

# Clinical Application of Transforaminal Percutaneous Endoscopic Lumbar Discectomy Via Superior Notch of Inferior Vertebral Pedicle Approach for Very High-grade Inferiorly Migrated Disc Herniation

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## Research article

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## Abstract

**Background:** To assess the efficacy of the superior notch of inferior vertebral pedicle approach of transforaminal percutaneous endoscopic lumbar discectomy for very high-grade inferiorly migrated disc herniation.

**Methods:** Data on 32 consecutive patients operated with percutaneous endoscopic surgery via the superior notch of inferior vertebral pedicle approach were reviewed. Age, gender, clinical diagnoses, operation time, hospitalization time, a self-administered questionnaire composed of the leg pain visual analogue scale (VAS leg pain) and the Oswestry Disability Index (ODI) had been recorded before operation and 1, 3, 6 and 12 months after operation, respectively. The clinical results were assessed at the final follow-up by using modified Macnab criteria. Complications were recorded during follow-up, and postoperative X-ray, CT and MRI examinations were performed.

**Results:** There were 21 males and 11 females. The mean age of patients was  $51.8 \pm 10.6$  years. MRI findings of patients with disc herniation were L2-3 level in 4 case, L3-4 level in 9 cases and L4-5 level in 19 cases, which were correlated with clinical symptoms. All patients completed a 12-month follow-up assessment after surgery. The mean operative duration was  $68.2 \pm 12.8$  min, and hospitalization time was  $3.6 \pm 0.8$  days. At 12 months follow up the VAS leg pain had improved by 6.3 ( $P < 0.05$ ) and the ODI by 43.6 points ( $P < 0.05$ ). Twenty-three cases (71.9%) were rated as excellent, 7 (21.9%) as good, 2 (6.2%) as fair at the final follow-up. On the basis of the modified MacNab criteria, the overall excellent and good rate was 93.8%. Two patients (6.2%) had transient dysesthesia after surgery. Postoperative radiological evaluations showed no signs of instability or recurrence of pathology.

**Conclusion:** Transforaminal percutaneous endoscopic lumbar discectomy via the superior notch of inferior vertebral pedicle approach could be a safe and effective minimally invasive technique for very high-grade inferiorly migrated disc herniation. This technique warrants further study and clinical application.

## Background

Percutaneous endoscopic lumbar discectomy (PELD) is a promising minimally invasive technique for the treatment of lumbar degenerative diseases such as lumbar disc herniation (LDH). Compared with standard open discectomy, the potential advantages of minimally invasive discectomy include less hemorrhage, much lower risk of intraspinal and superficial tissue infections, shorter hospitalization time, and earlier rehabilitation of routine work activities[1]. However, due to anatomical barriers, such as pedicle and narrowing of the foraminal space, it is sometimes difficult to insert the working cannula and the surgical scope is limited. Therefore, PELD has not been considered as the best treatment option for very high-grade inferiorly migrated disc herniation[2–4](Fig. 1). Very high-grade inferiorly migrated disc herniation was defined as a disc migration beyond the inferior margin of the pedicle[2, 4]. Due to the residual disc fragments, the surgical success rate of the surgery in the very high-grade inferiorly migrated lumbar disc herniation may be low[3]. Advances in surgical equipment and techniques provide opportunities to improve the surgical efficacy[2, 3, 5–10]. In order to expand the scope of the operation and gain access to the target, we adopted the superior notch of inferior vertebral pedicle approach. The aim of our study is to assess the surgery procedure for treatment of the very high-grade inferiorly migrated disc herniation through the superior notch of inferior vertebral pedicle approach, evaluate its clinical outcomes and provide the references for clinical treatment.

## Material And Methods

### Patients

The clinical data of 32 patients treated by endoscopic surgery via the superior notch of inferior vertebral pedicle approach from April 2016 to November 2019 in the Third Hospital of Hebei Medical University were analyzed retrospectively. All patients underwent routine preoperative X-ray, Computed Tomography (CT), and Magnetic Resonance Imaging (MRI)

examinations to clarify the diagnosis and preoperative planning. This study has been approved by the ethics committee of our hospital, and all the subjects investigated had signed informed consent forms.

The inclusion criteria were as follows: preoperative diagnosis of very high-grade inferiorly migrated lumbar disc herniation (as shown in Fig. 1), severe or intolerable unilateral radicular leg pain with or without sensory change, motor weakness, or decreased deep tendon reflex; no remission after conservative treatment for more than 6 weeks; corresponding nerve root compression was confirmed by imaging examination and related to neurological examination.

The exclusion criteria were definitive spinal stenosis, segmental instability, peripheral nerve disease, acute inflammation, malignant tumor or inflammation.

## **Surgical Methods**

Local anesthesia was performed in all cases. Patients could communicate with surgeons in time in a conscious state during the operation. The patients were placed on the C-arm fluoroscopy bed and took the prone position for operation.

There are differences in entry point and working cannula trajectory between superior vertebral pedicle notch approach and conventional approach (Fig. 2). The caudal angle was adjusted by the target area on the X-ray anteroposterior view. An inferiorly migrated case required a greater caudal angle. The skin entry point was located at a distance of about 8–14 cm from the midline horizontally. The length of this distance was determined by the preoperative imaging examination and the size of the patient. If the patient was obese, the distance from the midline was longer, otherwise, it is shorter. After successful local anesthesia, an 18-gauge needle at an angle of 30°–50° to the horizontal plane was inserted and pushed forward to the superior notch of the lower vertebra pedicle under the guidance of C-arm fluoroscopy. When the tip of the needle was located at the midline of the anterior and posterior fluoroscopy, the needle tip on the lateral fluoroscopy should contact the superior notch of the inferior vertebral pedicle (Fig. 2). Then use a 0.8 mm guide wire instead of the needle. Next, an approximately 8 mm incision was made. Adjust the direction as required to make the direction of the guide wire head-end reach the target, and insert the curved guide rod along the guide wire. Sequential reamers were introduced after the guide rod and tube insertion. Partial upper facet joints were removed using the reamer to enlarge the nerve foramen. Remove the last used reamer and insert the working cannula into the target. In the case of a very high-grade inferiorly migrated disc herniation, in order to expand the scope of the operation and to approach the target, cancellous bone was removed from the posterior superior margin of the lower vertebral body after foraminoplasty (Fig. 3). During the operation, the epidural space and the traversing nerve root will be exposed, occasionally the ruptured intervertebral disc material will be exposed first, so it could be easily removed. However, in most cases, the material of the intervertebral disc is located below the traversing nerve root, and care must be taken to avoid damaging the nerve root. Generally, the osteophyte of the posterior margin of the vertebral body and calcified posterior longitudinal ligament could be removed by the rotating endoscope and working cannula, and the dorsal and ventral sides of the nerve roots complete decompression could be realized. After the intervertebral disc material was removed, massive bleeding was controlled with a radiofrequency probe, bipolar coagulation and continuous saline irrigation. The working cannula and endoscope were removed after the evaluation of the nerve root. The operation time was recorded and routine treatment was given after the operation. 24 hours after operation, the patients were able to resume moderate activity with the assistance of girdle brace and adequate protection, and avoid strenuous activities or hard physical labor within 3 months after operation.

## **Data Collection**

### **General patient data**

Data of each patient were collected, including age, gender, lesion site, operation time, hospitalization time, any complications, and improvement of postoperative symptoms. Data were collected from patient charts, patient-based

outcome questionnaires on a regular visit, and telephone interviews.

## Clinical Assessment

The severity of lower limb pain was evaluated by visual analogue scale (VAS). The improvements in neurological function were assessed by Oswestry disability index (ODI). The final follow-up modified MacNab criteria scores were recorded for evaluating the early clinical outcomes. The four grades of the modified MacNab criteria are as follows[11]: Excellent: Complete elimination of symptoms, work activities and quality of life returned to the original levels. Good: Mild symptoms, minor activity restrictions without affecting the routine work and quality of life. Fine: Symptoms relieved, limited activity, affecting work and quality of life. Poor: Symptoms were no difference or deterioration after treatment than before. All cases finished the self-administered questionnaires (ODI and VAS for leg pain) before and at 1, 3, 6 and 12 months after surgery, respectively. The modified MacNab criteria were assessed by the patients at the final follow-up. All the data were collected by a doctor who was not involved in the treatment.

## Imaging Assessment

X-ray, CT and MRI examination of lumbar spine were performed at 1 month, 3 months and 12 months after operation, respectively. Lumbar spine flexion-extension X-ray was performed to evaluate whether there was intervertebral instability. CT was performed to observe the extent of resection of the posterior superior margin of the vertebral body and the related changes. MRI was performed to observe whether the nerve root and the dural sac were completely decompressed and whether there was recurrence in the operative segment.

## Statistical analysis

All of the statistical analyses were performed by SPSS 22.0 (SPSS Inc, Chicago, IL, USA). The measurement data were presented as means  $\pm$  standard deviation. The paired variance t-test was used to compare preoperative and postoperative scores. When  $P < 0.05$  was achieved, the difference was regarded as statistically significant.

## Results

### Patient demographic characteristics

From April 2016 to November 2019, 32 patients with very high-grade inferiorly migrated lumbar disc herniation underwent endoscopic surgery by using the superior notch of inferior vertebral pedicle approach. There were 21 males and 11 females with a mean age of  $51.8 \pm 10.6$  years. The mean operation time and the mean hospitalization time were  $68.2 \pm 12.8$  min and  $3.6 \pm 0.8$  days, respectively. The details and characteristics of all patients were shown in Table 1.

Table 1  
Patient demographics and characteristics

Item	Means $\pm$ SD (range) or n (%)
Age (years)	51.8 $\pm$ 10.6 (21–68)
Sex	
Male	21 (65.6)
Female	11 (34.4)
Levels involved	
L2-L3	4 (12.5)
L3-L4	9 (28.1)
L4-L5	19 (59.4)
Complications	2 (6.3)
Transient dysesthesia	2 (6.3)
Operation time (min)	68.2 $\pm$ 12.8 (51–98)
Hospitalization time (days)	3.6 $\pm$ 0.8 (3–5)

## Vas Scores

The mean VAS score of leg pain before the operation was  $8.42 \pm 1.21$ , which improved to  $2.72 \pm 1.12$ ,  $2.21 \pm 0.96$  and  $2.12 \pm 0.86$  at 1 month, 3 months and 12 months after surgery, respectively. Compared with the preoperative VAS score, the difference was statistically significant ( $P < 0.05$ , Table 2). These results showed that the symptoms of leg pain were significantly relieved and gradually improved after the operation.

Table 2  
VAS score results

Time	Pre-op	1 months post-op <sup>a</sup>	3 months post-op <sup>b</sup>	6 months post-op <sup>c</sup>	12 months post-op <sup>d</sup>
VAS score	$8.42 \pm 1.21$	$2.72 \pm 1.12$	$2.21 \pm 0.96$	$2.16 \pm 0.92$	$2.12 \pm 0.86$

VAS scores are presented as means  $\pm$  standard deviation ( $\bar{x} \pm s$ ,  $n = 32$ ). op operation. "a, b, c and d" respectively represents the comparison between 1 month, 3 months, 6 months and 12 months postoperatively and preoperatively. The paired t-test analysis showed that  $P^a$ ,  $P^b$ ,  $P^c$ , and  $P^d \leq 0.0001$ , the differences were statistically significant.

## Odi Scores

The mean preoperative ODI was  $68.45 \pm 9.32$ , which improved to  $33.46 \pm 10.32$ ,  $27.62 \pm 8.98$  and  $24.86 \pm 8.32$  at 1 month, 3 months and 12 months after operation, respectively. Compared with the preoperative ODI score, the differences were statistically significant ( $P < 0.05$ , Table 3). These results showed that the symptoms of the patients were relieved and their functions were gradually improved.

Table 3  
ODI score results

Time	Pre-op	1 months post-op <sup>a</sup>	3 months post-op <sup>b</sup>	6 months post-op <sup>c</sup>	12 months post-op <sup>d</sup>
ODI score	68.45 ± 9.32	33.46 ± 10.32	27.62 ± 8.98	26.43 ± 8.64	24.86 ± 8.32

VAS scores are presented as means ± standard deviation ( $x \pm s$ , n= 32). op operation. "a, b, c and d" represent the comparison between 1, 3, 6, and 12 months postoperatively and preoperatively, respectively. The paired t-test analysis showed that P<sup>a</sup>, P<sup>b</sup>, P<sup>c</sup>, and P<sup>d</sup> < 0.0001, the differences were statistically significant.

## Clinical Efficacy

At 12 months follow-up, 23 cases (71.9%) were rated as excellent, 7 (21.9%) as good, 2 (6.2%) as fair on the basis of the modified MacNab criteria. The overall excellent and good rate was 93.8% (Table 4).

Table 4  
Modified MacNab criteria

Outcome	Definition	n (%)
Excellent	Complete resolution of symptoms	23 (71.9)
Good	Mild symptoms, minor activity restrictions without affecting work and quality of life	7 (21.9)
Fair	Symptoms relief, activity restrictions that affect work and quality of life	2 (6.2)
Poor	Unimproved symptoms or worsening	0 (0)

## Imaging Results

All patients underwent routine lumbar spine flexion-extension X-ray and CT during various postoperative follow-up periods, which revealed no intervertebral instability. Lumbar spine CT reexamination showed that the resection range of the posterior superior margin of the vertebral body. There was no fracture in the corresponding vertebral body (Fig. 5). Compared with pre-operation, lumbar MRI reexamination showed complete spinal canal decompression and no recurrence in the operative segments (Fig. 4).

## Complications

Two patients suffered from postoperative temporary dysesthesia, and symptoms recovered over a 3-month period after treatment with gabapentin and mecobalamin. Complications such as intraspinal infections, superficial tissue infections, cerebrospinal fluid leakage, dura mater injury, corresponding segment instability, and local anesthesia-related perioperative complications were not found in this group of patients. The incidence rate of surgical complications was 6.2%.

## Discussion

With the development of surgical instruments and surgical techniques, the concept of PELD has shifted from indirect intervertebral decompression to epidural targeted decompression, and common types of disc herniation can be treated with PELD[3–7]. However, it is still a challenge for the very high-grade inferiorly migrated disc herniation. In the case of very high-grade inferiorly migrated disc herniation, endoscopic discectomy is less successful because endoscopic access to the lesion is often interrupted by anatomical structures, such as pedicle and narrowing of the foraminal space [7]. Lee et al[12]. analyzed 55 cases of failed endoscopic discectomy. The high-grade migration group showed a failure rate of 15.7% due to

the inadequate scope of the operation, poor visual field, insufficient decompression, and residual disc. Therefore, they suggested that open surgery should be performed for high-grade migration disc herniation[12]. However, open discectomy will inevitably destroy paravertebral muscles, vertebral lamina, and articular processes, affecting spinal instability[6]. To overcome these limitations, some methods have been developed, such as the extreme lateral approach, epiduroscopic approach, superior vertebral notch approach, and suprapedicular approach[6, 13–16]. No matter what surgical approach, the most fundamental breakthrough is that the working cannula should be as close to the target as possible[6]. The superior notch of inferior vertebral pedicle approach is a method of removing a migrated disc through the narrow space of the intervertebral foramen in the transitional region between the superior notch of the pedicle and the posterior margin of the vertebral body. Through the foraminoplasty and the removal of partial cancellous bone from the posterior superior margin of the lower vertebral body, the working cannula can be inserted into the target. The superior notch of inferior vertebral pedicle approach has several advantages. This approach requires that the needle should have a certain cephalad and lateral angle, which is greater than that in the TESSYS (transforaminal endoscopic spine system). The channel is longer than that of the TESSYS and can reach the inferior border of the pedicle and even the lower endplate of the inferior lumbar vertebrae. Expanded the surgical space and decompression range of the spinal canal. The dural sac can be exposed inwards, and the external orifice of the intervertebral foramina can be reached outwards. The exiting nerve root can be exposed upwards and the compression of the nerve root caused by the degenerated annulus fibrosus or osteophytes at the posterior border of the lumbar vertebral can be relieved. The inferior border of the vertebral pedicle and even the lower endplate of the inferior lumbar vertebral body can be reached downwards. The compression of the dorsal and ventral nerve roots can be completely alleviated.

For very high-grade inferiorly migrated disc herniation, targeted puncture, foraminoplasty, application of endoscopic grinding drill, and adjustment of working channel scope are particularly important to ensure the success of the operation. An optimal puncture trajectory should always aim at or approach the target as much as possible, which is most important for herniated fragments[5, 6, 17]. Because as close as possible to the target, it is conducive to the foraminoplasty, and the obstruction of the articular process to the working cannula can be minimized in the subsequent operation. For cases of very high-grade inferiorly migrated disc herniation, the entry point should have a certain cephalad and lateral angle. The puncture target was located in the midline of the anterior and posterior fluoroscopy and in the superior notch of the lower vertebral pedicle the lateral fluoroscopy (Fig. 2). For the L4/5 and L5/S1 levels, due to the obstruction of the iliac crest, articular process, and transverse process, it is sometimes not possible to accurately puncture the target, and curved guide rods can be used for fine adjustment. Foraminoplasty is helpful in order to be able to enter the epidural space and obtain high-grade migration fragments[6]. However, this procedure may lead to nerve injury and the tip of the articular process damage, increase the risk of postoperative segmental instability and lead to the most common complication of postoperative dysesthesia[5, 6, 18–20]. Therefore, the procedure should pay close attention to the patient's pain response during operation and adjust according to the situation of fluoroscopy. In this study, the resection area of foraminoplasty is the ventral side of the superior articular process. This area is the safest anatomical point, farthest from the nerve root. This procedure may reduce the risk of the exiting nerve root injury during operation to some extent on the basis of the anatomic relationship between exiting nerve root and foramen. There were two cases (6.2%) suffered from postoperative transient dysesthesia in this group of patients. The reasons may be irritation associated with the surgical approach, excessive intraoperative manipulation, and early unfamiliarity with the posterior lumbar anatomy. VAS leg scores improved from  $8.42 \pm 1.21$  to  $2.12 \pm 0.86$ , and ODI improved from  $68.45 \pm 9.32$  to  $24.86 \pm 8.32$ . The overall excellent and good rate was 93.8% on the basis of the modified MacNab criteria. In recent years, other endoscopic techniques have reported an overall success rate of high or very very high-grade migrated disc herniation ranged from 84.6–100%[3–5, 13, 21] (Table 5). Our results are basically consistent with those reported by other endoscopic techniques. In our opinion, this technique is difficult to directly compare with the previously reported methods, because the diagnosis of the study population is different and the surgical techniques are also different. However, compared with other endoscopic techniques, it may be helpful to prove the efficacy of the superior notch of inferior vertebral pedicle approach.

Table 5  
Comparison of clinical and surgical results with other endoscopic techniques

Author	Number of patients	Diagnosis	Mean operative duration (min)	Mean hospital time (day)	Mean follow-up period (month)	Surgical technique	Success rate (%)	Complication
Lee CW et al. [5]	64	Highly migrated, High canal compromised, combined with foraminal stenosis	45.6	1.54	12.2	Foraminoplastic superior vertebral notch approach	95.3	2 dysesthesia 1 reoperation
Wu X et al. [21]	22	highly migrated lumbar disc herniation	88.86	1.68	18.1	Two-level PELD	90.9	1 dysesthesia 1 reoperation
Ahn Y et al. [4]	13	Very high-grade lumbar migrated disc herniation			12	PELD with foraminoplasty	84.6	1 dysesthesia
Chae KH et al. [13]	53	Highly inferior Migrated disc herniation	90	1.33	9.8	Suprapedicular approach	88.8	7 dysesthesia
Kim HS et al. [3]	18	high grade inferiorly migrated lumbar disc herniation			8.4	PELD with suprapedicular circumferential opening technique	100	No
Present study	32	Very high-grade inferior migrated disc herniation	68.2	3.6	12	Superior notch of inferior vertebral pedicle approach	93.8	2 dysesthesia
PELD: percutaneous endoscopic lumbar discectomy								

When the inferiorly migrated disc material is beyond the visual scope of the endoscope and cannot be completely removed, under the premise of protecting the nerve root and dural sac, part of the superior margin of the lower vertebral body or part of the articular process bone was removed with a grinding drill to expand the surgical space. During the operation, the working cannula can be adjusted to the dorsal, ventral and even contralateral sides of the nerve root to perform all-around decompression according to specific conditions. Although our surgical data showed a favorable clinical outcome, the safe range of removal of the posterior superior margin of the lower vertebral body is not completely clear. Our experience is to remove bone as little as possible without affecting the surgical procedure. It is needed to observe the potential risk of vertebral fracture and the stability of the spine over a long time. Don't rush to remove the migrated disc material when it was found during surgery. The surrounding fibrous rings, posterior longitudinal ligaments and scar tissue should be released first.

Shake slowly with the strength of the wrist, which will facilitate the complete removal of the migrated disc material. It is strictly prohibited to "Violent tugging" to avoid remnant disc fragments, or even nerve root or dura mater injury. In the case of ensuring sufficient decompression, the surgical operation of the tissues such as the posterior longitudinal ligament, ligamentum flavum and other tissues should be minimized to prevent tissue adhesion after surgery. The removal of the migrated disc material and the removal of the superior margin of the lower vertebral body or the articular process bone are often accompanied by bleeding, resulting in blurred operative field. Do not operate at this time, so as not to avoid side injuries. The bleeding site can be controlled naturally by means of the working cannula compression hemostasis. Appropriate pre-hemostatic treatment of the surrounding tissue was performed with radiofrequency before removal of the migrated disc material, which is helpful to reduce intraoperative bleeding. In addition, hemostasis can be achieved through high-pressure fluid irrigation, absorbable gelfoam and other hemostatic materials.

There are some limitations to our study. First, it was a retrospective analysis of cases in a single institution. Second, this study has a small sample size and a lack of the control group and short duration of follow-up. Long-term large sample study and follow-up observation are needed to evaluate the clinical outcomes.

## **Conclusion**

Transforaminal percutaneous endoscopic lumbar discectomy via superior vertebral pedicle notch approach could be a safe and effective minimally invasive technique for very high-grade inferiorly migrated disc herniation. This approach can achieve satisfactory clinical results and reduce the incidence of dysesthesia caused by exiting nerve root irritation. However, the removal of partial cancellous bone from the posterior superior margin of the lower vertebral body may result in long-term bone defects. The clinical results and the biomechanical changes in the corresponding lumbar vertebral body should be paid close attention to for a long time.

## **Declarations**

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### **Availability of data and materials**

All relevant data supporting the conclusions are included within the article and tables. The dataset used and analyzed during the current study are available from the corresponding author on reasonable request.

### **Ethics approval and consent to participate**

The study was approved by the Ethical Review Boards of The Third Hospital of Hebei Medical University. All procedures performed in studies involving human participants were in accordance with the ethical standards and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

### **Competing interests**

The authors declare that they have no conflict of interest.

### **Consent for publication**

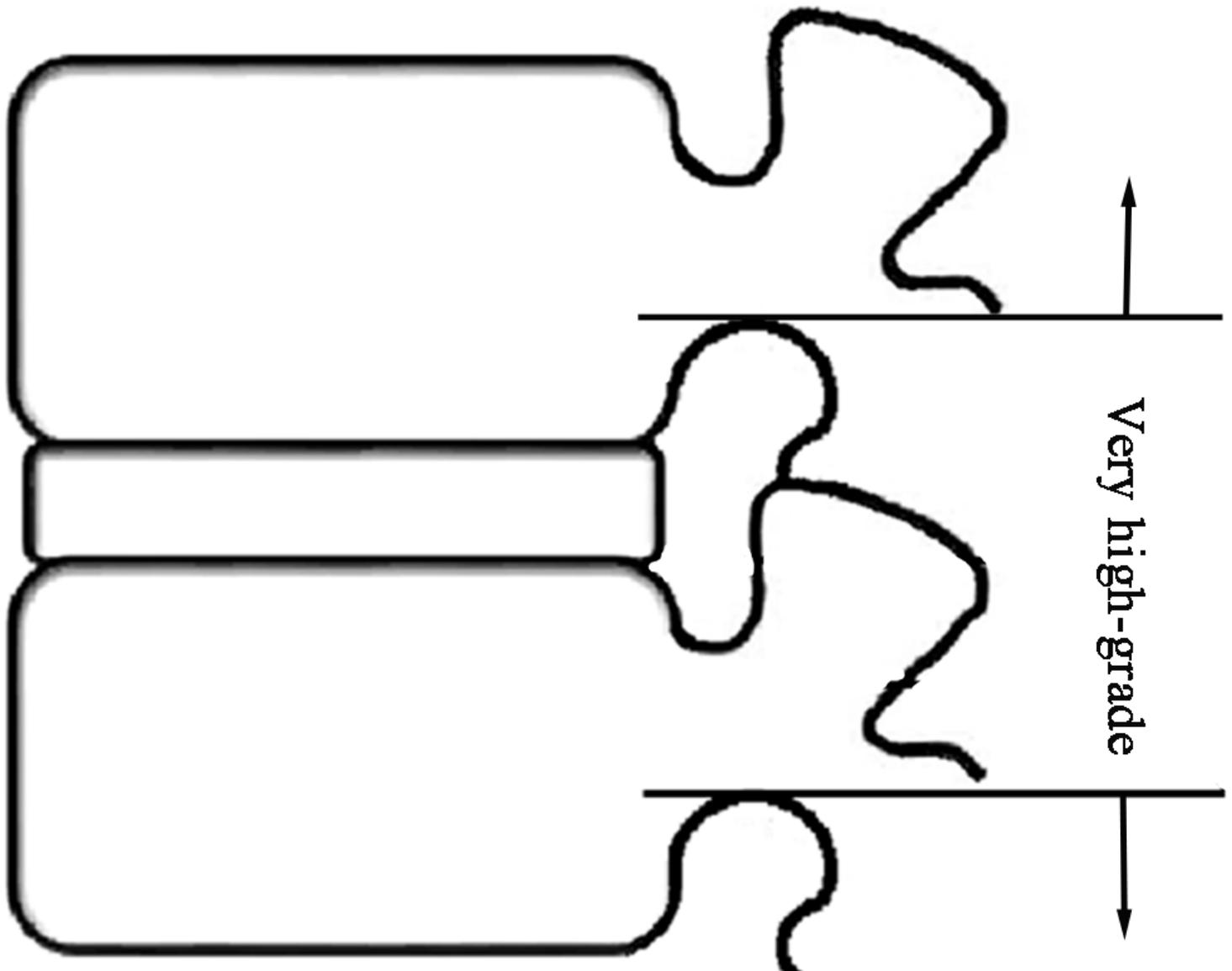
All surgical images and data included in this paper have obtained informed consents from related participants.

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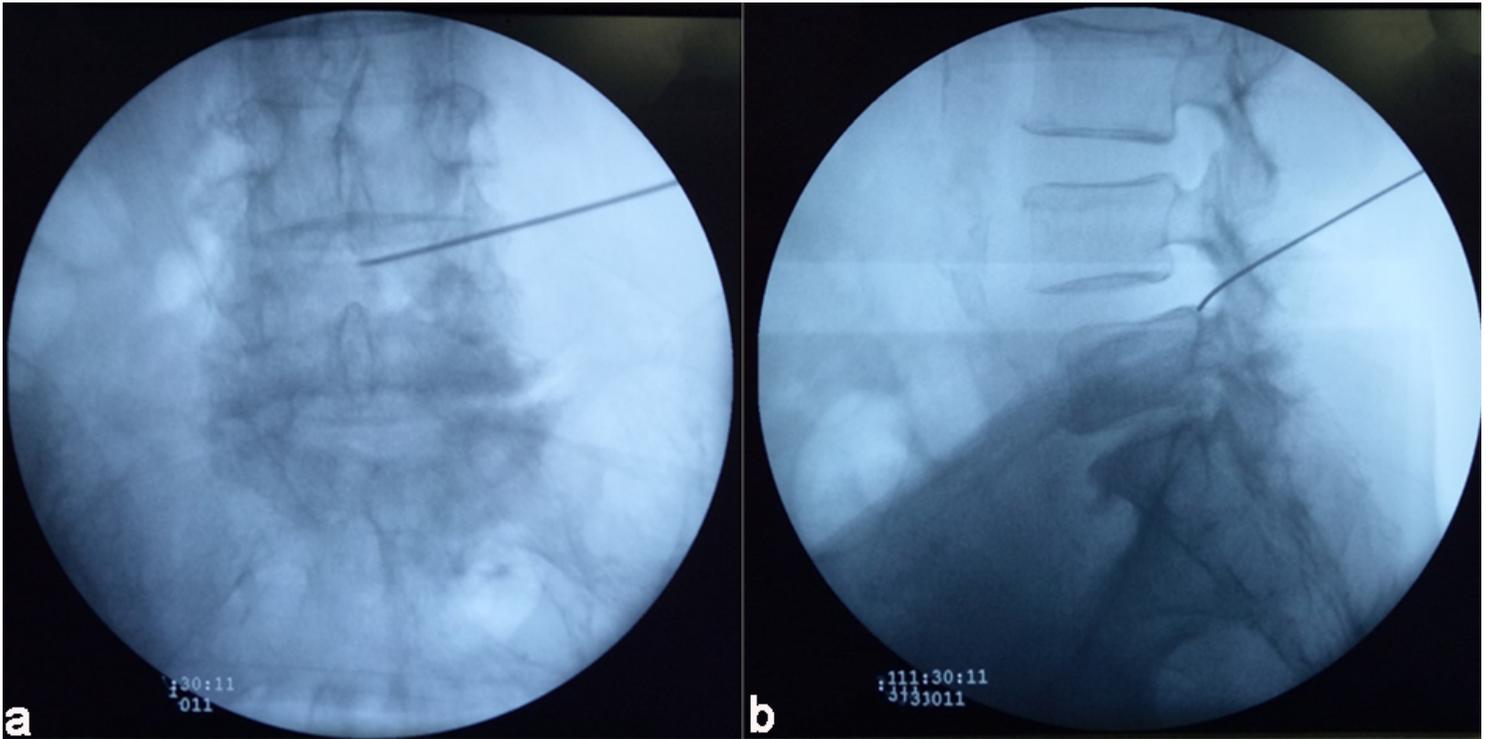
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## Figures



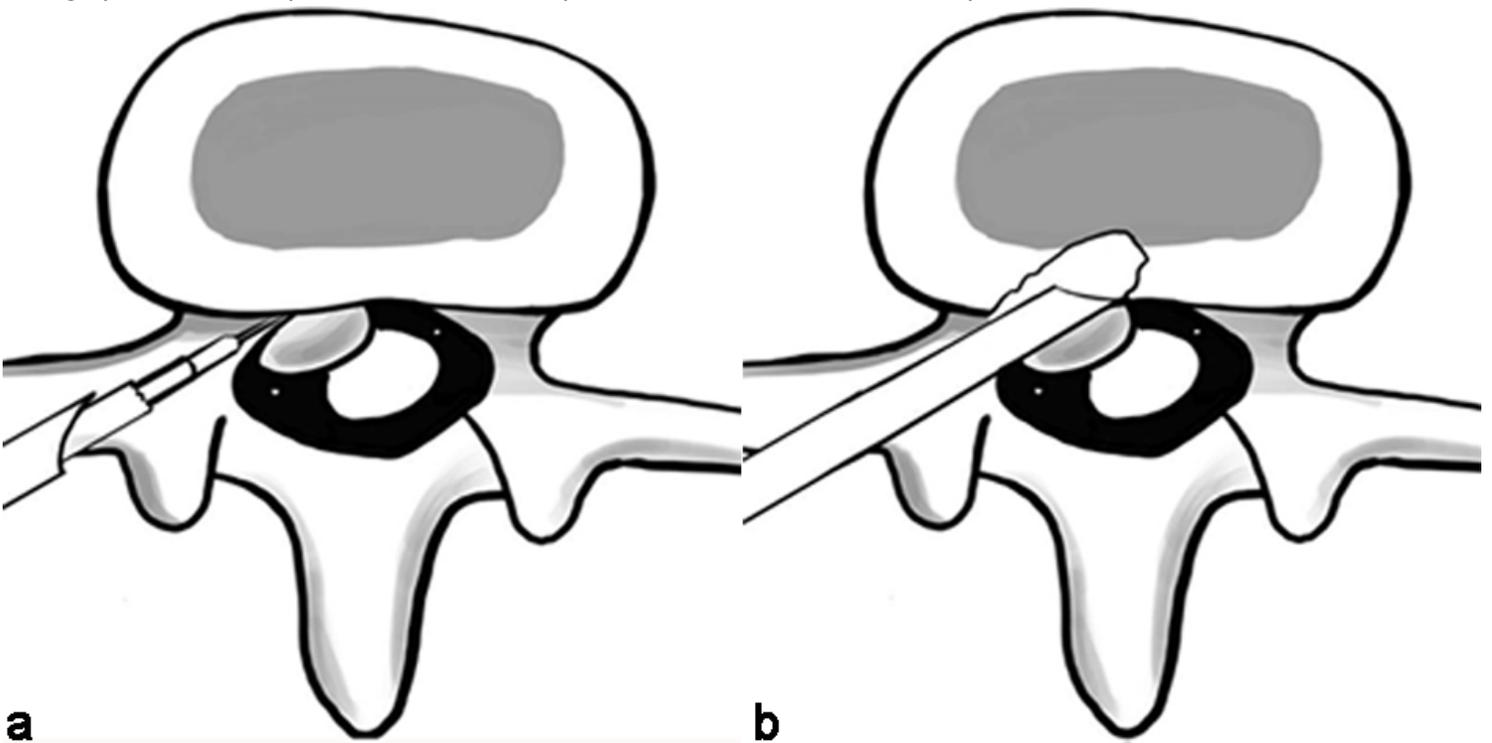
**Figure 1**

Very high-migrated lumbar disc herniation: a disc migration that extends beyond the inferior margin of the pedicle in either cranial or caudal direction.



**Figure 2**

Needle insertion to target. a On the anteroposterior radiograph, the needle tip was located at the midline. b On the lateral radiograph, the needle tip was located at the superior notch of the lower vertebral pedicle



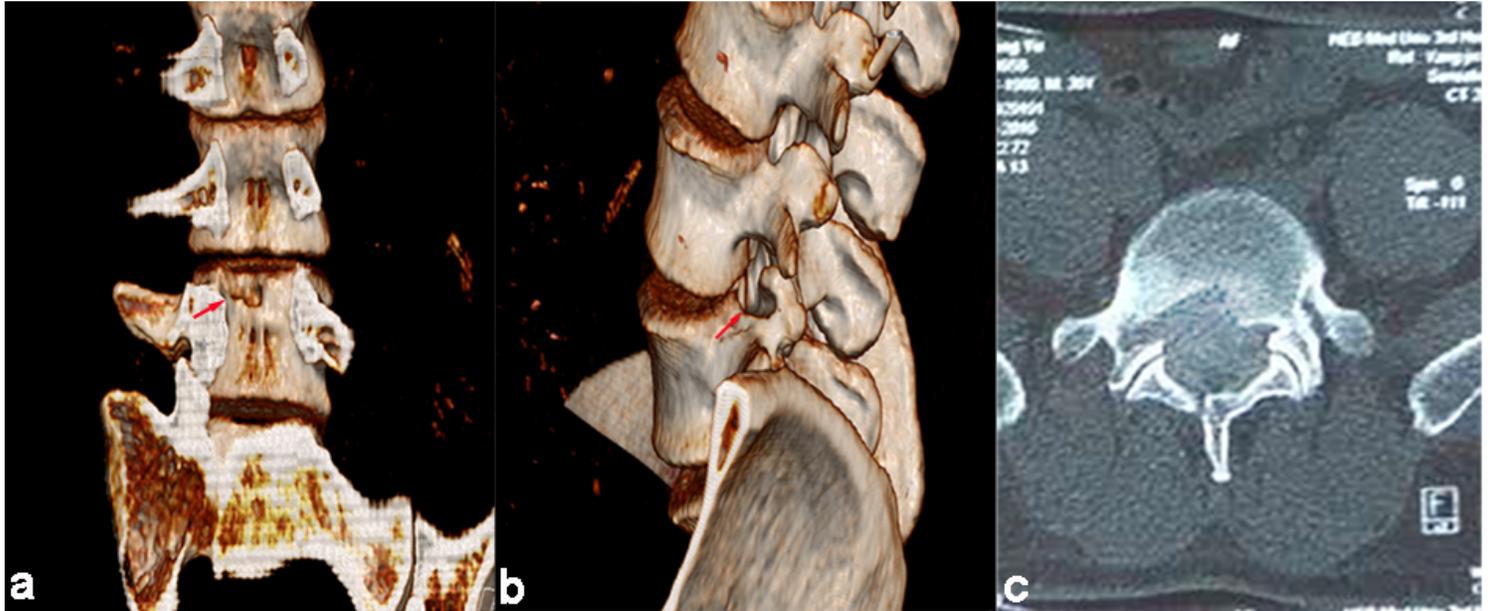
**Figure 3**

The removed procedures of the posterior superior margin of the vertebral body. a Taking the posterior superior margin of the lower vertebral body as the insertion target. b Partial removal of the posterior superior margin of the lower vertebral body to expand the scope of surgery.



**Figure 4**

High-grade inferiorly migrated disc type. A 27-year-old male with a very high-grade inferiorly migrated disc herniation. a Preoperative magnetic resonance image (MRI) showing a large, very high-grade inferiorly migrated disc material. b, c The fluoroscopic images of the location of the working cannula. Anteroposterior position (b) and lateral (c) fluoroscopic view of the superior notch of inferior vertebral pedicle approach. d Sagittal T2 MRI at 3 months postoperatively demonstrates resolution of the herniated disk. e Endoscopic view of the superior notch of inferior vertebral pedicle approach. f Endoscopic view of the nerve root shows that it was totally released after decompression (the red triangle indicates the nerve root).



**Figure 5**

Postoperative CT imaging. The posterior superior margin of the vertebral body and the ventral side of the superior articular process was removed (red arrow).