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Research/Technical Note

Application and Previous Report of External Channel Positioning System in Enlarged Foraminoplasty

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Abstract: Transforaminal total endoscopic lumbar discectomy (TELD) is a typical minimally invasive procedure that has been successfully used in patients with different types of lumbar disc herniation in recent years. However, the procedure has a steep learning curve. External channel positioning system changes the blind technique of traditional foraminoplasty, which relies on fluoroscopy for repeated evaluation, and makes it a new technique that relies on mechanical operation and objective evaluation, thereby improving safety and reducing learning curve. The application is now reported. *Objective*: To explore the impact of external channel location system (ECLS) for the improvement of intraoperative parameters and surgical outcomes of foraminal enlargement plasty (FEP) in patients with lumbar disc herniation (LDH). *Methods*: This prospective case series study enrolled patients with LDH who scheduled for FEP in the Affiliated Hospital of Chengde Medical College between February 2021 and February 2022. The intraoperative parameters and surgical outcomes included nerve root and dural injury, puncture localization and postoperative and preoperative pain (visual analog scale, VAS, and Oswestry disability index, ODI). *Results*: Eighteen patients were enrolled for analysis. None showed nerve root and dural injury after 3 months, and without recurrence reported. There were 17 (94.4%) patients had a successful puncture localization in one procedure. No significant difference between percent (P) 25 and P75 values of the duration of puncture localization, number of X-ray sessions required for puncture localization, and the duration of operation were observed (all $P > 0.05$). Postoperative VAS (1.45 ± 0.99 and 6.65 ± 2.08) and ODI (0.13 ± 0.06 and 0.73 ± 0.07) scores were significantly decreased compared with preoperative values ($P < 0.05$). According to the modified Macnab criteria, 8 and 10 cases had excellent and good outcomes, respectively. *Conclusion*: ECLS might have favorable improvement for intraoperative parameters and outcomes of FEP.

Keywords: External Channel Location System, Foraminal Enlargement Plasty, Puncture Localization, Case Series

1. Introduction

Lumbar disc herniation (LDH) is increasingly diagnosed thanks to the aging population and heavy workload, which requires surgery when symptomatic in case of failed conservative treatment [1]. In recent years, different types of LDH have been successfully treated by transforaminal full-endoscopic lumbar discectomy, a typical minimally invasive procedure [2]. However, beginner surgeons are unfamiliar with the anatomy of transforaminal endoscopic surgery, who have a steep learning curve [3].

Technically, bone hingers or reamers can quickly cut enlarged upper arthroprocesses or osteophytes [4]. However, as blinded techniques, these tools also have inherent drawbacks. C-arm guided foraminoplasty may cause excessive radiation exposure, inadequate bone clearance, bleeding, lumbar instability caused by significant resection of important bone structures, and even sensitive nerve damage [5, 6]. Therefore, auxiliary devices, such as navigation, endoscopic high-speed grinding, microscopic bone knife, and holmium lasers, have been further developed to assist in enlarging the foramina. Unfortunately, in case of severe bone stenosis, these techniques may be ineffective and time-consuming, and the corresponding high cost of auxiliary equipment increases the burdens on both hospitals and patients. This indicates that urgent solutions are needed.

Based on traditional location tools for completing foramina enlargement, the external channel location system (ECLS) was developed. This name was used to distinguish it from the traditional transforaminal endoscopic spine system and the Yeung endoscopic spine system [7, 8]. The ECLS could replace traditional blind techniques for foraminoplasty that rely on repeated evaluations, because the new technique relies on mechanical operation and objective evaluation, thereby improving safety while not increasing the burden of auxiliary equipment. However, little is known about the application of ECLS. Therefore, this study aimed to explore the ECLS for the improvement of intraoperative parameters and surgical outcomes of foraminal enlargement plasty (FEP) in patients with LDH.

2. Methods

2.1. Study Design and Patients

This prospective case series enrolled patients with LDH who scheduled for FEP in the Affiliated Hospital of Chengde Medical College between February 2021 and February 2022. Inclusion criteria were: (1) required and scheduled for FEP; (2) lumbar disc herniation (central or paracentral type); (3) lumbar spinal stenosis with lateral recess stenosis; (4) imaging diagnosis of lumbar MRI and disc CT compliance. Exclusion criteria were: (1) requirement of other spinal surgery or have received surgical treatment in 6 weeks (2) psychiatric disorders; (3) cauda equina syndrome; (4) concurrent spinal infections, vertebral fractures, and/or spinal tumors.

The study protocol was approved by the ethics committee of the Affiliated Hospital of Chengde Medical College, and all patients provided signed informed consent.

2.2. Location Tool (ECLS)

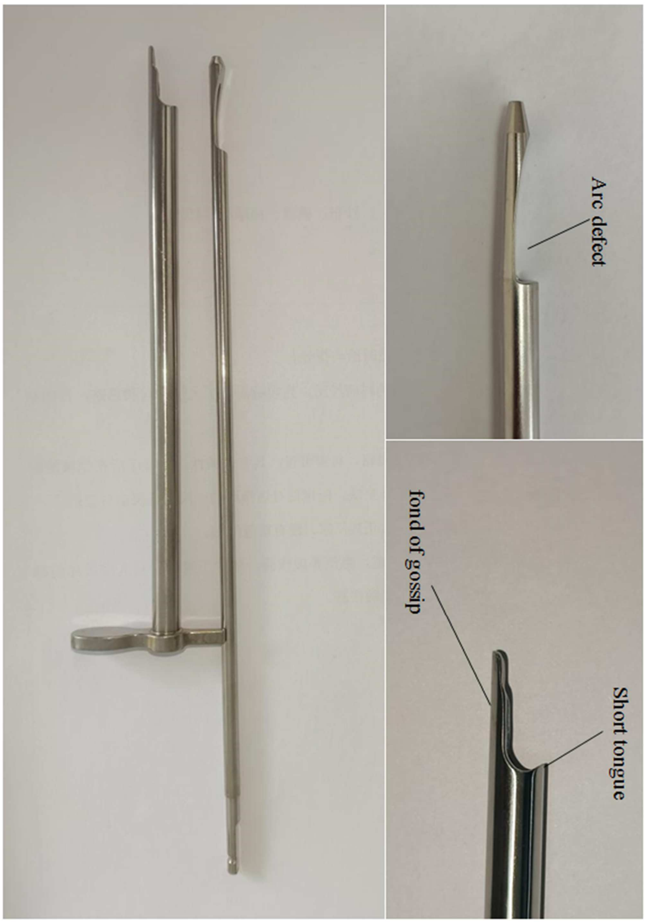


Figure 1. *Arthroid guide rod, 250 mm long, with 6 mm diameter rod arm; distal vertebral blunt head, 4 mm diameter, with the distal side of the arc defect site. Outer channel location sleeve: 180 mm long, outer diameter of 8.8 mm, inner diameter of 7 mm; the distal cylinder wall includes a long tongue, a short tongue. Long tongue length is 16 mm, wall thickness is 1.2 mm, corresponding short tongue length is 2 mm, and wall thickness is 0.6 mm.*

The author's team designed articular process positioning guide bar and external channel location sleeve (Figure 1). Bone drill with 6.5-mm diameter was performed with the TEESYS system (Supplemental Figure 1).

2.3. Surgical Technique

Position: Taking the 4/5 segment of waist as an example. The patient was placed on the operating bed, with the affected limb, head pillow, and shoulder in the same height, according to their own habitual side position sleep posture; then, a waist pillow and any auxiliary position device were placed, ensuring a natural position for the patient. *Skin puncture point determination:* about 1 cm above the highest point of the iliac wing, an horizontal line was traced to the back midline; a long ruler was placed along the skin's horizontal line from the back of the soft tissue of the back, to the vertex of the spike, and 1 cm outside the separation point of the skin's horizontal line and the long ruler is the skin puncture point.

Anesthesia: After disinfecting the sterile towel in the surgical area, 0.75% lidocaine was infiltrated at the skin puncture point for anesthesia; a 18G needle was monitored by C-arm fluoroscopy, and the anesthetic was infiltrated layer by layer until the surgical joint around the anesthesia area was completed, as for the traditional surgical anesthesia.

Foraminal enlargement plasty: Joint guide rod through the foramina: after foramen anesthesia and skin incision (8 mm), joint guide wire or direct puncture to the foramina was performed, rotating the joint guide rod and ventral bone. This continued until the joint guide rod penetrates the lateral recess, the blunt tip of the joint guide rod support penetrates the fiber ring or vertebral posterior edge, the guide defect fit to the upper joint process ventral bone, the joint guide rod is relatively fixed, and arthroid rod placement is completed. A perspective view confirmed that the tip of the arthoid rod passes through the foramen to the lateral crypt (Figure 2).

Figure 2. *X-ray fluoroscopy confirming that the tip of the facet guide rod passed through the foramina and reached the lateral recess.*

Stable localization of the foraminal end: After the localization of the guide rod, the outer channel location sleeve was inserted along the guide rod. The long tongue end along the guide was inserted into the foramina, the short tongue end reached the lateral bone of the articular process. At this time, the bone thickness of the ventral joint of long and short tongues does not exceed 3 mm (Figure 3), given the external channel abduction force to maintain the joint guide rod arc defect and the ventral bone of the upper joint. Meanwhile, the tail end of the outer channel was hammered, forwarding the outer channel sleeve along the joint process guide rod until the end of the long tongue reaches the posterior edge of the fiber annulus or the inferior vertebral body. The lateral bone of the upper joint is embedded in the short tongue end. The long and short tongues cooperate to complete the fixation of the interforaminal end. The tip of the long tongue of the anterior and posterior outer channel reaches the lateral crypt, the lateral long tongue is lower than the posterior edge of the vertebral body or the posterior edge of the fiber annulus, and the long and short tongues wrap part of the ventral bone of the upper joint in the channel (Figure 4).

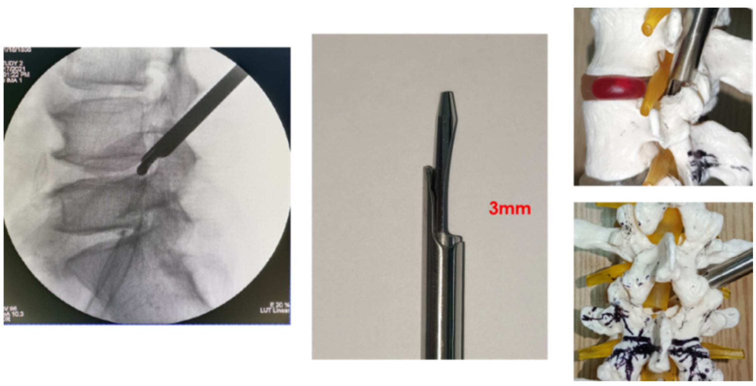
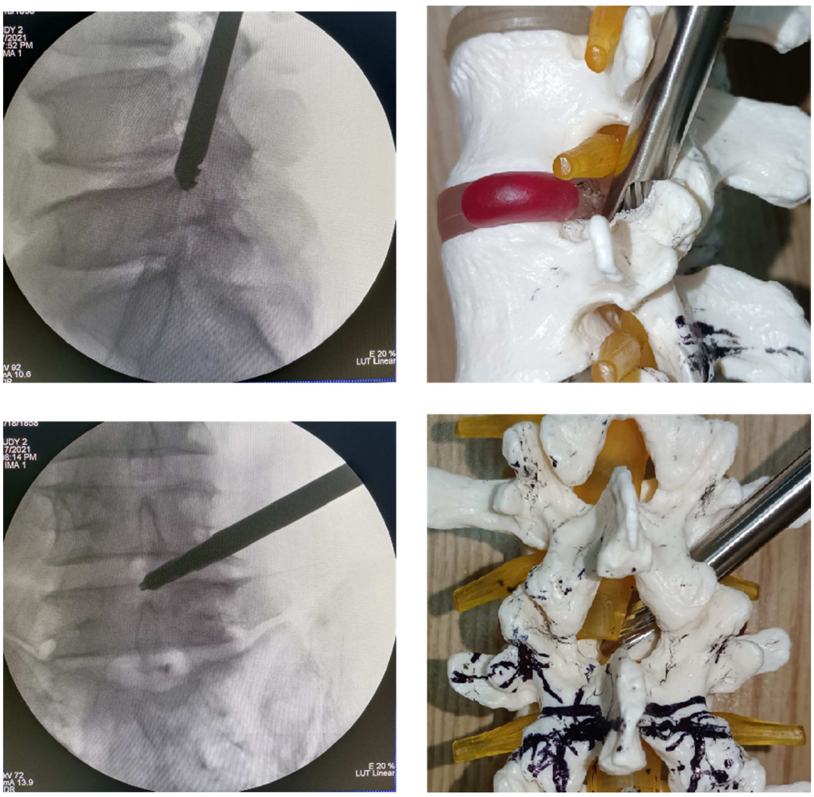


Figure 3. *The external channel location sleeve was placed along the guide rod of the articular process. The end of the long tongue entered the intervertebral foramen along the guide rod, and the end of the short tongue reached the lateral bone of the articular process. The ventral bone thickness of the articular process was wrapped by the long and short tongues did not exceed 3 mm.*

Figure 4. *On X-rays, the tip of the external passage reached the lateral recess, and the lateral lingual reached the posterior edge of the vertebral body or the posterior edge of the annulus fibrosus. The long and short tongues enclosed part of the ventral bone of the superior articular process in the passage.*

Foraminal enlargement: the joint process guide rod was pulled out, through the foraminal end fixed after the external channel location socket; the bone drill was directly applied 6.5-mm through the working channel in the sleeve. Bone drill to the lateral crypt can complete foraminal enlargement; in case of no neurological symptoms, the bone drill could enter the spinal canal. This step accurately evaluates the depth of bone drill entry into the process based on the length of the working sleeve and the step mark on the tongue and the inner edge of the joint on the ortho X-ray perspective image (Figures 5).



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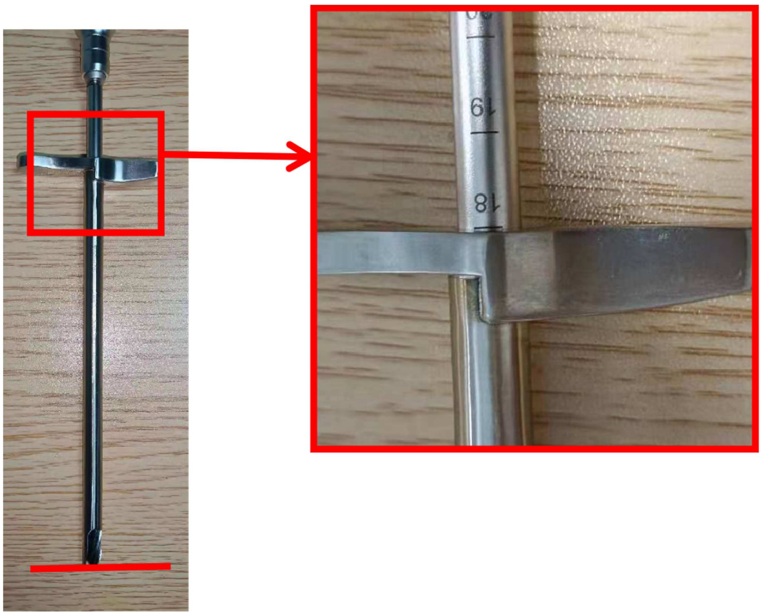

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Figure 5. *The depth of the drill can be evaluated according to A) X-ray fluoroscopy and B-C) bone drill calibration during the operation.*

After foramina enlargement, the endoscope can be placed directly through the working sleeve of the external channel. Fluoroscopic evaluation showed that the thickness of the ventral facet osteotomy was less than 3 mm (Figure 6). The endoscopic operation is the same as the traditional operation. Within 4 weeks postoperatively, strict support protection function practice was performed, and daily work and life resumed after 4 weeks.

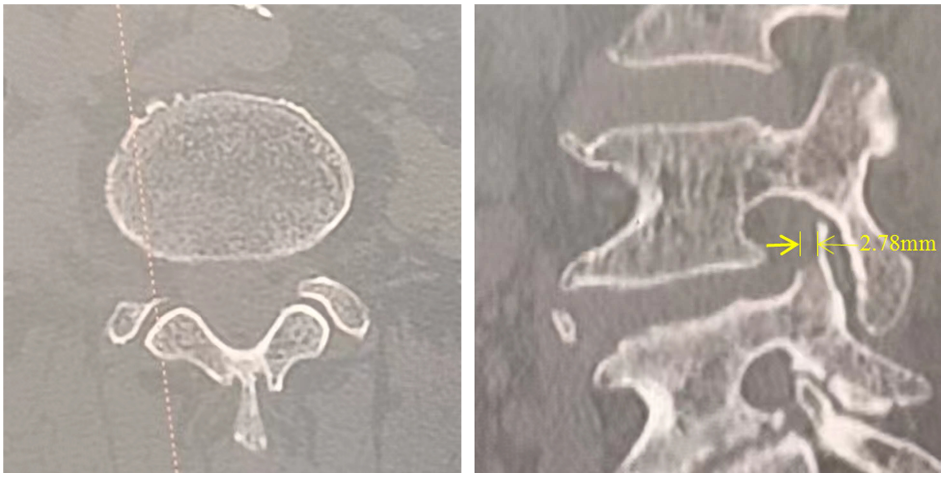

Figure 6. *Fluoroscopic evaluation showed that the thickness of the ventral facet osteotomy was less than 3 mm.*

2.4. Data Collection and Definition

Once localization is successful (with the rod into the foramina sequence mechanical operation to the foramina enlargement, no external location sleeve adjustment, and microscopic operation achieving the purpose of the nucleus pupillary clearance), duration of puncture localization (from anesthesia completion to the foramina enlargement), duration of operation, preoperative and postoperative VAS scores, and ODI score were assessed. Last follow-up outcomes were evaluated using modified Macnab criteria: Excellent, symptoms and signs completely disappeared, and work and life basically normal. Good, symptoms obviously relieved, with occasional slight waist and leg pain, but no need for analgesic drugs, little impact on work and life, reduced symptoms, but some limb pain and discomfort, limited activity, nonsteroidal anti-inflammatory analgesics, and work and life significantly affected. Poor, lumbar and leg pain not improved or even worsened, needing further treatment.

2.5. Statistical Analysis

SPSS 13.0 (SPSS Inc., Chicago, IL, USA) was used to analyze the data. Continuous data were expressed as mean ± standard deviation (SD) and compared by t-test. Categorical data were expressed as n (%), and compared by the Chi-square test. Two-sided $P < 0.05$ was considered statistically significant.

3. Results

Totally, 18 patients were enrolled, and none showed nerve root and dural injury after 3 months, with no recurrence detected. There were 17 (94.4%) patients had a successful puncture localization in one procedure. No significant difference between the P75 and P25 values of duration of puncture localization, the number of X-ray sessions required for puncture localization, and duration of operation were observed (all P > 0.05) (Table 1). Postoperative VAS (1.45 ± 0.99 and 6.65 ± 2.08) and ODI (0.13 ± 0.06 and 0.73 ± 0.07) scores were significantly decreased compared with preoperative values (P < 0.05) (Table 2). According to the modified Macnab criteria, 8 and 10 cases had excellent and good outcomes, respectively.

Table 1. *P75 and P25 of parameters had small differences. Parameter.*

	n	P25	M	P75
Duration of puncture localization	20	3.25	4.00	5.00*
Number of X-ray sessions required for puncture localization	20	4.00	5.00	5.00*
Duration of operation	20	48.50	55.00	59.00*

P=percent; * P > 0.05

Table 2. *VAS and ODI scores before and 3 months after surgery.*

Variable	1 day before surgery	Three months after surgery	P
VAS	6.631578947	1.421052632	< 0.001
ODI	0.7255	0.1345	< 0.001

4. Discussion

This study demonstrated the ECLS was successful in puncture localization and resulted in excellent and good outcomes. In addition, pain was markedly decreased after the surgery, and the duration of puncture localization had a linear relationship with the duration of operation.

Traditional foraminal enlargement plasty localization methods rely heavily on the surgeon's experience, as well as tactile feedback, spatial understanding, repeated fluoroscopy and puncture attempts [9, 10]. This may prolong the surgical time and increase the risk of damage to the paraspinal tissue, dural sac and nerve root [11, 12]. Furthermore, locating bone markers by tactile feedback is insensitive or non-reproducible [13]. Such complexity, in the beginning of learning PELD, may undermine self-confidence and make learning curve steep and lengthy [6, 13]. In addition, long-term radiation exposure may be associated with underlying diseases, including cataract formation, leukemia, skin erythema, thyroid cancer, and other malignancies [14-16]. Therefore, it is important to reduce fluoroscopic exposure to surgeons and patients to decrease the risk of potential radiation-induced disease. In the transforaminal surgical approach, foraminal enlargement is completed using high-speed grinding drill or holmium laser lens [17-20], and safety is greatly improved. Through the o-shaped arm [21], multiplane intraoperative images may help accurately determine the anatomy of the operative area and place the puncture needle in the optimal target site. Choi et al [22] used an image set becoming x-ray and X Mr (XMR suite) used in PELD, suggesting that using XMR in PELD provides a precise skin puncture point and intraoperative decompression. However, auxiliary devices are very cumbersome in the operating room, with long surgical time needed, expensive puncture and localization, and difficult utilization. Therefore, safe and accurate puncture localization is performed by foraminal enlargement [13, 23] Prerequisites, such as not increasing the cost of auxiliary equipment and reducing radiation damage, are important factors in the wide development of a technology.

Advantages of external channel localization are as follows. (1) Strong guidance: the foramina of the traditional tool is enlarged and formed, with the replacement of the tool from the puncture to the ventral bone grinding. [24] Bending and breaking of the guide wire may be in the direction of the image puncture, requiring repeated fluoroscopic evaluations or even reoperation. The outer channel location sleeve wall hardly ensures a stable direction for the working channel, and the guiding function is determined. (2) Stability of the foraminal end: During foramina enlargement by traditional tools, the guide wire cannot limit the rolling displacement direction of bone drilling at the foraminal end, which requires repeated fluoroscopic evaluations and even re-operation. After the localization of the outer channel location sleeve, due to the innovative interforaminal end stabilization setting, the displacement of bone drilling can be limited, giving full play to bone drilling and bone grinding, and not requiring repeated fluoroscopic evaluations.

The new tool can accurately assess bone grinding thickness and drilling into depth: the locations of foraminal enlargement, rod and external channel, and sleeve tongue mechanical block guarantee the outer channel sleeve bone thickness does not exceed 3 mm, that is, the joint of ventral osteothickness will not exceed 3 mm; even if the foraminal end is extremely narrow, requiring secondary osteotomy, the tongue of the outer channel location sleeve remains in the joint block to prevent excessive removal of ventral bone instability. External channel location sleeve length is 180 mm, through the long tongue vertex, and the relationship between the penetration can accurately assess the depth of the tunnel into grinding, completing foraminal enlargement. This could help avoid bone drilling into the spinal canal, which could cause walking nerve root and dural damage. Such tool is especially advantageous for patients with spinal stenosis.

The safety of channel osteotomy is high. Traditional tools are guided by the central guide wire, and the bone drilling thread is directly connected to the surrounding soft tissue. After reaching the foramina to the spinal canal, once in contact with the outlet nerve root, there is a risk of nerve root injury [11, 12]. After completion of foraminal enlargement using the ECLS, the external channel location sleeve long tongue remains with the ventral side of the osteotomy surface in the form of a hole; bone debris from bone grinding are left in the hole and not scattered around the foramina. Therefore, endoscopy can be completely clean, which ensures the safety of osteotomy.

There were some limitations in this study. The number of cases was relatively low, and the accuracy and safety of mechanical operation for this tool need further statistical analysis with traditional technology. However, the author has rich experience in traditional foraminal endoscopic surgery; in clinic, the external channel location system would be used for mechanical operation instead of feel experience, and is a promising technology for foraminal expansion.

5. Conclusion

The ECLS might have favorable improvement for intraoperative parameters and outcomes of FEP, which is worth popularizing.

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Conflicts of Interest

The authors declare no conflicts of interest.

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