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Endoscopic Foraminoplasty and Neuro-Ventral Decompression for the Treatment of Lumbar Disc Herniation Combining with Lateral Recess Stenosis

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Abstract

Objective: To evaluate the feasibility and clinical effect of endoscopic foraminoplasty and neuro-ventral decompression for the treatment of lumbar disc herniation combining with lateral recess stenosis.

Method: From June 2015 to August 2016, thirty patients with typical radicular symptoms and neurogenic intermittent claudication were treated. There were 17 cases with lumbar disc herniation with lateral recess stenosis at L4/L5 and 13 cases at L5/S1. The mean course of disease was 10.6 ± 6.1 months. The preoperative and postoperative visual analogue scales (VAS) were used to assess the intensity of pain. The outcomes were evaluated by Oswestry disability index (ODI) and Japanese Orthopaedic Association Scores (JOA). Clinical signs were observed and compared before and after the operation. These patients had undergone the normalized endoscopic foraminoplasty for spinal canal decompression and discectomy to decompress the traversing and exiting nerve.

Result: Based on MacNab's criteria assessment, 17 patients (56.7%) showed excellent, 9 (30.0%) good, 4 (10%) fair, and 0 (0%) poor results. Our results demonstrated that normalized endoscopic foraminoplasty for the treatment of lumbar disc herniation combined with lateral recess stenosis can significantly improve the VAS, ODI and JOA score at each time point postoperatively compared with preoperative parameters ($P<0.05$). There were no significant differences in the VAS, ODI and JOA scores at each postoperative time point compared with immediate postoperative assessment.

Conclusion: The endoscopic foraminoplasty and neuro-ventral decompression is safe, and efficacious for the treatment of lumbar disc herniation with concomitant lateral recess stenosis. Careful selection of surgical indication, and normalized, skilled surgical techniques are the key to the successful clinical outcome

Keywords: Endoscopy; Foraminoplasty; Neuro-ventral decompression; Lateral recess stenosis; Disc herniation

Introduction

Lumbar disc herniation and lateral recess stenosis is one of the common sequel of spinal degenerative disease. At present, the treatment for lumbar spinal stenosis (LSS) includes (1) Traditional partial-laminectomy, of which the disadvantage is posterior spinal bone structure and muscle damage, increasing the incidence of postoperative iatrogenic spinal instability [1]; (2) Expansive open-door laminoplasty, of which the surgical procedure is complicated and prone to result in inadequate decompression [2]; (3) Microendoscopic decompression, of which the surgical procedure also has limitations and can be relatively complex, prone to induce dural sac tear, nerve root injury and other complications [3]. In recent years, with the in-depth study of spinal endoscopic surgery, the treatment for lumbar spinal stenosis with endoscopic foraminoplasty has gradually gained attention. Making up for the lack of previous minimally invasive surgery, so that truly minimally invasive ideas and techniques can be reflected [4]. The percutaneous transforaminal endoscopic decompression (PTED) only removes the degenerative and protrusive part of the nucleus pulposus and directly resects the lesion site of the responsible segment. The operation has the features of small incision, local anesthesia, safety and the similar treatment result compared with open surgery [5]. Compared with the traditional posterior lumbar open surgery, the percutanous transforaminal surgery is with less trauma, less impact to the normal anatomical structure, faster and rapid recovery. Throughout ages, posterior laminoplasty has been the major treatment for spinal stenosis. The wide application of percutaneous transforaminal endoscopy makes it possible for surgeons to reach the ventral part of nerve root and dural sac. With the maturity of PTED, many surgeons have explored the application of transforaminal endoscopic technique in lumbar spinal stenosis. Our clinical center has adopted the treatment of normalized endoscopic foraminoplasty and neuro-ventral decompression (FNVD) for thirty cases of the lumbar disc herniation combining with lateral recess stenosis. We removed the prolapsed tissue under the direct vision for cauda equina and nerve root decompression and reduced the destabilizing impact on the spinal structure as much as possible, which achieved better clinical efficacy.

Materials and Methods

General materials

Collecting thirty cases of patient information from spinal endoscopy in our hospital from June 2015 to August 2016. Patients with lumbar disc herniation and degenerative lateral recess stenosis underwent transforaminal endoscopic discectomy and lateral recess enlargement. Including 18 males and 12 females, 62-81 years of age; 13 cases of L5/S1 segment and 17 cases of L4/L5 segment. Imaging data showed that 11 patients had inclusive disc herniation and 19 patients had annulus fibrosus tear with nucleus prolapse. All patients had lateral recess stenosis in the index segment. All the patients had neurological correlation symptoms consistent with lesion in the image. The straight leg raising test in the affected side of the preoperative was less than 60 degrees. All of the cases were treated with endoscopic foraminoplasty and neuro-ventral decompression. The ventral part of the superior articular process was removed from the lateral foramina, and lateral recess decompression was performed. The prominent or prolapsed nucleus was decompressed. Visual analogue scale (VAS), Oswestry disability index (ODI) and Japanese Orthopaedic Association Scores (JOA) scores were recorded preoperatively and postoperatively. Clinical result was evaluated by MacNab standard method [6].

Surgical methods

We applied minimally invasive endoscopic surgery instruments and chose the postero-lateral approach in the prone position.

Determination of the puncture point: placing two Kirschner wires with AP view C-arm fluoroscopy position before the operation. Taking L4/L5 as an example: one was placed at the body surface in parallel with the upper edge of the lumbar 5 vertebral body, and the other Kirschner wire was adjusted to be placed in line with the midline of the upper edge of L5 vertebra and the tip of L5 upper articular at the lesion side. The angle between the two lines should be the puncture head inclination. The joint point of the latter Kirschner wire and the ipsilateral axillary line should be the puncture point. As for L5-S1 segment, the puncture angle should be adjusted based on the actual level of iliac crest. The angle of tail should be about 40-60 degrees to the head side and the angle of abduction should be about 30-50 degrees. The puncture angles for other index segments should be decreased from bottom to top (Figure 1).

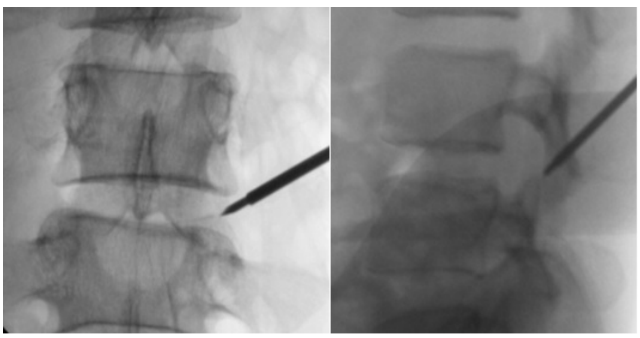

Figure 1: Type I TOM located and hammered the tip at the surface of the superior articular process.

During the operation, the surgeon utilized 30 ml 0.5% lidocaine to perform the local anesthesia layer-by-layer in the direction of the puncture channel. After the C-arm fluoroscopy was positioned, the 18G needle was punctured from the puncture point and slowly inserted in the preset direction (Figure 2).

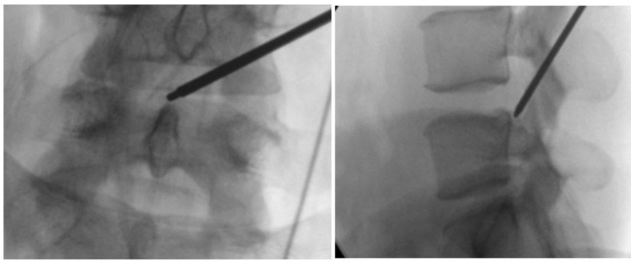

Figure 2: Type III TOM located and hammered the tip at the midline of the spinal canal and ventral of the dural sac.

The positioning needle was located just in line with the spinous process in the middle of the vertebral body at the anteroposterior fluoroscopy, and the direction of head tilt should stay fixed. The ventral angle was adjusted so that the tip was located at the post-upper edge of the inferior vertebra body at the lateral fluoroscopy.

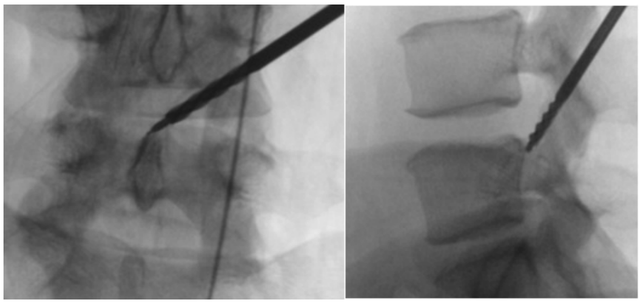

Figure 3: The bone drill established the tract and did foraminoplasty under the guidance of the wire.

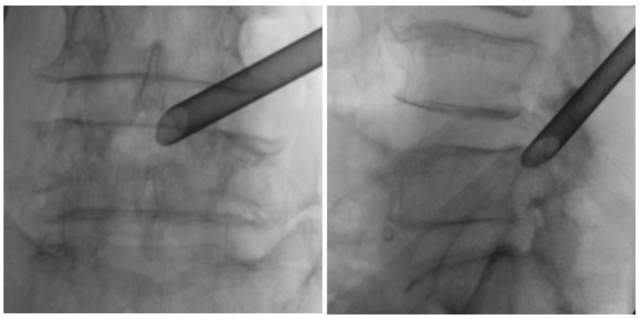

Figure 4: Tip of the tract was located in line with the spinous process at the anteroposterior fluoroscopy, and at the post-upper edge of the inferior vertebral body at the lateral fluoroscopy.

After making 7 mm skin incision at the puncture point and replacing the puncture needle with a guide wire, step by step, we expanded the soft tissue along with the guide wire (Figure 3).

We then placed the TOMshidi locator and hammered the nail at the surface of the superior articular process. Before entering the spinal canal, we replaced it with the blunt TOMshidi needle, and hammered the TOM needle deep into the canal in front of the dural sac. And then, drilled step by step along the guide wire using the diameter of 4-8 mm bone drills to remove part of the facet joint, gradually expanded the foramen. Over the dilator, we inserted a working cannula with an outer diameter of 7.5 mm into the foramen and placed the intervertebral foramen along the working cannula (Figure 4).

Figure 5: Using nucleus pulposus forceps to remove the herniated disc and using dynamic drill to remove the osteophytes at the posterior vertebral body.

Figure 6: Lateral recess was enlarged via foraminoplasty with dynamic drill.

No forcing the bone drill and cannula deeply into the spinal canal if lower extremity radiating pain was caused when setting up the work channel. The working cannula can be placed directly just in the proximity of the spinal canal and do the foraminoplasty in the endoscopic view. After using the dynamic power drill to remove the hyperplasia part of the superior joint tip, layer by layer, propelled the tube and lens to observe and identify the tissue structure and lesion under endoscopic visualization. Vertebral hyperplasia, posterior hardening or ossification edge of the vertebral body and hyperplastic connective tissue adhesion to the posterior longitudinal ligament were sequentially removed or trimmed at the ventral part of dural sac and traversing nerve root. If necessary, decompression was supplemented by microscopic bendable power drill to perform lateral recess opening and forming especially grinding the tiny sclerotic tissue under the ventral nerve root for the complete decompression (Figure 5).

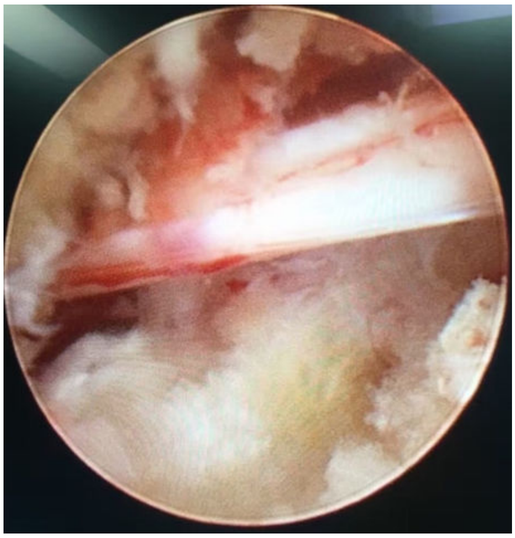

Figure 7: ROM of the nerve root increased obviously after decompression.

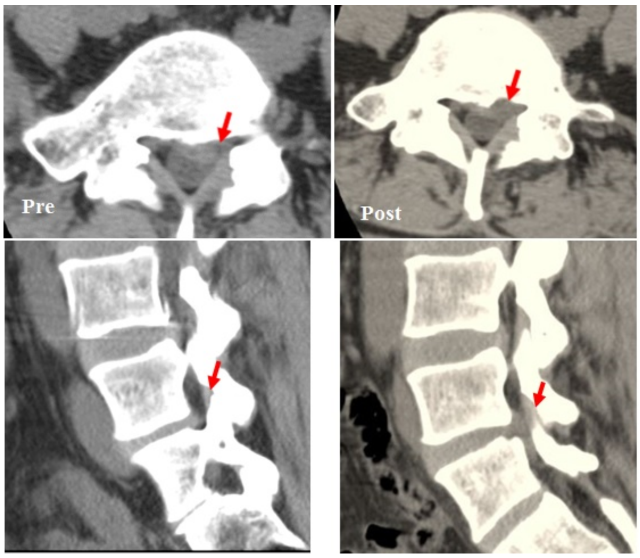

Figure 8: Preoperative and postoperative CT imaging showed the lateral recess enlarged and the tip of the facet joint was removed.

By shrinking and modeling the broken fibrous ring using bipolar radiofrequency ablation, full decompression space, was confirmed by visualizing the traversing nerve root and dural sac from end to end. The significant improvement of blood supply and the full autonomy of the dural sac can be seen when fully decompressed; intraoperative straight leg-raising test showed that the nerve root was pulsating freely (Figures 6 and 7).

At the end of the operation, the patient's symptoms of pain, soreness and numbness, etc, were reduced or even disappeared. We then rotated the working sleeve for final examination. Early functional exercises and rehabilitation should be guided after the operation as soon as possible. The postoperative CT images showed that the lateral recess was enlarged during foraminoplasty (Figure 8).

Clinical efficacy evaluation

The VAS, ODI and JOA scores, which were recorded before and immediately after the operation, through three and six months follow-up interviews, were used to analysis the efficacy of improving the pain in back and legs. MacNab Efficacy Criteria Evaluation of Postoperative Efficacy (Excellent: Painless, unlimited activity; Good: Pain in back or legs occasionally and the pain may interfere with patient's normal life; Fair: Functional improvement, but intermittent pain may still occur and usually the patient needs to change job and lifestyle; Poor: No improvement in symptoms, need further surgery).

Statistical methodology

The SPSS 13.0 statistical software was used for statistical analysis to calculate the mean and the standard deviations of the sample scores. Nerve function scores were compared using the paired-samples T test. $P<0.05$ was considered statistically significant.

Results

According to MacNab's criteria, the six-month postoperative outcome follow-up showed that the rates of excellent, good, fair and poor were 56.7% (17/30 cases), 30% (9/30 cases), 13.3% (4/30 cases) and 0.0% (0/30 cases), respectively. Compared with the preoperative scores, the VAS, ODI and JOA scores improved significantly at each time point after treatment, with significant difference ($P<0.05$). Compared with the postoperative discharged scores, the VAS and ODI, JOA score difference within the same group between the 3 and 6 months postoperative were not statistically significant ($P>0.05$). The operation time ranged from 60 to 95 minutes and the average number of fluoroscopy was 20 times. All patients had no severe complications such as dural tear, nerve root injury, intervertebral space infection, spinal cord hypertension (Table 1).

Time points	n	VAS	ODI	JOA
Preoperative	30	7.15 ± 1.23	30.36 ± 9.16	16.8 ± 1.9
Postoperative discharged	30	2.72 ± 1.62*	15.63 ± 2.67*	25.6 ± 2.6*
3-6 months postoperative	30	2.43 ± 0.76*	15.81 ± 1.18*	24.8 ± 2.3*
Final follow-up	30	2.52 ± 0.76*	15.53 ± 0.96*	25.9 ± 1.7*
(*P<0.05, compared with pre-operative scores)				

Table 1: The comparison of clinical evaluation indexes before and after FNVD in 30 patients with LSS.

Discussion

With the growth of age, on the basis of disc degeneration, the disc height tends to become narrow, and intervertebral ligaments tends to relax, the local stress of facet joints increases, and the upper and lower joints overlap combining with repeated friction. The long time repeated lesion and repairing may cause hypertrophy of facet joints, and hyperplasia and calcification of capsule and ligamentum flavum [7]. These pathological changes result in bulged or herniated disc, calcified annulus fibrosus and hyperosteogenic vertebral margin [8]. Among patients with lumbar spinal stenosis, those with lateral recess stenosis account for a large proportion [9]. Once the disc is prominent and the nerve root was not given way to space, it is often required for open surgery to resolve the severe symptoms. In recent years, spinal endoscopy is used more and more often in the treatment of this disease, which has been clinically proven to be a simple and effective minimally invasive surgical approach [10-12]. Kambin, Hijikata, Leu and Yeung are leaders in minimally invasive endoscopic spine surgery [13,14]. However, it was not widely accepted until the late 1990s when Yeung brought about YESS technique breaking the high learning curve [13,15]. Later, Yeung described SED and foraminoplasty for extruded herniated nucleus pulposus and achieved clinical success in relieving LBP [13]. The YESS technology, entering via the Kambin safety triangle to the disc, is characterized by nerve decompression from the inside disc to the outside [15]. Based on YESS technique, Hoogland proposed transforaminal endoscopic spine system (TESSYS), which promoted the next series of innovations for foraminoplasty to directly grind part of the superior facet to decompress the nerve root from the outside disc to the inside [16,17]. Both of the YESS and TESSYS techniques have the same ultimate target area, i.e., the prominent and prolapse tissue of the intervertebral disc. With the constant modification of the foraminoplasty techniques, the lumbar spinal canal stenosis can be treated effectively as well.

FNVD is a modified TESSYS technique that focuses on the ventral decompression of the nerve root and dural sac. This technology does not have any advantages over YESS and TESSYS among patients with the simple disc herniation. It mainly focuses on the patients with spinal stenosis, especially the lateral recess stenosis. We know that lumbar spinal stenosis, in addition to yellow ligament hypertrophy, are mostly caused by the ventral factors, such as disc herniation, facet joint hyperplasia, posterior vertebral osteophytes and so on. So, the ventral decompression of the nerve root and dural sac can effectively expand the ventral space of spinal canal and improve the patient's symptoms. In this study, the main modification for TESSYS technique is to normalize the puncture site and angle. Locating the needle closely to the ventral side of upper facet tip and directly arriving at the central upper edge of the vertebral body, and then using different types of manual drills to grind hyperplastic calcifications and osteophytes, in order to achieve foraminoplasty and lateral recess decompression.

Specifically, by lifting the positioning needle point on the facet joint, we regard the lower lumbar vertebral articular process tip as the conventional needle point. During the design of the channel, we increase the angle of the head tilt in the coronal plane, as of 45 degrees or more, which decreases the distance between the puncture point and spinous process, and this makes it possible to effectively retain the lateral part of the superior articular process during the foraminoplasty. As the result, the ventral part of the articular process causing the lateral recess stenosis can be drilled and the stenosis can also be effectively expanded. And due to the increased punctured head tilt angle, the working cannula can be successfully placed even if for the patients with high iliac crest. At the same time, this puncture angle makes the bone drill enter the vertebral canal at the tip of the traversing nerve root sliding from the dural sac to reach the ventral and medial sides of the nerve root. So intraoperative bone drilling will not easy to directly stimulate the traversing nerve root like TESSYS technology. If the buttocks soreness or lower limb radiating pain occurs during the reaming process, the general reason is the entry of the bone drill causes increased pressure in the spinal canal which stimulate the nerve. In accordance with the method of endoscopic treatment until the spinal canal pressure relieved, and then gradually deepen the working channel and endoscopic to continue the operation.

Lateral recess can be divided into two parts including osteoarthrosis and bone. According to clinical observation, the bony part may almost cause no stenosis if there is abnormal stress stimulation. The stenosis occurs mainly at the osteoarthrosis part. Therefore, the stenosis of the nerve root canal is actually that of lateral recess fossa and foramen [18]. With the degeneration of intervertebral disc, the height of intervertebral space is decreased, the intervertebral body ligaments are loosened, the local stress of the facet joint is increased. The repeated action and stimulation will result in the bulging or protruding of the intervertebral disc, calcification of annulus fibrosus, osteophytes at the posterior vertebral margin, proliferation and aggregation at the inner part of facet joint, and the hyperplasia and calcification of the facet capsule and ligamentum flavum [19]. In addition, the spinal canal space decrease can cause the spinal venous obstruction, nerve root ischemia and hypoxia which lead to the lower extremity pain, numbness, weak and other typical symptoms [20]. The purpose of nerve root ventral decompression is to remove the above stenosis risk factors to obtain wide loosening, restore nerve root function, and thereby eliminate the symptoms.

Endoscopic identification of nerve roots is very important. The nerve root is not only the target of surgical decompression, but also an important anatomical landmark. The elderly patients may present the hyperplasia of the posterior longitudinal ligament, ligamentum flavum and other soft tissue, with which the nerve roots tend to adhere severely or even be wrapped. The nerve roots from severe canal stenosis are slender with the obstruction of venous reflow, dilatation, hyperemia, and hypoxia of the capillaries and dysfunction. At this point, the separation of nerve roots should be carefully performed to avoid iatrogenic damage [21]. Microscopic longitudinal ligament hypertrophy shows pale yellow adjacent to the nerve root, the posterior longitudinal ligament hypertrophy is often dark red, and the degenerative disc shows darker with the performance of brown or dark yellow. Most of the intervertebral disc accompanies with varying degrees of fibrosis and calcification. Osteophyte hyperplasia of the posterior margin of the upper and lower vertebral labrum is obvious. The combination of the nucleus and the end plate is loose with more common free broken cartilage end plate. It is necessary to pay particular attention to free nucleus pulposus and fracture of the cartilage endplate and to carefully explore during the surgery.

Comparing with TESSYS technology, FNVD has a wider decompression space and can expose the dural sac or even the contralateral nerve root. It can take account of the walking root, the exiting root and do the decompression resulting from the degeneration of the annulus fibrosus or osteophytes at the same time. Compared with the interlaminar endoscopic approach, transforaminal approach has the advantages of reducing sacral muscle lesion, preserving the structural integrity of the dorsal ligamentum flavum and not pulling the nerve, and at the same time expanding the concealed side of lateral recess, directly decompressing the ventral site of the nerve, only needing local anesthesia, i.e., FNVD belongs to the un-full endoscopy technique puncturing quickly and safely to reach the target area caused by disc herniation or other kind of degenerations.

With the endoscopic operation, FNVD can do the nerve root decompression satisfactorily. It has several advantages: removing the proliferation and calcification of the annulus, posterior edge of the vertebral body, upper facet joint, capsule and ligamentum flavum to the head end; treating the degenerated disc and ligamentum flavum with nucleus clamp to reveal the traversing nerve root at the direction of the inward; the posterior longitudinal ligament is visible from the center, and even the contralateral nerve root can be revealed; tracing the traversing nerve root to the pedicle edge of the lower vertebral body, the lateral recess can be decompressed from the tail direction. All the above operations will be beneficial to achieve the complete release and decompression of the target nerve root.

Conclusion

It is well known that common factors for spinal stenosis, such as intervertebral disc herniation, osteophyte at vertebral posterior margin and internal hyperplasia of the articular process, could be resolved with ventral decompression by ventral decompression through transforaminal approach, in which could protect ligamentum flavum, the important physiologic structure. Therefore, ventral decompression could interfere and harm intraspinal tissue much less, which takes more advantages in spinal stenosis without ligamentum flavum hypertrophy. Hence, ventral decompression for nerve root and dural sac is a important method in treating spinal stenosis.

The biggest drawback of traditional open surgery for lumbar spinal stenosis is destroying the posterior structure of the spine that a considerable number of patients occur segment instability [22]. In addition, paraspinal muscles and soft tissues falling into the spinal canal due to the loss of bony support, organization of hematoma, scar tissue hyperplasia and other factors may easily lead to the new iatrogenic canal stenosis [23]. The FNVD technology in this study can not only do the full decompression for the nerve root, but also achieve the maximum maintenance of the posterior lumbar structure which plays an important role to prevent iatrogenic stenosis and muscle atrophy. FNVD technology has the advantages of broad vision field, direct target without blind zones. Common factors for spinal stenosis, such as intervertebral disc herniation, osteophytes at posterior vertebral margin and internal hyperplasia of the articular process, could be resolved with FNVD, which could protect ligamentum flavum, the important physiologic structure. The translaminar approach decompression, however, is more suitable for the central stenosis with hypertrophic ligamentum flavum and facet joints. Individualized treatment should be recommended to ensure the curative effect of minimally invasive spine surgery [24].

This clinical study still lacks a large number of cases and needs to be further validated through multi-center research. Anyway, we do believe that such kind of technique will be generalized in the near future because of its feasibility, safety and normalization.

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