndrome [19–22]. In cadaveric or radiographic studies, the foraminal dimensions, such as foraminal height and foraminal area, significantly increased with endoscopic foraminal decompression [23, 24]. However, no randomized controlled trials or high-quality comparative cohort studies on endoscopic lumbar foraminotomy or foraminoplasty have been published.

14.6 Complications

Although a minimally invasive procedure is able to reduce the rate of complications, the risk cannot be completely avoided. Theoretically, all the complications associated with conventional open surgery may occur. These include the following: injury to neural structures, dural tear, epidural bleeding, injury to vessels, injury to intra-abdominal organs, spondylodiscitis, soft tissue infection, incomplete decompression, and persistent radicular symptoms.

Among them, the most essential complication of PELF is exiting nerve root injury [25–32]. In the transforaminal or extraforaminal approach, the risk of injury to the exiting nerve root cannot be completely eliminated. The highest risk exists while performing the approach itself to the

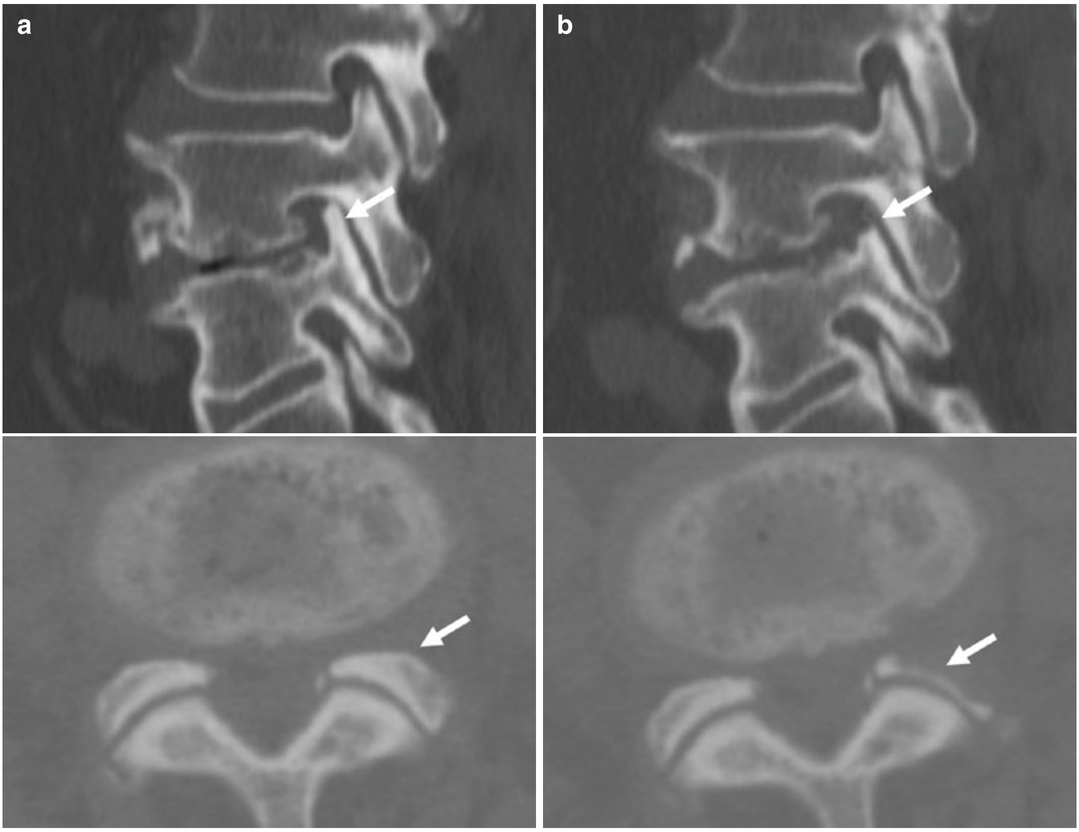

Fig. 14.5 Illustrated case of a 67-year-old male patient. (**a**) Preoperative CT scan showing severe foraminal stenosis (arrow) at L4-5 level on the left side. (**b**) Postoperative CT scan showing full-scale foraminal decompression (arrow) after percutaneous endoscopic lumbar foraminotomy. Note the pinched tip of superior articular process is removed (arrow) after the procedure

narrowed foramen. Once occurred, postoperative dysesthesia or motor weakness may develop. To prevent approach-related exiting nerve root injury, the surgeon should pay close attention to feedback from the patient during the transforaminal or extraforaminal approach under fluoroscopic guidance. If there is irritation while advancing the dilator or working cannula into the foramen, it is necessary to change the direction of the approach to a more caudal and dorsal aspect of the foramen.

Intraoperative epidural bleeding from the epidural vein or bone may disturb endoscopic visualization during the procedure and potentially cause postoperative epidural hematoma. Most epidural bleeding can be controlled by pressured saline irrigation or a radiofrequency electrode. Bleeding from the site of bone removal can be controlled with thrombin-soaked gelfoam. However, injury to the radicular lumbar artery adjacent to the exiting nerve root may cause a disastrous event. In cases of massive retroperitoneal hematoma with hypovolemia or severe flank pain, hematoma evacuation should be performed [33, 34]. This can happen during an inadequate foraminal approach and not during decompression. Therefore, a proper percutaneous foraminal approach technique is essential to prevent this major complication.

Dural tear may occur during delicate decompression [35]. Minor dural tear in which the rootlet is not herniated and confined in the dural membrane can be controlled by application of gelfoam with an adhesive agent. However, if rootlet herniation occurs during the procedure, open reduction and primary closure should be carried out. Unrecognized or untreated dural tear may cause serious neurologic deficit.

Infection related to endoscopic surgery is relatively rare because the procedure is performed percutaneously and with continuous saline irrigation mixed with antibiotics. However, once occurred, the clinical manifestations may be of a serious nature [36, 37]. After intradiscal procedures, infection results in spondylodiscitis. Early diagnosis with clinical suspicion is essential for proper management. This can be managed with antibiotics alone or with salvage operations, such as repeated endoscopic irrigation or fusion surgery.

14.7 Key to Success in Patient Selection

The essential keys to success of PELF are proper patient selection and precise surgical technique. There are some prediction rules in patient selection.

First, regarding the extent of foraminal stenosis, focal lesions are better than diffuse lesions. Because percutaneous endoscopic decompression is usually performed with a narrow working corridor under local anesthesia and with limited time, focal decompression at the critical point is important. In cases of wide range stenosis, open surgery under general anesthesia may be more adequate. Second, regarding the number of stenotic lesions, a single lesion is better than multiple lesions for the same reasons. Third, regarding the zone of foraminal stenosis, foraminal lesions are better than extraforaminal lesions. Considering the characteristics of endoscopic visualization and current surgical instruments, definitive endoscopic decompression of the extraforaminal zone remains a challenging task to the surgeon.

Another good candidate for endoscopic foraminotomy is dynamic foraminal stenosis. The stenotic lesion may not be definitive on routine static MRI or CT. In such cases, the exiting nerve root is pinched by the tip of the SAP based on the patient's posture. Dynamic MRI or diagnostic nerve root block may help in diagnosing dynamic foraminal stenosis. Focal resection of the tip of the SAP under endoscopic control may lead to a significant effect.

14.8 Key to Success in Surgical Technique

Above all things, a safe percutaneous approach to the stenotic foramen while protecting the exiting nerve root is the most important point of the procedure. A blunt obturator should be gently introduced to dissect the working space while observing the patient's response in aware status. Then, the final working cannula should be inserted over the obturator with the sharp end of the cannula directed away from the exiting nerve root. The recommended landing point of the working cannula is at the caudal and dorsal aspect of the foraminal portion. Second, endoscopic foraminal unroofing should be continued until the lateral wall of the ligamentum flavum. In most cases, the proximal or axillary portion of the exiting nerve root is the most critical point of the foraminal stenosis; definitive decompression at this critical point is essential. After confirming axillary decompression, subsequent full-scale foraminal decompression can be achieved. Finally, the exiting nerve root should be decompressed until the nerve root is freely mobilized. Exposure of the neural tissue alone is not enough. Any fibrotic tissue adhering to the nerve root should be released completely at the final step of the procedure.

14.9 Current Limitations

A long learning curve is the most significant shortcoming of this procedure [12, 13]. A foraminal approach to the foraminal pathology is usually more difficult than a transforaminal approach to the intracanal pathology. In other words, "to the foramen" is more difficult than "through the foramen," demonstrating the irony of the transforaminal approach. Second, this procedure may not be effective for extraforaminal stenosis, especially at the L5-S1 level. The exiting zone of the L5 nerve root may be pinched between the hypertrophied transverse process of the L5 and the thick sacral ala at the extraforaminal zone. The angle of endoscopic visualization and the depth of the working space are less favorable with a routine endoscopic approach at the extraforaminal zone. In addition, in terms of scientific evidence, only technical reports or case series have been published. Therefore, there is a paucity of high-quality randomized trials or systematic reviews on PELF.

14.10 Future Perspective

Considering the current state of the technology, most cases of lumbar foraminal stenosis can be treated using a percutaneous endoscopic technique. However, these techniques remain exclusive properties of endoscopic specialists. Published articles on this technique are also relatively scarce and the scientific relevance is limited. However, as the desire for more minimally invasive techniques increases, the technical evolution should meet the requirements of modern spinal care. The technical development of PELF can be achieved in two ways. First, improvement of endoscopic visualization, especially angled optics, will allow the surgeon to visualize a wider surgical field with a smaller size endoscope. Second and more important, development of surgical instruments will enable the surgeon to decompress the stenotic lesion more safely and completely. For example, a high-speed articulating bone burr will make bone resection faster, safer, and wider. Steerable punches and forceps will help remove fibrotic tissue and osteophytes more delicately. Finally, development of a stronger laser, radiofrequency, or ultrasound will make tissue ablation more effective. Thus, the PELF technique will become more practical and popular in the near future.

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