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Posterior Inclinatory Approach for the Degenerative Foraminal Stenosis with the Biportal Endoscopic Technique: Clinical and Radiological Outcomes

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Abstract

Objective: Biportal Endoscopic Spine Surgery (BESS) presents a multitude of advantages, including enhanced flexibility, improved magnification, and an expanded field of view. These characteristics render it particularly suitable for the performance of minimally invasive procedures targeting spinal stenosis. This study introduces an innovative approach termed Posterior Inclinatory Access by BESS technique (PIA-BESS), which is specifically designed for treating degenerative spinal foraminal stenosis.

Methods: Between March 2021 and July 2023, a total of 19 patients presenting with symptomatic nerve root involvement due to foraminal stenosis underwent the PIA-BESS surgical procedure. Preoperative and postoperative assessments involved the acquisition of Magnetic Resonance Imaging (MRI) and Computed Tomography (CT) scans to measure changes in the cross-sectional area of the spinal canal and intervertebral foramen. Clinical outcomes were evaluated using the Oswestry Disability Index (ODI) scores and the Visual Analog Scale (VAS) scores for both buttock and radicular pain. The dynamic Intervertebral Angle (IVA) and vertebral slip rate, as determined from preoperative and postoperative X-rays, were employed to evaluate post-surgical vertebral stability.

Results: The intervertebral foraminal increased from 32.26 ± 13.49 mm^2 to 79.95 ± 19.78 mm^2 ($P<0.05$). The area of the spinal canal increased from 105.37 ± 21.66 mm^2 to 145.63 ± 17.86 mm^2 ($P<0.05$). ODI scores reduced from 73.27 ± 13.21 to 9.26 ± 7.65 ($P<0.05$); VAS score reduced from 5.79 ± 1.08 to 0.84 ± 0.9 ($P<0.05$). There are significant differences between the pre-operation and post-operation. While the dynamic IVA and vertebral slip show no significant change.

Conclusion: The PIA-BESS approach is an effective and low-complication method for addressing stenosis in the lower lumbar foraminal region. It provides effective decompression for bony stenosis or extruded and sequestered discs in the foraminal region while enabling simultaneous exploration of the exiting and traversing nerve roots. This approach allows for a good surgical field view while also aiming to preserve the facet joint as much as possible.

Keywords: Foraminal stenosis; Biportal endoscopic technique; Posterior inclinatory approach; Nerve root lesion

Abbreviations

BESS: Biportal Endoscopic Spine Surgery; PIA-BESS: Posterior Inclinatory Access by BESS technique; MRI: Magnetic Resonance Imaging; CT: Computed Tomography; ODI: Oswestry Disability Index; VAS: Visual Analogue Scale; TLIF: Transforaminal Lumbar Interbody Fusion; TESSYS: Transforaminal Endoscopic Spine System

Introduction

Foraminal stenosis is one of the common forms of lumbar degenerative disease. Statistics show that the incidence of this type of lumbar degenerative disease is between 8% to 11%, with the majority originating from the L5-S1 level (75%) [1,2]. Conditions such as disc herniation, facet joint hypertrophy, and ligamentum flavum thickening often lead to symptoms of both traversing nerve root and exiting root nerve. Currently, treatment options include decompression combining intervertebral fusion and fixation, open surgery decompression, microscope decompression, and endoscopic decompression.

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The conventional surgical approach for intervertebral fusion and fixation is known as Transforaminal Lumbar Interbody Fusion (TLIF) surgery. TLIF surgery involves the excision of the inferior facet joint and a portion of the superior facet joint, complete removal of the intervertebral disc, decompression of the foraminal area and lateral recess, followed by interbody instrument fusion [3]. This surgical procedure demonstrates efficacy, particularly in patients with lumbar instability, as it simultaneously stabilizes the unstable lumbar vertebrae and provides decompression. However, spinal fusion surgery is not devoid of challenges, as it is associated with various reported complications such as persistent lower back pain, reduced lumbar mobility, and the occurrence of adjacent segment disease, among other potential issues [4].

The paraspinal surgical approach was first reported by Wiltse et al. in 1968 [5] and was improved in 1988 [6]. This approach is considered the classic surgical approach for lumbar foraminal lesions, which can be completed with open or microscopic assistance [7]. Although the surgery can protect the stability of the facet joint, this surgical approach does not enter the spinal canal, thus limiting its effectiveness for inner foraminal and same-segment lateral recess stenosis.

The development of spinal endoscopy allows surgeons to perform more precise surgeries [8]. The visualization underwater medium is clearer. TESSYS access technology was invented in 2003. After twenty years of development, TESSYS access has shown good results for disc herniation [9,10]. However, the foraminoplasty procedure under endoscope often suffers from limited surgical visibility, surgical approach limitations, and a higher risk of exiting root injury, and patients often experience strong discomfort during local anesthesia.

Biportal Endoscopic Spinal Surgery (BESS) is a type of full-endoscopic spinal surgery technology that has emerged in recent years. It offers a clear field of vision underwater medium, flexible operation under dual channels, flexible and variable surgical approach, and more surgical instruments [11,12]. The most common surgical method in BESS technology is the interlaminar approach, which can enter the spinal canal, and has the advantage of minimal damage and bone destruction for ordinary lumbar disc herniation discectomy. However, for foraminal stenosis, more facet joints and lamina need to be removed, which could lead to lumbar instability [13]. For extraforaminal stenosis or free intervertebral disc, an extremely lateral approach similar to Wiltse and Spencer can be adopted [14]. Due to the limitations of the surgical approach, it is also difficult to deal with stenosis of the inner foraminal area or combined with the same-segment lateral recess.

Therefore, based on BESS technology, we have developed a new posterior oblique surgical approach (PIA), which can effectively decompress the traversing root, exiting root in the spinal canal, lateral recess, and the foraminal region. The purpose of this study is to evaluate the effectiveness of this surgical method.

Materials and Methods

We conducted this study in compliance with the principles of the Declaration of Helsinki. The study was a retrospective medical chart review with approval by the Institutional Review Board of the fourth affiliated Hospital of Zhejiang University. All patients who underwent Biportal Endoscopic Spine Surgery with Posterior Inclinatory Approach (PIA-BESS) for lumbar foraminal stenosis provided a signed informed consent form before the surgery.

Between March 2021 and July 2023, a single surgeon (Qingfeng Hu) team performed 934 BESS surgical procedures for lumbar degenerative diseases. Among the total 934 patients, 19 patients treated *via* PIA-BESS for degenerative foraminal stenosis combined or not combined lateral recess stenosis were included in this study. Demographic characteristics, classification of pathologies, distribution of operation level, operative time, and surgical complications were reviewed.

Surgery preparation

Indications and contradictions: Inclusion Criteria: (1) Patients presenting with foraminal nerve root symptoms induced by osseous foraminal narrowing, with or without concurrent lateral recess stenosis. (2) Patients with intervertebral disc herniation or fragments within the foramen causing nerve root symptoms. Exclusion Criteria: (1) Patients with lumbar instability. (2) Patients with bilateral lower limb neurological symptoms. (3) Patients with central spinal stenosis. (4) Patients with severe kyphosis or scoliosis.

Preoperative evaluation: Patients underwent routine assessments, utilizing anteroposterior, lateral, oblique, and dynamic radiographic examinations, to evaluate the alignment of the spine, disc space height, the extent of foraminal osseous encroachment, and the presence of instability. Additional radiological investigations, including Magnetic Resonance Imaging (MRI) and Computed Tomography (CT) scans, were executed to ascertain the degree of foraminal stenosis and procure precise information about the facet joint - such as the level of joint hypertrophy, tropism, the size and form of the bony spur, as well as the inclination angle of the spinous process. This comprehensive evaluation enabled the surgeon to determine the extent of facet joint resection and the optimal approach angle for achieving ideal decompression while ensuring the preservation of segmental stability.

Instruments: We use a 30° 4-mm-diameter arthroscope (Smith & Nephew, USA) (Figure 1a), a 90° 3.75 mm radiofrequency ablator, and a 1.4-mm micro ablator radiofrequency probe (Bonss Medical, Jiangsu Bonss Medical Technology Company., Ltd., China) (Figure 1b). We also used ordinary instruments in the BESS such as different kinds of Kerrison Rongeur, 3 mm-diameter straight and curved round burr, and 3-mm curved chisels, pituitary forceps, and cannula for water outflow (Figure 1c-31).

Surgical procedures

Skin incision and portals establish: Patients generally undergo surgery in a supine position after general anesthesia. The surgeon stands on the patient's healthy side (Figure 2a) for the procedure. The surgical incision is made by making two longitudinal surgical incisions, approximately 0.5 cm long, above the spinous process. Insert two Kirschner wires diagonally outward from the incision and anchor them at the level of the intervertebral foramen (Figure 2b, 2c). After determining the position under fluoroscopy, establish an operating channel and an endoscopic observation channel along the position of the Kirschner wire (Figure 2d-2f).

Bone work for the trajectory to the foramina: Soft tissues overlying the lamina and the ligamentum flavum were ablated to expose the bone edge in the targeted interlaminar space (Figure 3a, 3b). A high-speed burr was utilized to partially resect the lamina. The shaping of the lamina required burring upward to the point of the ligamentum flavum, thereby exposing the entire ligament. Subsequently, decompression was performed by navigating along the

Figure 1: Instruments used in the PIA-BESS.

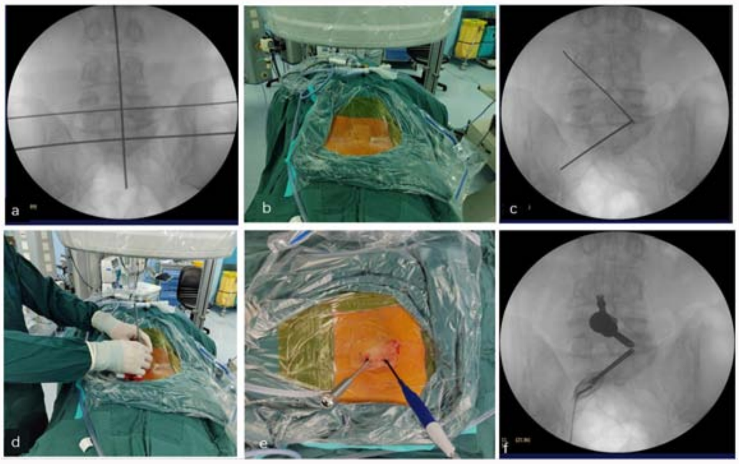

Figure 2: Portals position and establish. a-c) Kirschner needles positioning for the foramina of L5/S1. d-f) portals establishment according to the direction of the Kirschner needles.

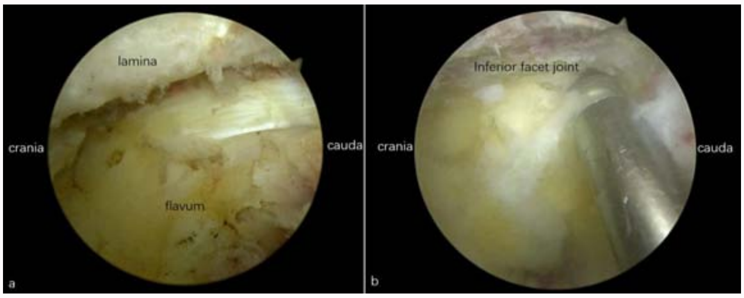

Figure 3: Exposing and bone work for the trajectory to the foramina.

inferior articular process in an outward and upward direction.

Flavectomy and foraminoplasty: Following the removal of the ligamentum flavum, the dural sac and the facet joint of the inferior articular process can be visualized. The partial resection of the superior articular process, using a burr or a lamina rongeur, exposes the foraminal area. Tools such as disc forceps, Kerrison rongeur, and high-speed burr are then used to remove any protruding nucleus pulposus or osteophytes, and any hypertrophied ligamentum flavum within the foraminal area (Figure 4a). After the removal of the compressive elements, the exiting nerve root's course can be visualized (Figure 4b).

Nerve root exploring and decompression: Following the course of the exiting nerve root, thorough exploration and decompression are carried out until the nerve is in a tension-free state. A nerve retractor may be used to gently manipulate the nerve root, confirming its tension-free state before concluding the procedure. Intraoperative X-ray confirms the retractor's position within the foramen, ensuring that the foraminal nerve root canal has been adequately decompressed (Figure 5a, 5b).

Clinical and radiology evaluating

All patients were followed up for at least six months after the surgery. The clinical results were evaluated and compared preoperatively and 6 months postoperatively using the Oswestry Disability Index (ODI) and the Visual Analog Scale (VAS) scores for buttock and radicular pain.

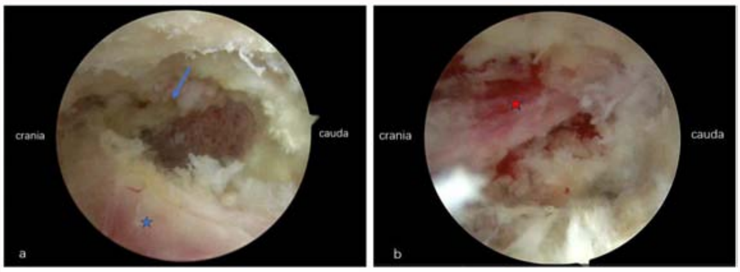

Figure 4: Endoscopic view of flavectomy and foraminoplasty. Blue arrow: Foramina region. Blue pentagram: Dura sac. Blue triangle: Intervertebral disc. Red pentagram: Exiting nerve root.

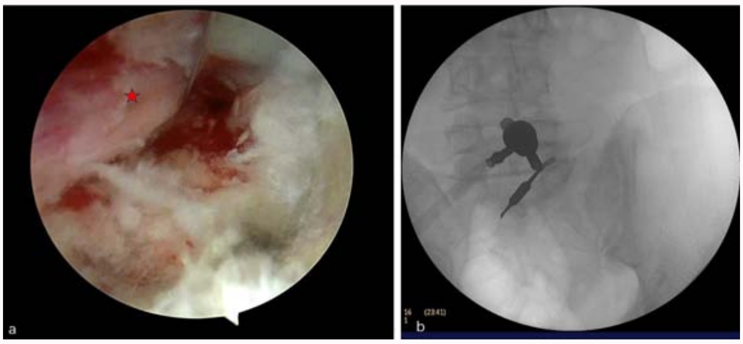

Figure 5: Nerve decompression. a) endoscopic view of exiting nerve root decompression. b) X-ray film of the decompression region. Red pentagram: Exiting nerve root.

For patients with intervertebral foramen stenosis mainly caused by bone stenosis, we used a comparison of preoperative and postoperative CT scans to evaluate the surgical decompression effect. For patients with intervertebral foramen stenosis mainly caused by free nucleus pulposus, we use preoperative and postoperative MRI to evaluate the surgical decompression effect. We measured the Cross-Sectional Area of the Intervertebral Foramen (CSA-IVF) at the sagittal level of the pedicle (Figure 1a, 1b), and the cross-sectional area of the spinal canal at the axial level of the foramina (Figure 1c, 1d). The measured area is expressed in square millimeters.

To evaluate the stability of the vertebra, we analyzed the dynamic Intervertebral Angle (IVA) and slip based on X-ray imaging obtained before the surgery and at the 6-month follow-up. These assessments provided insights into the long-term stability of the spinal structure.

Statistical analyses

Statistical calculations, including means and standard deviations, were obtained using SPSS version 17.0. Paired t-tests were used to compare the differences in each parameter of the perioperative outcome. Statistical significance was established at a p-value of less than 0.05.

Results

In two years, 19 patients (13 men and 6 female) were enrolled in our study. The mean age was 67.21 ± 9.56 years. Of these 19 patients, of these, 2 patients received decompression at L3-4, 7 patients at L4-5, and 10 patients at L5-S1. Five patients foraminal stenosis is mainly caused by disc herniation and displacement. Besides, 14 patients foraminal stenosis is mainly caused by osseous structure hypertrophy, thickened ligamentum flavum, and other degenerative hyperplasia (Table 1).

We use the ODI and VAS score systems to evaluate the clinical effect. According to the most recent follow-up, the back and leg pain of patients get remarkably released after the surgeries. ODI scores reduced from 73.27 ± 13.21 to 9.26 ± 7.65 (P<0.05); VAS score reduced from 5.79 ± 1.08 to 0.84 ± 0.9 (P<0.05).

Table 1: Demographic data of the patients (n=19).

Characteristic	Value
Age (year)	67.21 ± 9.56
Sex, male: female	13:06
Level	
L3-4	2
L4-5	7
L5-S1	10
Sides	
Left	7
Right	12
Diagnosis	
DH	5
DFS	14
Operation time (min)	78.63 ± 21.11
Hospital stay (day)	5.84 ± 1.38
MacNab	
Good	4
Excellent	15

DH: Disc Herniation
DFS: Degeneration of Foramen Stenosis

We measured the cross-section area of the spinal canal in the axial image at the level of the foramina and the cross-section area of the intervertebral foraminal in the sagittal image at the level of

Table 2: Morphometric of radiology and clinical outcomes.

	Pre-operation	Post-operation	P value
The Cross-Sectional Area of the Spinal Canal (CSA-SC) (mm^2)	105.37 ± 21.66	145.63 ± 17.8	<0.05
Cross-Sectional Area Intervertebral Foramen (CSA-IVF) (mm^2)	32.26 ± 13.49	79.95 ± 19.78	<0.05
ODI	73.27 ± 13.21	9.26 ± 7.65	<0.05
VAS	5.79 ± 1.08	0.84 ± 0.9	<0.05
IVA (°)	6.14 ± 1.44	5.95 ± 1.45	0.68
Slip (%)	3.78 ± 2.47	3.85 ± 2.53	0.94

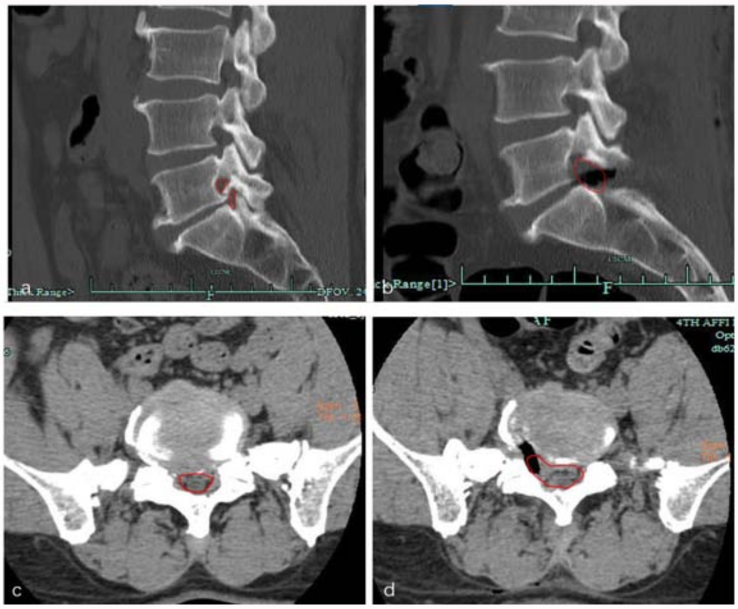

Figure 6: Measurements of CSA-IVF and CSA-SC before and after the surgery. a) the CSA-IVF at the level of the vertebral pedicle before the surgery. b) the CSA-IVF at the level of the vertebral pedicle after the surgery. c) the CSA-SC at the level of foramina before the surgery. d) the CSA-SC at the level of foramina after the surgery at the level of foramina.

the pedicle (Figure 6). As shown in the table, the area of the spinal canal increased from 105.37 ± 21.66 mm^2 to 145.63 ± 17.86 mm^2 and the intervertebral foraminal increased from 32.26 ± 13.49 mm^2 to 79.95 ± 19.78 mm^2. There are significant differences between the pre-operation and post-operation areas.

According to the radiology measurements, the dynamic IVA and dynamic slip show no significant difference after the surgery. So, we can conclude that the PIA-BESS approach for foraminal stenosis wouldn't cause iatrogenic vertebral instability (Table 2) (Video 1).

Discussion

According to the anatomical structure, the lumbar spinal canal can be divided into the central canal and the lateral canal region. The lateral spinal canal includes the entrance zone, mid zone, and exit zone. The entrance of the lateral canal is also known as the lateral recess, the midzone describes the foraminal region, and the exit zone of the lateral canal is identified as the area lateral to the facet joints [15]. The abnormalities and pathologies of the lateral canal region can be quite challenging due to obstructions posed by the facet joints and the pedicles. Excessive bone removal during surgery could lead to iatrogenic lumbar instability, while insufficient removal may fail to achieve good therapeutic outcomes. Therefore, the choice of an appropriate surgical approach and technique is of paramount importance.

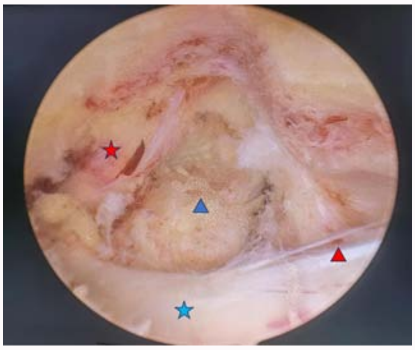

Figure 7: Endoscopic view of PIA-BESS. Red pentagram: Exiting nerve root. Red triangle: Transversing nerve root. Blue pentagram: Dura sac. Blue triangle: Intervertebral disc.

In the past, patients with lateral canal stenosis often required instrumental fusion due to iatrogenic instability caused by decompression enlargement. However, the BESS technique offers a clearer visual field, more flexible surgical instruments, and a wider range of approach options. BESS enables access to the sublaminar space, extending from the central canal to the deeper foramen [16,17]. The sublaminar pathway provides access to the lateral and foraminal recess area, effectively decompressing the contralateral side [13]. However, this technique requires resection of the root portion

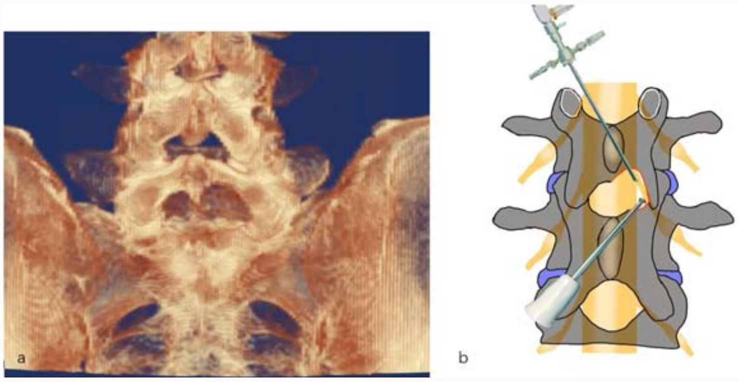

Figure 8: Bone removed for PIA-BESS. a) The facet joint is well preserved in the post-operation CT scan. Only a small portion of the lamina was removed. b) Illustration for the bony work of PIA-BESS.

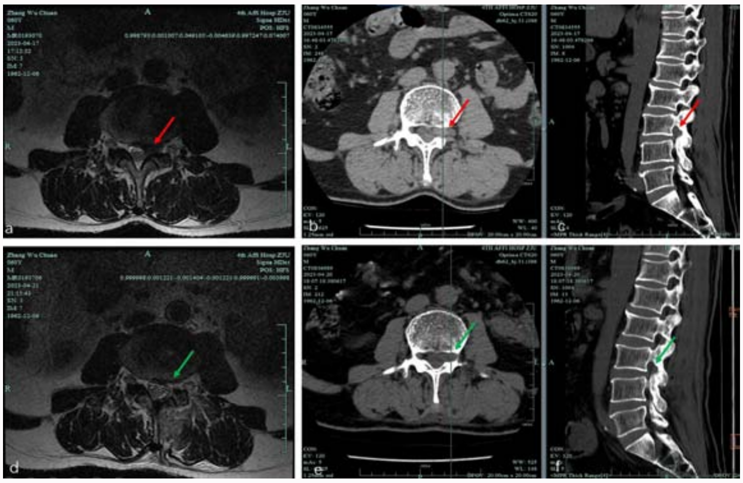

Figure 9: Rostrally Migrated Lumbar Disc Herniations in the foraminal area. a-c) Preoperative MRI and CT scans show the free nucleus pulposus caused the compression of the nerve root at the level of foramina. d-f) Postoperative MRI and CT scans indicate the herniated nucleus pulposus is removed.

of the spinous process to establish a longer sublaminar pathway, and it does not address lesions in the extraforaminal region.

Therefore, this study introduces a new surgical approach. The study demonstrates that PIA-BESS (Posterior Interlaminar Approach using the dual-channel endoscope) is an effective and low-complication approach for addressing stenosis in the lower lumbar foraminal region. It provides effective decompression for bony stenosis in the foraminal region and for extruded and sequestered discs, while also enabling simultaneous exploration of the exiting and traversing nerve roots (Figure 7).

PIA-BESS allows for a good surgical field of view without removing the root portion of the spinous process, and only a small amount of lamina bone is removed, thus preserving the stability of the lumbar posterior column (Figure 8). The PIA-BESS approach can avoid the need to remove the bottom of the spinous process and reduce manipulation of the dural sac. However, it should be noted that the laminar angles differ at different levels of the lumbar spine. We believe that the L5-S1 level is the most suitable for PIA-BESS, as it provides a wide interlaminar space. Nevertheless, with proficiency in the technique, we have successfully performed PIA-BESS on patients with disc herniation protruding laterally and superiorly at the L3-4 level, achieving good results (Figure 9).

Although we conducted a new approach for the foramina stenosis, there are also some limitations of the study. Firstly, we find that it is more convenient to deal with the left side lesion (surgeon on the patient's right side) for a right-handed surgeon. When it comes to the right-side lesion, the right-handed surgeon may meet some operation difficulties. On the other hand, the characteristics of this technique determine its suitability for treating lesions in the lateral recess and intervertebral foramen area, while it is challenging to manage lesions in the central spinal canal. The study is a retrospective study with relatively strict indications. Random control trials compared to other techniques are needed in the future.

Video 1: https://youtu.be/3Ddjk5kDhtE

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