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Suprapedicular Foraminal Endoscopic Approach to Lumbar Lateral Recess Decompression Surgery to Treat Degenerative Lumbar Spinal Stenosis

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Data Collection B
Statistical Analysis C
Data Interpretation D
Manuscript Preparation E
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Background: To discuss the strategy of suprapedicular foraminal endoscopic approach to lumbar lateral recess decompression and evaluate the safety and effectiveness of this strategy.

Material/Methods: Complete clinical information of 52 cases of lumbar lateral recess decompression with therapy of suprapedicular foraminal endoscopic approach were analyzed during the period from February 2010 to April 2014 in the Third Hospital of Hebei. All patients were followed up for 24 months, and VAS, JOA, ODI, and LRD were compared between preoperative and postoperative therapy and changes of FA. Intraoperative and postoperative complications were recorded and the safety of the surgery was evaluated. The surgical "excellent" and "good" rates were evaluated using MacNab score.

Results: VAS scores for lumbago and leg pain at 3, 6, 12, and 24 months after surgery were significantly lower than before surgery ($p < 0.05$). JOA scores at 12 and 24 months after surgery were significantly higher than before surgery ($p < 0.05$). ODI at 12 and 24 months after surgery were significantly lower than before surgery ($p < 0.05$). LRD after surgery was higher ($p < 0.05$), and FA was lower than before surgery.

Conclusions: Use of the suprapedicular foraminal endoscopic approach to lumbar lateral recess decompression is safe and effective, and this minimally invasive treatment can achieve satisfactory results, especially for elderly patients with complicated underlying diseases.

MeSH Keywords: **Lumbar Vertebrae • Spinal Puncture • Spine**

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Background

Degenerative lumbar spinal stenosis is one of the most common diseases in spine surgery. The incidence rate is 1.70% to 8.00% in people over age 50 years, and is higher in females than males [1]. The disease can occur in the central canal, lateral recess, or intervertebral foramen, and the most common site is the narrow entrance zone of the lateral recess [2]. Lateral recess stenosis oppresses the nerve root, which can cause clinical symptoms of leg pain and numbness [3], as well as causing muscle atrophy, lower limb weakness (in severe cases), and need for specific back muscle exercises [4,5]. Decompression of the lateral recess to relieve root symptoms is the key to treatment of degenerative lumbar spinal stenosis.

Currently, lumbar lateral recess decompression surgery includes various forms of laminectomy, which can simultaneously use a lumbar fusion and internal fixation devices. The defects of open surgery are obvious, including trauma, bleeding, and long bedrest after surgery. Complications are more common in elderly patients with underlying diseases [6,7]. In addition, elderly patients often also have osteoporosis[8], so the incidence of internal fixation loosening is higher after surgery [9], which further increases the difficulty of open surgery. In recent years, with the vigorous development of minimally invasive spine surgery, spinal endoscopic technology has made revolutionary progress, and percutaneous endoscopic lumbar discectomy is continually improving and has received widespread attention because of its advantages of being less invasive and more accurate, and leading to more rapid recovery [10,11]. The traditional Yeung Endoscopic Spine System (YESS) and Transforaminal Endoscopic Spine System (TESSYS) approaches for lumbar disc herniation have achieved satisfactory results [12,13], but these approaches often fail to sufficiently reduce pressure in the entrance region of the lateral recess.

In 2009, Kim et al. [14] reported on 456 patients who underwent percutaneous endoscopic suprapedicular approach surgery for sequestered disc herniation, reporting satisfactory clinical efficacy. This approach was further developed on the basis of the TESSYS approach. Because of the obstruction of the pedicle, it is difficult to remove the nucleus pulposus free to caudal using YESS and TESSYS approaches. Kim et al. used the suprapedicular approach to remove the upper edge portion of the soft tissue and bone pedicle with bipolar radiofrequency probes and trephine, which increased the cephalad angle of the working column to remove nucleus pulposus under direct vision. Theoretically, this approach can be used in degenerative lumbar spinal stenosis caused by lateral recess stenosis, especially for elderly patients complicated with underlying disease and who are not appropriate for open surgery. However, the current literature on this approach is limited to the treatment of sequestered lumbar disc herniation.

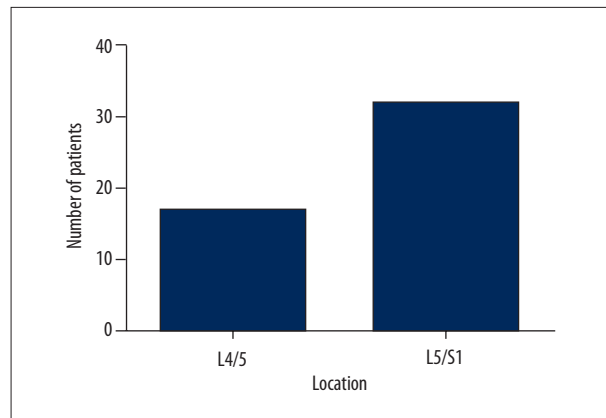


Figure 1. Selective nerve root closed surgery combined with CT and MRI of lumbar disc determined distribution of responsible segments.

The present study collected and analyzed information on 52 cases of degenerative lumbar spinal stenosis and we used suprapedicular foraminal endoscopic approach to relieve lumbar lateral recess decompression. Our objective was to access the value of this approach in the treatment of degenerative lumbar spinal stenosis and to discuss the strategy, safety, and effectiveness of this approach.

Material and Methods

General Information

From February 2010 to April 2014, 52 patients with lumbar spinal stenosis underwent transforaminal endoscopic surgery in our hospital, including 18 males and 30 females, aged 52 to 84 years old, with a duration of 6 to 23 months (average 8.50 months). Seventeen patients were complicated with hypertension, coronary heart disease, diabetes, cerebral infarction, arrhythmias, heart failure, chronic obstructive pulmonary disease, and other medical disorders, with hypertension (12 cases), coronary heart disease (9 cases), and diabetes (9 cases). Selective nerve root block combined with the CT and MRI for lumbar intervertebral discs confirmed that L4–5 were the affected segments in 17/52 case) and L5–S1 were the affected segments in 32/52 cases (Figure 1). All patients signed informed consent. The study was approved by the Ethics Committee of our hospital.

Inclusion criteria were: 1) Unilateral lower extremity radicular pain and intermittent claudication; 2) Patients had more leg than radicular pain; 3) Failure to respond to conservative retreatment and failure to resolve focal deficits; 4) Imaging examinations showed lumbar lateral recess stenosis consistent with symptoms and signs of degenerative lumbar scoliosis, calcified lumbar intervertebral disc, and osteophyte on

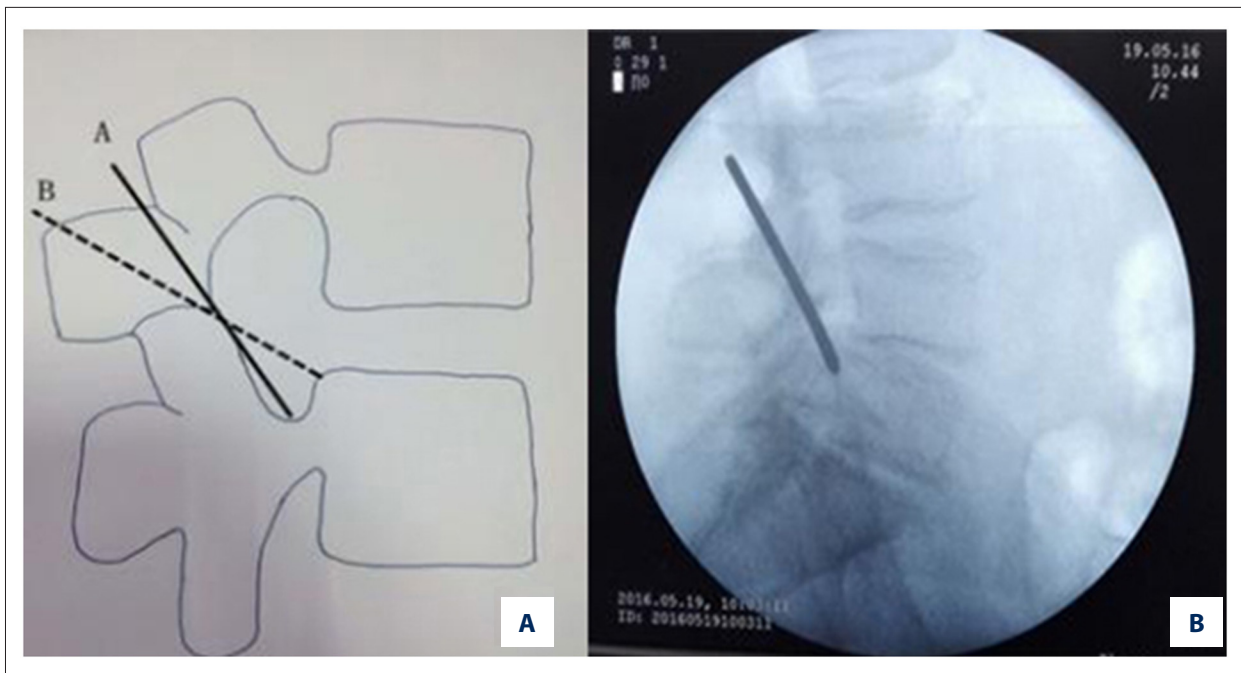


Figure 2. (A) A. Puncture schematic route of narrow lateral recess, from the facet tip to the bottom of the pedicle. B. Puncture schematic route of traditional TESSYS technology. (B) Guild bar puncture from the facet tip to the bottom of the pedicle.

the posterior aspect of vertebral body; 5) Underwent conservative treatment for at least 6 months with poor efficacy or continuously worsening symptoms; and 6) Flexion X-ray examination before surgery showed no lumbar instability and spondylolisthesis occur.

Exclusion criteria were: 1) Patient had no unilateral leg pain, foraminal/extraforaminal stenosis; 2) Extraforaminal stenosis; 3) Pathological conditions (infection/tumor/fractures); 4) Protruding sections scheduled for surgery was not influenced by iliac crest and parapophysis of L5; 5) Patients complicated with serious illness, protruding sections scheduled for surgery; 6) Obese patients with BMI ≥ 28 kg/m²; and 7) Incomplete information or lost to follow-up during follow-up period.

Surgical methods

Position and anesthesia

All surgeries were performed by the same surgeon (W.Z.). The position of patients was lateral position with the affected side on upper and contralateral waist padded. Standard lateral X-ray was screened to locate and puncture during surgery. Surgical approach took posterior-lateral approach. The needle point and distance were depended on the patient’s body type and lumbar disc herniation type. The distance was 12–14 cm. Skin, subcutaneous tissue, and deep fascia were anesthetized by 1% lidocaine, and the facet was anesthetized by 0.5% lidocaine.

Facet forming

The 18G needle was used to puncture and the facet was located using a C-arm fluoroscopic. There was a difference between TESSYS surgery and suprapedicular approach. The suprapedicular approach required that the anteroposterior X-ray showed the needle on the facet tip with lateral X-ray, connected with the facet tip and the bottom of the pedicle as the lateral puncture route (Figure 2). The 22G needle was removed from the 18G puncture needle, then we inserted a guide wire and removed the puncture needle when the position was correct as determined by fluoroscope. An 8-mm cut was made in the center of the puncture point on the skin. the guide bar and dilating catheter were inserted along the guide wire to enlarge surgical access. Then, the dilatation catheter was removed and a trepan was inserted along the guide bar. Hypertrophy of yellow ligament and facet was removed to expand the intervertebral foramen (Figure 3). The leading edge of the trepan should not exceed the inner edge of the connection of the pedicle to avoid damaging dura and nerve. The trepan was removed, and a working column was put into the spinal canal along the guild bar. When the position was correct as determined by fluoroscopy, we placed the endoscope.

Endoscopic decompression of nerve root

The difference between simple disc herniation and degenerative lumbar spinal stenosis was that nerve root compression of degenerative lumbar spinal stenosis could come from disc,



Figure 3. Removed hypertrophy of yellow ligament and facet to expand the intervertebral foramen using trepan.

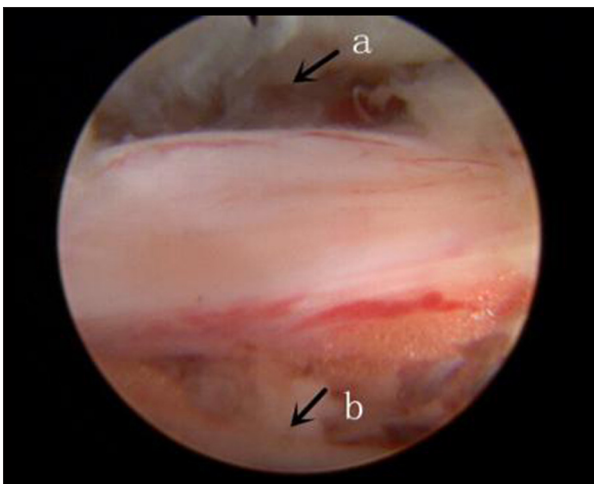


Figure 4. a. Decompression structure of ventral nerve roots.
b. Decompression structure of dorsal nerve root.

annulus, or posterior longitudinal ligament of the ventral nerve root, or could come from the yellow ligament of the dorsal nerve root, osteophytes with facet hyperplasia, or lateral recess from pedicle plane. We should start individualized decompression release for the dorsal nerve root and the ventral and lateral recess (Figure 4). Using the method that Kim et al. [13] reported, the working column was moved from foramen plane to lower vertebral pedicle plane (Figure 5). We could observe that the pedicle was surrounded by soft tissues, fat, and blood vessels. The upper-edge portion of the soft tissue and bone pedicle were removed by use of bipolar radiofrequency electrode and trephine. Hyperplasia fractures and soft tissue around the nerve root were sufficiently depressurized. Dural sac beat independently when the nerve root was completely slackened. The blood supply of the nerve root surface was significantly improved, the vessel was filled with blood, and the nerve root was reset. Straight leg raising testing done in surgery showed the nerve root slipped freely after being pulled.

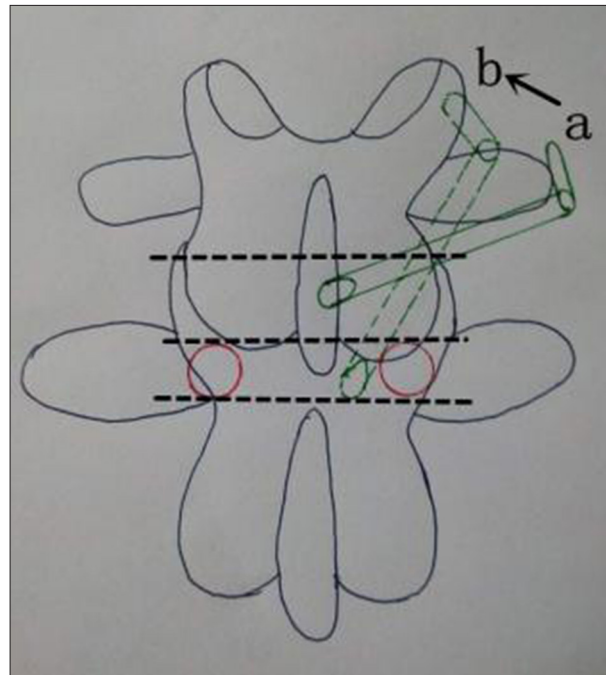


Figure 5. Schematic diagram of working channel adjustment.
a, b. Working channel adjustment from disc level to the upper edge of lower vertebral pedicle.

Observed indicators

People who was not involved in this study evaluated lumbago and leg pain at 1 day before surgery, and at 3, 12, and 24 months after surgery using the visual analogue scale (VAS). Neurological function at 1 day before surgery and at 12 months after surgery was evaluated using the Japanese Orthopaedic Association (JOA) assessment. Ability to perform activities of daily living was evaluated using the Oswestry disability index (ODI). MacNab score with last follow-up was noted to evaluate early clinical efficacy: “excellent” indicates no pain in waist and leg, and no activity limitation; “good” indicates occasional pain in waist and leg that did not affect work and life; “medium” indicates function was improved but the patient had intermittent pain and ability to perform activities of daily living did not improve; and “bad” indicates no improvement in pain and function. Complications were noted in surgery and after surgery.

Assessment of imaging

Conventional spiral CT was used for operation segments. Scanning plane was paralleled to the intervertebral space. Scanning Conditions were: Sensation 64-slice CT machine, 120 kV, 200 mA, thickness of 3 mm. If the angle of the CT cross-section and endplate was $>5^\circ$, then we excluded the case. Three surgeons (YP, JL, and YP) measured the diameter of the lateral recess and facet area using the PACS image transmission

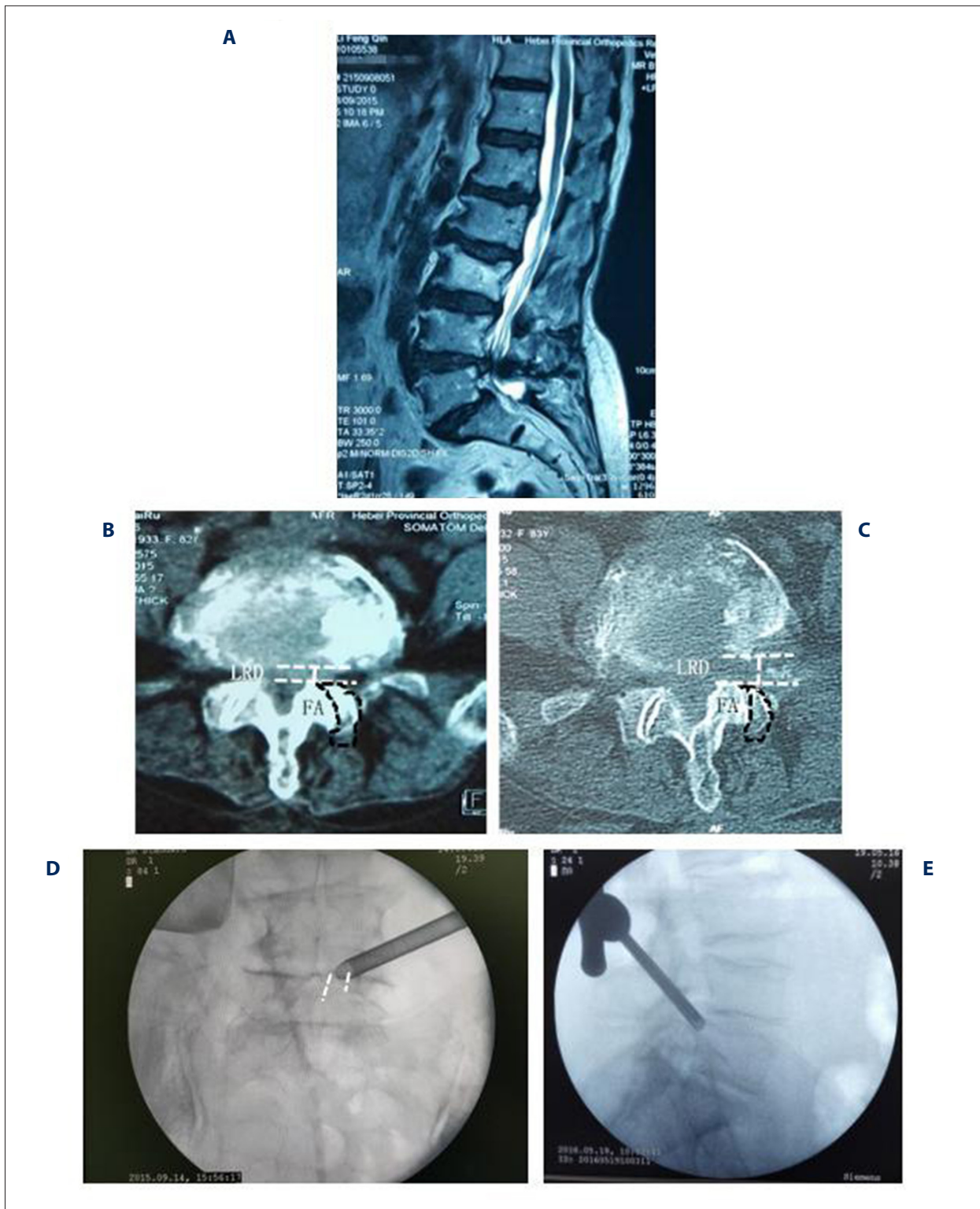


Figure 6. Female, 71 years old, left leg pain for 3 years with intermittent claudication. **(A)** Preoperative MRI of lumbar showed multi-segment degeneration. **(B)** Preoperative CT of lumbar showed the left nerve root canal stenosis of L4–5 segments. Before surgery LRD=0.39 cm, FA=1.25 cm². After surgery, CT showed decompression of the left nerve root canal of L4–5 segments. After surgery, LRD=0.80 cm, FA=0.95cm². LRD – lateral recess diameter; FA – facet area. **(C)** Placed the working channel. Dotted line area is lateral recess area that can be depressurized using the suprapedicular approach.

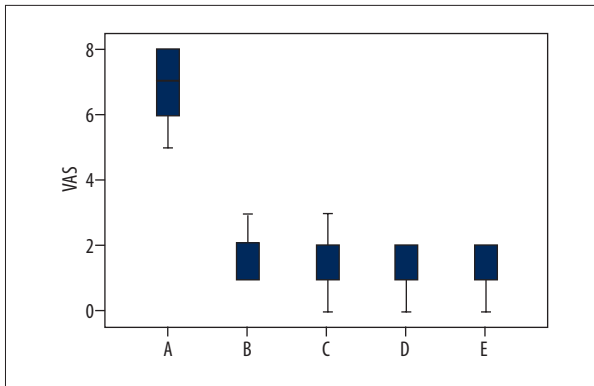


Figure 7. VAS score of Preoperative and postoperative follow-up of back pain. A. 1 day before surgery. B. 3 months after surgery. C. 6 months after surgery. D. 12 months after surgery. E. 24 months after surgery.

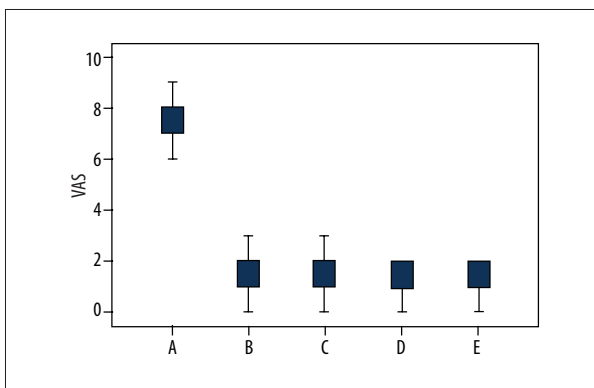


Figure 8. VAS score of preoperative and postoperative follow-up of leg pain. A. 1 day before surgery. B. 3 months after surgery. C. 6 months after surgery. D. 12 months after surgery. E. 24 months after surgery.

system according to the method of Laurysen [15]. Each parameter was measured 3 times and averaged.

Statistical method

Data were analyzed using SPASS (version 9.0). VAS scores did not have normal distribution before surgery, as shown by M (P25, P75). The Wilcoxon test was used to compare VAS scores before and after surgery. The *t* test was used to analyze JOA scores and ODI index before and after surgery, with a test level of $\alpha=0.05$.

Results

We achieved successful surgery in all 52 cases (a typical case is shown in Figure 6), and arranged follow-up for them. One case had dural injury in surgery and the defect was directly closed under microscope visualization; DuraGen and a fibrin sealant were used. The patient was confined to bed for 2 days.

Table 1. JOA score and ODI index of preoperative and postoperative follow-up.

	JOA score	ODI index (%)
Before surgery	10.70±0.67	62.50±6.60
12 month after surgery	20.30±0.69	16.60±3.20
24 month after surgery	22.60±0.50	13.50±1.20
P value	<i>P</i> **<0.05	<i>P</i> **<0.05

JOA – Japanese Orthopaedic Association; ODI – Oswestry disability index. * 12 month after surgery compared with before surgery; * 24 month after surgery compared with before surgery.

Preoperative and postoperative follow-up of VAS scores of lumbago and lower limb radiation pain

Median lumbago VAS scores before surgery and at 3, 6, 12, and 24 months after surgery were 7 (6, 8), 2 (1, 2), 1 (1, 2), 1 (1, 2), and 1 (1, 2), respectively. Significant differences were found at 3 months after surgery ($p=0.006$), 6 months after surgery ($p=0.001$), 12 months after surgery ($p=0.001$), and 24 months after surgery ($p=0.001$) compared with before surgery (Figure 7). Median sciatica VAS scores at 1 day before and at 3, 6, 12, and 24 months after surgery were 8 (7, 8), 2 (1, 2), 1 (1, 2), 1 (1, 2), and 1 (1, 2), respectively. Significant differences were found at 3 months after surgery ($p=0.002$), 6 months after surgery ($p=0.02$), 12 months after surgery ($p=0.02$), and 24 months after surgery ($p=0.02$) compared with before surgery (Figure 8).

Preoperative and postoperative follow-up of JOA scores

JOA scores before surgery and at 12 and 24 months after surgery were 10.70±0.67, 20.30±0.69, and 22.60±0.50, respectively. JOA scores at 12 and 24 months after surgery were higher than those before surgery. Significant differences were found at 12 months after surgery ($p=0.016$) and 24 months after surgery ($p=0.009$) compared with before surgery (Table 1).

Preoperative and postoperative follow-up of ODI index

ODI index before surgery and at 12 and 24 months after surgery were (62.50±6.60)%, (16.60±3.20)%, and (13.50±1.20)%, respectively. Significant differences were found at 12 months after surgery ($p=0.001$) and 24 months after surgery ($p=0.02$) compared with before surgery (Table 1).

Assessment of imaging

We found sufficient decompression in the dorsal and ventral nerve root when we reviewed lumbar spine CTs of 52 patients after surgery (Figure 6). Lateral recess diameters before and

Table 2. Lateral recess diameter (LRD) and facet area (FA) changes of preoperative and postoperative follow-up.

	LRD (cm)	FA (cm ²)
Before surgery	0.40±0.12	1.48±0.20
Immediately after surgery	0.82±0.08	0.92±0.11
P value	P=0.012	P=0.032

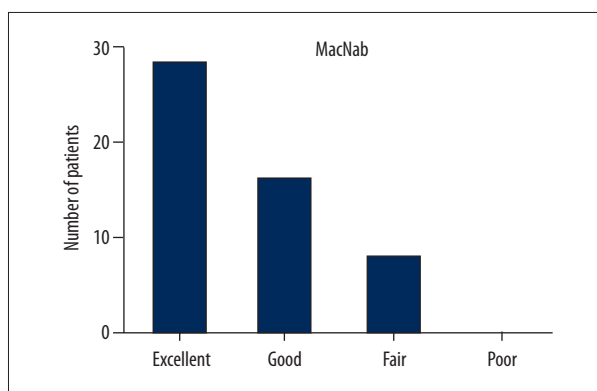


Figure 9. Excellent rate of surgery.

after surgery were (0.40±0.12) cm and (0.82±0.08) cm, respectively. There were significant differences between before and after surgery (p=0.012). Facet areas before and after surgery were (1.48±0.20) cm² and (0.92±0.11) cm², respectively. There were significant differences between before and after surgery (p=0.032) (Table 2).

Excellent rate of surgery

According to the criteria of MacNab score, 28 cases (53.85%) were excellent, 16 cases (30.77%) were good, 8 cases (15.38%) were medium, and 0 cases (0.00%) were bad at last follow-up. Total excellent and good rates combined were 84.62% (Figure 9).

Discussion

In the present study, VAS scores of lumbago and leg pain after surgery were significantly lower than before surgery, while JOA scores were significantly higher. There were significant differences between before and after surgery, which showed that the suprapedicular approach in foramen endoscopic lateral recess decompression surgery could relieve symptoms of leg pain and promote recovery of neurological function. The key to lateral recess decompression was enlarging and forming the foramen, and setting work channels correctly. The foramen was enlarged sufficiently to depressurize dorsal nerve root structure

(hypertrophic yellow ligament and hyperplasia facet). This removed oppression of the dorsal nerve root, assured that the set of work channels was correct, and provided sufficient operating space for work channels shifting to head, tail, ventral, dorsal, and midline to remove materials causing pressure around the nerve root. To ensure a sufficiently enlarge foramen, surgeons carefully used a trephine to further skive the dorsal nerve root structure, then laced the guide bar and work channels. Placing the guide bar and work channels directly in the narrow intervertebral foramen can oppress the nerve and lead to leg pain, and can even damage the nerve. Therefore, if the foramen is enlarge sufficiently, the guide bar and work channels should be put outside the intervertebral foramen, directly facing the facet joints surface [16] (“float guide rod technology”). According to the suprapedicular approach designed by Kim [14], tissue and bone of the upper-edge portion of the pedicle are removed using equipment such as the endoscopic trephine. A microscopic bone knife was used to enlarge the head angle of the working column and to depressurize the lateral recess inlet area under direct vision.

In 52 cases, 28 (53.85%) were excellent, 16 (30.77%) were good, 8 (15.38%) were medium, and 0 (0.00%) were bad at last follow-up. The combined excellent and good rate was 84.62%. Yeung and Tsou [17] reported a 89.30% combined excellent and good rate of lateral foramen endoscopic lumbar discectomy surgery in 307 cases. Schuber [13] applied TESSYS technology to treat 611 cases of lumbar disc herniation, of which 588 were followed up for more than 2 years (follow-up rate 91.20%). The combined excellent and good rate was 95.30%, which showed that the clinical effect was better when applying transforaminal endoscopic surgery in lateral recess stenosis. There was 1 incident of dural rupture in surgery, which might be connected with the pressure stick dural. The spinal structure of degenerative lateral recess stenosis was not clear, as in disc herniation in young patients. The nerve root often stuck to surrounding structures, sometimes even surrounded by yellow ligament and fibrous scar [18], which should be carefully distinguished under microscope and care must be taken to avoided accidental injury caused by blindly clamping. Because of the limited endoscopic operative field, broken dura could not be sutured. Therefore, we sutured incisions tightly in surgery, added appropriate electrolytes after surgery, and used antibiotics to prevent infection. We do not recommend using contrast agent or methylene blue injection dye in the nucleus pulposus. On the one hand, nerve pressure of degenerative lateral recess stenosis was not only herniated disc tissue, but also hardening hyperplasia osteophytes and scar tissue. Methylene blue injection could not dye to these tissues, so it is not meaningful to use contrast agent and nucleus stain. On the other hand, when merging dural injury, iohexol and methylene blue infection might enter the epidural. Hence, there was potential risk of intradural infection. There were no symptoms of intracranial hypotension headache after

the above treatment, all incisions healed, and there were no serious complications. ODI index after surgery was lower than before surgery, and there was a significant difference in ODI index before and after surgery. This was an alternative minimally invasive surgical treatment for elderly patient with multiple underlying diseases.

There is more blood loss when treating lateral recess stenosis using transforaminal endoscopic surgery. This might be connected with high frangibility of vasculature, osteoporosis, long-term use of anticoagulant drugs, and hypertension disease. Intraoperative uncontrollable bleeding could accidentally injure the nerve root in surgery, causing physical and psychological harm and economic loss to patients [19]. Control measures to stop bleeding are necessary to carry out transforaminal endoscopic surgery. Endoscopic hemostasis measures were: 1) Bipolar radiofrequency heat coagulation; venous plexus bleeding of spinal canal and foramen could use bipolar radiofrequency to cauterize bleeding and can protect the nerve root; 2) Blocked outlet of foraminal mirror and increased spinal pressure; 3) Elevated the position of wash water bag to increase spinal pressure; 4) Stuffed gelatin sponge or hemostatic gauze. When previous methods were not effective, we put gelatin sponge or hemostatic gauze on the bleeding area, and applied gentle pressure for 3–5 minutes. Because of minimally invasive transforaminal arthroscopy, there was no need

to use antibiotics. Hence, we needed to remove gelatin sponge or hemostatic gauze after complete hemostasis to avoid the risk of infection. For patients with serious bleeding, we placed the drainage tube conventionally and prolonged the postoperative ambulation time to avoid active bleeding and the formation of hematoma and nerve oppression.

This was a retrospective study; therefore, there may have been bias in selecting cases and evaluating effectiveness. Because of the short follow-up period, further studies with longer follow-up are needed to monitor for possible increased lumbar instability.

Conclusions

Use of the suprapedicular foraminal endoscopic approach to lumbar lateral recess decompression is safe and effective. This minimally invasive treatment can achieve satisfactory results, especially for elderly patients with complicated underlying diseases. Long-term effects need to be assessed by double-blind clinical studies.

Conflict of interest

All authors declare that there is no conflict of interest.

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