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Original Article

Percutaneous transforaminal endoscopic decompression on lateral recess stenosis: technical notes and outcomes of two years follow-up. A case series study

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Abstract: Although the lumbar endoscopic technique has been developed for many years, PTED for treatment of lateral recess stenosis is a relatively new subject. The purpose of our study was to present a detailed description and evaluation of PTED technique combined with a modified facetectomy method. From January 2014 to February 2016, 70 patients with lateral recess stenosis in our department were treated with PTED using the THESSYS system. All patients underwent a unilateral single-level operation. Outcomes of symptoms were evaluated by follow-up interviews at 3 months, 6 months, 1 year, and 2 years after surgery. Low back pain and leg pain were measured by Visual Analog Scale (VAS) score (0-10 points). Functional outcomes were measured using Oswestry Disability Index (ODI) and modified MacNab criteria. VAS and ODI values before and after surgery were analyzed with ANOVA. Finally, two years follow-up data were obtained from 65 patients consisting of 30 males and 35 females. ODI values and VAS scores significantly decreased at each time point postoperatively. According to the modified Macnab criteria, excellent and good results were obtained in 89.23% (58/65) of patients at the final follow up. However, one patient was complicated with epidural abscess. In conclusion, PTED is a safe and effective technique for treatment of lumbar lateral recess stenosis. The "eccentric trephine method" can help surgeons to perform PTED with ease and safety. Although PTED is a minimally invasive procedure, infection risk must always be considered in the postoperative evaluation of patients.

Keywords: Spinal stenosis, decompression, surgical, facetectomy, epidural abscess

Introduction

Lumbar spinal stenosis (LSS) is a medical condition in which a narrowing of the spinal canal leads to irritation or compression of the dural sac and/or nerve root. It can be classified into central stenosis, lateral recess stenosis, and foraminal stenosis according to pathological zone [1]. Lateral recess is a fibro-osseous corridor where the nerve root extends from the dural sac and descends obliquely downward to the foramen [2]. Accordingly, lateral recess stenosis (LRS) can be defined as a narrowing of this corridor, which results in corresponding clinical manifestations. LRS is often caused by lumbar degenerative changes such as facet hypertrophy, thickening of ligamentum flavum, lumbar disc herniation or bulging, and osteophytes of the vertebral bodies [3, 4]. Conventional surgical procedures for treatment of LRS include open laminectomy and facetectomy, which permit a more direct and adequate decompression of lateral recess [5]. However, these wide decompressive methods can cause extensive destruction of the posterior column structures, which usually results in iatrogenic instability and failed lumbar surgery syndromes [6]. In addition, concurrent spinal fusion will increase patient burden and postoperative complications. To address these problems,

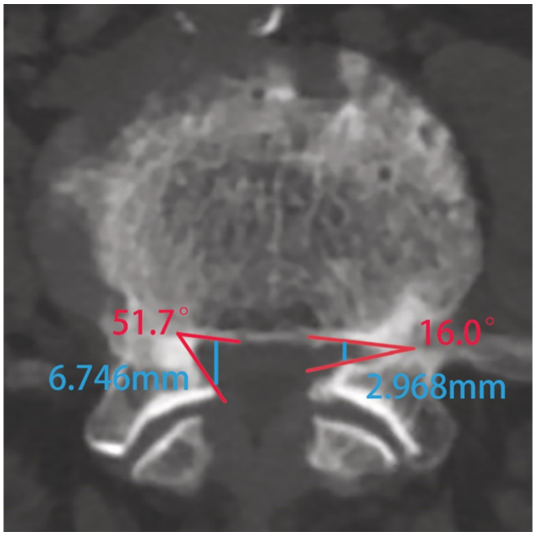

Figure 1. Imaging measurements of lateral recess stenosis based on CT. Lateral recess angle is defined as the angle between the lines(red) parallel to the roof and bottom of lateral recess, lateral recess depth is defined as the distance (blue lines) between the superior articular process and the posterior vertebral body at the superior border of the pedicle.

researchers have developed a great deal of less-invasive decompression techniques, such as laminotomy, trumpet laminectomy, and unilateral microdecompression with crossover [7, 8]. However, the major concern with these techniques is a higher risk of reoperation [9].

Advances in lumbar endoscopic instrumentation and technique, have created a truly minimally invasive approach (usually referred to the interlaminar or transforaminal approach) for treating LSS. Especially since the introduction of THESSYS technique by doctor Hoogland and his colleagues [10], percutaneous transforaminal endoscopic decompression (PTED) has become increasingly popular in surgical intervention of LSS. The THESSYS system allows surgeons to cut off the superior articular process (SAP), enlarge the intervertebral foramen, and perform intracanal operations under direct endoscopic vision. Previous studies [11, 12] have documented the advantages of THESSYS technique, including the use of local anesthesia, no need of neuromuscular retraction, no need of excessive bone removal, and early return to ordinary life. However, the original design of classical THESSYS aimed at herniated discs (HDs), so the resection of SAP was limited to meet the requirement of placing working sheath to target HDs. Considering the significant role of SAP-osteotomy for foraminal enlargement and decompression of lateral recess [13], we designed the "eccentric trephine method" based on THESSYS technique. Our department used this technique to treat LRS from January 2014 to February 2016, the outcomes of two years follow-up were satisfactory, except that a rare complication occurred. Our objective was to discuss technical notes and effectiveness and complications of this modified technique.

Material and methods

General information

This is a retrospective case series study which was approved by the Institutional Review Board of Shanghai East Hospital. All patients who underwent PTED came from the Spinal Surgery Department of Shanghai East Hospital. Patient inclusion criteria: (1) neurogenic claudication accompanied with unilateral leg pain despite conservative treatment for more than 12 weeks; (2) bony lateral recess stenosis was confirmed by radiological measurements using any of the following criteria (**Figure 1**): depth of lateral recess ≤3 mm [2], height of lateral recess ≤2 mm [14], or angle of lateral recess <30° [15]; (3) selective nerve root block was used to identify the responsible segment in clinical uncertain cases. Patients with a finding of segmental instability or spondylolisthesis or severe central canal stenosis were contraindicated for the procedure. Patients with infectious diseases, systemic neurological disorders, or tumor were also excluded. In addition, the PTED technique was not applicable to patients with sequestered lumbar disc or L5/S1 LRS with high iliac crest.

All patients underwent preoperative radiographs, CT, and MRI examination. Oswestry Disability Index (ODI), Visual analog score (VAS) for leg pain and low back pain were recorded before surgery. Informed consent and protocols were provided to all the patients, which described details of the surgery including mechanism of treatment, predictive outcomes, potential risks, and side effects. Anti-coagulant was discontinued at least 5 days prior to surgery. Surgical equipment used in PTED include Percutaneous Endoscope Spine Surgical System (Joimax, Germany) and tip-flexible electrode bipolar radiofrequency system (Elliquence LLC, USA).

Surgical procedure

PTED was performed under local anesthesia in the prone position on a radiolucent table, with the hip and knee flexed slightly. All patients were operated by the same surgeon with more than 5 years of experience in endoscopic spinal surgery. During the operation, patients remained awake and cooperative to communicate with the doctor. The surgical process could be divided into three steps as follows. Puncture locating: The angle of approach and skin entry point was planned according to body size and location of pathological region based on preoperative imaging studies. A more oblique angle would facilitate the lateral decompression of nerve root. Under the guidance of C-arm fluoroscopy, an 18-gauge needle was inserted into the intervertebral foramen by sliding tightly past the SAP. The needle tip should lie at the posterior wall of the inferior vertebra in lateral view and at the medial pedicular line in anterior-posterior view. Then the needle was replaced by the guide wire and an 8 mm skin incision was made; Working sheath placement: A tapered obturator was introduced into the foramen by the guide wire until its tip reached the posterior wall of the vertebra in the lateral view. After the protective cannulas were placed, the trephine was used to undercut SAP and enlarge the intervertebral foramen. Then the working sheath was introduced and further proceeded into the spinal canal, so that the lateral recess could be decompressed. For facilitating the subsequent decompression of lateral recess, we usually removed 1/2-1/4 ventral portion of SAP, as well as part of the inferior pedicle; Endoscopic decompression: It could be summarized into two operating models. Hard tissue management included further grinding SAP, removing calcified ligaments, and osteophytes usually located at the posterior-superior margin of the inferior vertebra. In this process, an electric micro-drill was the primary tool. Soft tissues such as hypertrophied ligamentum flavum and protruded disc fragments were treated mainly with grasping forceps and bipolar radiofrequency coagulator. For keeping the visual field clear, full use of bipolar electrocoagulation was made, along with cold saline irrigation, water pressure hemostasis, hemostatic drugs, and hemostatic materials.

After the above operations were completed, the looseness of traversing nerve root and dural sac was rechecked, then the working sheath was removed and the skin was closed. The patient should be monitored for several hours to determine whether there were any postoperative problems. After surgery, all the patients were given a daily 1500 ug oral dose of vitamin B12 (Mecobalamin) for 8 weeks. If necessary, non-steroidal anti-inflammatory drugs were also prescribed to patients.

Outcome assessment

Dynamic radiographs of all patients were performed at the final follow-up to evaluate lumbar stability. MRI or CT examination was usually performed within one week after operation. Outcomes of symptoms were evaluated at 3 months, 6 months, 1 year, and 2 years after surgery. Low back pain and leg pain were recorded by Visual Analog Scale (VAS) score. Functional outcomes were measured using Oswestry Disability Index (ODI) and modified MacNab criteria.

Statistical analysis

Statistical analyses were performed with SPSS 17.0 software (SPSS Inc., Chicago, IL). ODI values, VAS scores for low back pain and leg pain before and after surgery (3 months, 6 months, 1 year, and two years) were analyzed with ANOVA. $P<0.01$ was considered as significant.

Results

General information

Finally, 65 of 70 cases with LRS who underwent PTED were successfully followed up for a period of 24 months by telephone questionnaire or by outpatient interview, consisting of 30 males and 35 females. The average age was 51.2 years ranging from 36 to 78 years. There were in total 25 cases with combined HDs which were excised during the operation. The modified technique used in the surgical procedure was based on THESSYS technique and no additional learning curve was needed.

Outcomes

There were no cases converted to an open procedure during the surgery. No patients had dys-

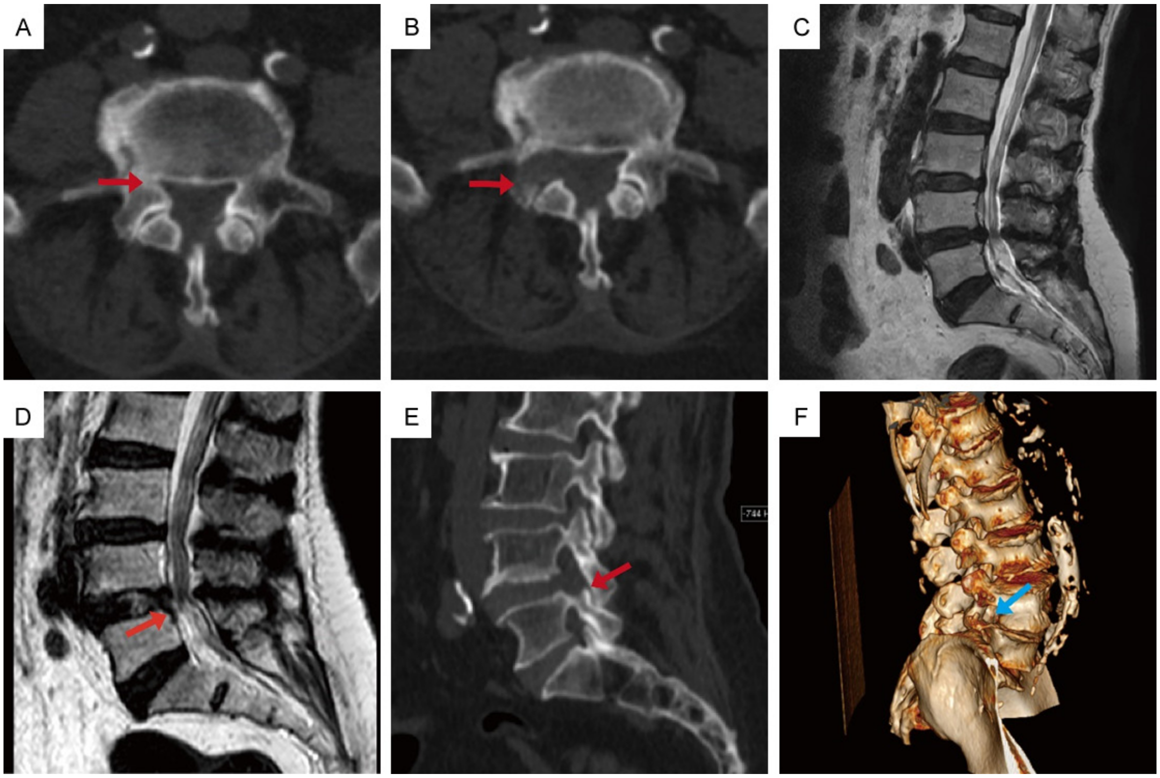

Figure 2. Imaging findings before and after PTED surgery. A. Stenosis of right lateral recess at L4/5 level (red arrow). B. Ventral portion of SAP is removed, and lateral recess is unroofed (red arrow). C. Compression of the dural sac at L4/5 level. D. Osteophytes on the posterior-superior margin of L5 vertebrae are removed (red arrow), and the dural sac acquires adequate decompression. E. Part of the inferior pedicle is removed (red arrow). F. Three-dimensional CT reconstruction image showing morphology of the right intervertebral foramen after PTED (blue arrow).

Table 1. Preoperative and postoperative clinical outcomes of PTED

	Pre-operation	3 months post-op	6 months post-op	1 year post-op	2 years post-op
Vas of leg pain	7.82±0.98*	2.98±1.01*	1.85±0.78*	1.45±0.79*	1.40±0.63*
Vas of low back pain	5.16±1.42*	2.12±0.68*	1.96±0.71*	1.61±0.75*	2.05±0.67*
ODI	63.78±10.50*	25.69±9.24*	17.97±5.35*	15.43±4.73*	10.72±4.08*

*p<0.01, compared with pre-operation.

functional nerve root injury or iatrogenic segmental instability. The operation time ranged from 48-85 minutes per lateral recess (average 58 mins). The average hemorrhagia amount was 22 ml (range, 10-35 ml). The mean hospital stay after the procedure was 1.5 days (range, 1-4 days). Postoperative MRI/CT examination (**Figure 2**) showed adequate decompression of lateral recess and removal of combined HDs in all patients. One patient was complicated with postoperative dysesthesia (POD) and restored after about 2 weeks' conservative treatment. Two cases experienced moderate aching pain and numbness of the lower limb and their symptoms were relieved after the application of glucocorticoid and mannitol for 3 days. Two cases underwent reoperation, one underwent lamina fenestration, and nucleus resection under microscope due to disc protrusion on the contralateral side at the same level, the other one had a debridement surgery because of intraspinal infection. The mean ODI values and VAS score of low back pain and leg pain were significantly improved at all time points after surgery (**Table 1**). According to the modified Macnab criteria, 39 cases were given "excellent", 19 cases were given "good", 3 patients without relief of low back pain and 2 patients with slightly foot drop were classified as "fair", 2 cases with reoperation were given

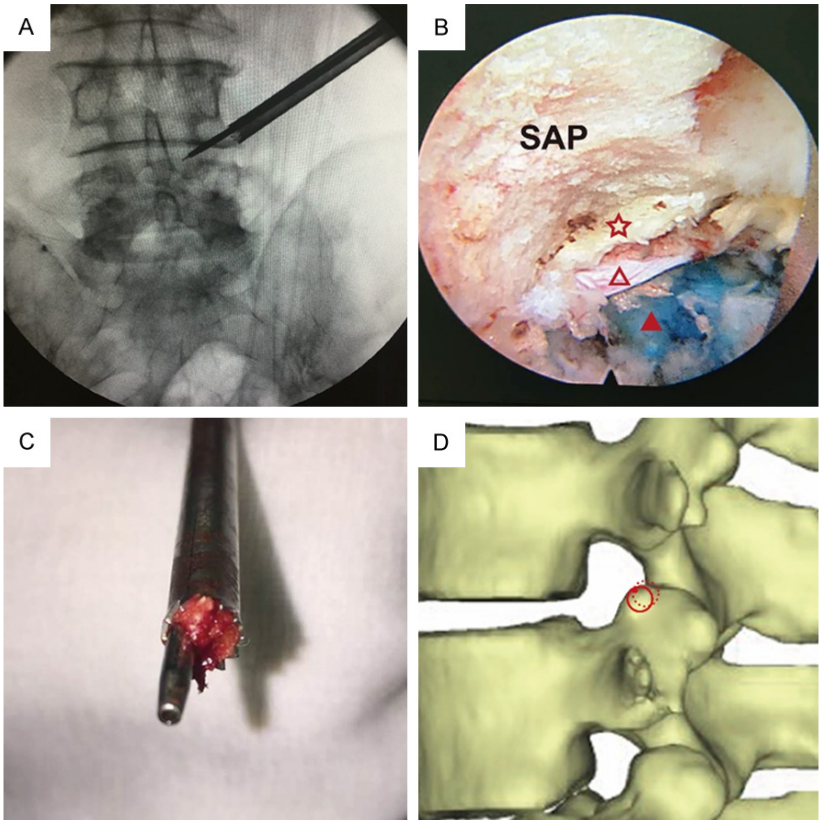

Figure 3. Illustration of the “eccentric trephine method”. A. Intraoperative fluoroscopy image shows that the trephine is placed eccentrically. B. Endoscopic view of PTED shows residual SAP, ligamentum flavum (red asterisk), traversing nerve root (red hollow triangle), and blue stained intervertebral disc (red solid triangle). C. Removal of the bone structure from SAP by “eccentric trephine method”. D. Analog diagram of adjustable osteotomy site by using “eccentric trephine method”.

“poor”. Excellent and good results were obtained in 89.23% (58/65) of patients at the final follow up.

Discussion

Technique notes: a modified facetectomy method

Lateral recess is a triangular space in the lumbar spinal canal, bordered by the medial pedicle wall, the ventral side of SAP, and the posterior surface of the vertebral body. The most common etiology for LRS is the hypertrophy of SAP [2, 13]. Therefore, one of the key points of PTED technique is to treat SAP appropriately, that is, an effective SAP-osteotomy process can not only achieve satisfactory foraminoplasty but also facilitate decompression of nerve root. The original design of classical THESSYS aimed at HDs, so the resection of SAP was limited to meet the requirement of placing working sheath to target HDs. The MaxMore technique (upgraded THESSYS) shifted focus on direct locating on SAP so that it could treat SAP more efficiently, however, direct locating on SAP often faced challenges because the puncture needle was easy to slip due to the smooth surface of SAP. If the entry angle of needle was adjusted to make needle tip fixed on SAP more easily, the followed obturator and working sheath would deviate from the original planned route. In such a situation, the “eccentric trephine method” was designed (**Figure 3**) as follows: the puncture needle was slid tightly past the SAP, then the obturator was introduced and fixed on posterior wall of the inferior vertebra; after soft tissue was expanded sequentially, only a final 8 mm protective cannula (7.5 mm inner diameter) was left; the space between cannula and obturator could make the trephine placed eccentric within cannula on the SAP. By such method, the trephine could be completely attached to SAP and more bone stucture could be removed at each time. If necessary, the above procedure could be repeated. The advantages of the “eccentric trephine method” included improving the efficiency of SAP-facetectomy and reducing the risk of nerve injury. Moreover, the direction of the eccentric trephine could be adjusted to target different part of SAP according to different requirement of facetectomy which would facilitate the subsequent decompression of lateral recess (**Figure 3D**). The detailed comparisons of this modified technique with other endoscopic techniques for the treatment of LRS are list-

Table 2. Comparison of MIS techniques for treatment of lateral recess stenosis

	Advantages	Disadvantages
Traditional THESSYS	Sequential resection of SAP	Multiple times of enlarging the foramen are often needed
Maxmore technique	Direct puncture positioning on the SAP	1. The puncture needle is easy to slip when located on the smooth surface of SAP 2. Multiple times of enlarging the foramen are often needed
Modified THESSYS (eccentric trephine method)	1. More resection of SAP at one time and nearly one-time foraminoplasty 2. Less risk of nerve injury 3. Adjustable osteotomy site	Potential segmental instability
Interlaminar endoscopic technique [16]	Direct dorsal decompression of lateral recess	1. General anesthesia is needed 2. Sacrifice of the inferior articular process that don't participate in the formation of lateral recess 3. Limitation of possibility to deal with foraminal stenosis, if present

SAP, superior articular process.

Table 3. Systematic review of transforaminal endoscopic surgery for treatment of lumbar spinal stenosis

Published year	Follow-up cases	Classification	Evaluation indicators	Outcomes	Complications
2009	64 cases, average 38 months [20]	Foraminal stenosis	ODI, VAS	59% of patients had at least 75% improvement	2 dural leak
2014	33 cases, 2 years [19]	Foraminal stenosis	Modified Macnab criteria, VAS, ODI	Excellent and good rate 81.8%, improvement rate of VAS and ODI 76.4%, 70.7%, respectively	1 reoperation due to failed decompression, 2 postoperative dysesthesia
2014	114 cases, 10 years [11]	Foraminal stenosis	VAS, ODI, Prolo Score	Improvement rate 82.2%, 70%, 77% respectively	19% with symptoms of nerve root irritation
2014	220 cases, average 46 months [12]	Foraminal stenosis and lateral recess stenosis	Macnab criteria, VAS	Excellent and good rate 85%, VAS improvement rate 62.7%	No approach related complications
2016	85 cases , 2 years [21]	Lateral recess stenosis	Modified Macnab criteria	Excellent and good rate 90.6%	3 postoperative dysesthesia

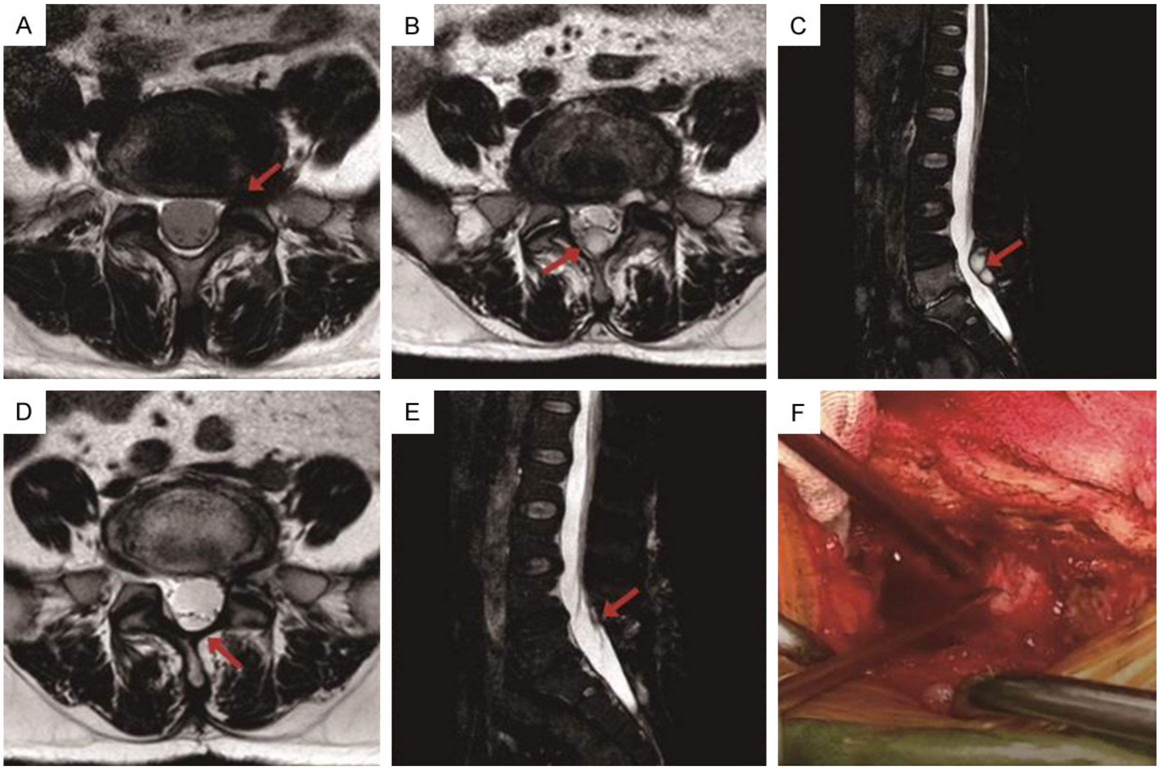

Figure 4. Epidural abscess after PTED surgery. A. Stenosis of left lateral recess combined with HDs at L5/S1 level (red arrow). B, C. Location of epidural abscess after PTED surgery (red arrow). D, E. Left hemilaminectomy (red arrow) and complete removal of epidural abscess after surgery. F. Intraoperative view of inflammatory granulation tissues beneath the lamina.

ed in **Table 2** [16]. Perhaps the major concern with this method was the possibility of spinal instability resulted from "excessive" resection of SAP, however, it has been shown that the unilateral partial facetectomy was safe for segmental spinal stability [17, 18], which was compliant with our results.

In the PTED procedure, we used trephine to remove the ventral part of SAP (**Figure 2B**) and unroofed the foramen [19]. It was important to remove posterolateral vertebral osteophytes (**Figure 2D**) that protruded into the triangular space. Limited resection of the superior border of medial pedicle wall (**Figure 2E**) was necessary as the nerve root is more likely to be squeezed by hypertrophic facet at this area [2]. Furthermore, this would be helpful for widening the visual field. The above steps could achieve an adequate decompression of bony stenosis (from the anterior and posterior and lateral border of lateral recess).

A rare complication

In a systematic review of transforaminal endoscopic surgery for lumbar spinal stenosis, outcomes and complications of PTED are summarized in **Table 3** [11, 12, 19-21]. In the present study, one patient was complicated with deep infection occurred about 6 weeks after surgery. A preliminary diagnosis of intra-canal epidural abscess was made depending on enhanced MRI (**Figure 4B** and **4C**), which was confirmed by the intraoperative pathological results. After decompressive hemilaminectomy and debridement of infected tissues were performed, the patient had substantial symptomatic relief. Postoperative MRI examination showed complete removal of the epidural abscess (**Figure 4D** and **4E**). However, muscular weakness in the lower extremity of the patient still existed at the last follow-up. To the best of our knowledge, epidural abscess related to transforaminal endoscopic surgery hadn't been reported before. Although the exact cause of epidural abscess in this case was not clear, it was a lesson that we didn't found the infection earlier. We believed that the use of non-steroidal anti-inflammatory drugs after surgery might conceal some of the early symptoms of epidural abscess. On the other hand, because PTED is such a minimally invasive procedure, we might have missed some clinical manifestations that indicated the possibility of deep infection.

The major limitation of this study is that the follow-up time was not long enough. Lack of a control group is another shortcoming. It should be noted that there is currently no evidence from randomized controlled trials supporting the effectiveness of transforaminal endoscopic surgery on treating LRS. Randomized controlled trials with long-term follow-up comparing this modified technique with other minimally invasive surgical techniques are needed in our future work.

In conclusion, PTED is a safe and effective technique for treatment of LRS. The “eccentric trephine method” can help surgeons perform PTED with ease and safety. Although PTED is a minimally invasive procedure, infection risk must always be considered in the postoperative evaluation of patients.

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Disclosure of conflict of interest

None.

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