

## Retrospective Study

# Percutaneous Full-Endoscopic Anterior Transcorporeal Cervical Discectomy for the Treatment of Cervical Disc Herniation: Surgical Design and Results

Xi Chen, MD<sup>1</sup>, Jian-An Gao, MD<sup>2</sup>, Qian Du, MD<sup>3</sup>, Yang Qiao, MD<sup>4</sup>, Wei-Jun Kong, MD<sup>3</sup>, and Wen-Bo Liao, MD<sup>3,5</sup>

From: <sup>1</sup>Department of Rehabilitation, The Affiliated Hospital of Southwest Medical University, Luzhou, Sichuan, China; <sup>2</sup>Department of Hospital Infection Control, The First People's Hospital of Zunyi, Zunyi, Guizhou, China; <sup>3</sup>Department of Spine Surgery, The Second Affiliated Hospital of Zunyi Medical University, Zunyi, Guizhou, China; <sup>4</sup>Department of Orthopaedic Surgery, Henan Provincial Orthopedic Hospital, Zhengzhou, Henan, China; <sup>5</sup>Department of Spine Surgery, The Affiliated Hospital of Zunyi Medical University, Zunyi, Guizhou, China

Address Correspondence:  
Wen-Bo Liao, MD  
Department of Spine Surgery,  
The Affiliated Hospital of Zunyi  
Medical University, No. 149  
Da Lian Road, Zunyi, Guizhou  
563000, China  
E-mail: wenbo900@sina.com

Disclaimer: There was no external funding in the preparation of this manuscript.

Conflict of interest: Each author certifies that he or she, or a member of his or her immediate family, has no commercial association (i.e., consultancies, stock ownership, equity interest, patent/licensing arrangements, etc.) that might pose a conflict of interest in connection with the submitted manuscript.

Manuscript received: 11-09-2020  
Revised manuscript received:  
01-22-2021  
Accepted for publication:  
01-28-2021

Free full manuscript:  
[www.painphysicianjournal.com](http://www.painphysicianjournal.com)

**Background:** Studies that focus on percutaneous full-endoscopic anterior transcorporeal cervical discectomy (PEATCD) have rarely been reported. Therefore, the available data on the surgical design of PEATCD and related clinical outcomes are very limited.

**Objectives:** To design a surgical plan for PEATCD and to evaluate its clinical efficacy in clinical application.

**Study Design:** A retrospective cohort study.

**Setting:** A center for spine surgery, rehabilitation department and pain medicine.

**Methods:** Based on the size and precise location of the disc protrusions on magnetic resonance imaging (MRI), the diameter and direction of the bone channel were designed to make a surgical plan for PEATCD. A total of 26 patients with central/paracentral cervical disc herniation (CDH) who underwent PEATCD through the designed surgical plan from October 2015 to September 2016 were enrolled in the retrospective study. Clinical outcome evaluations included Visual Analog Scale (VAS) scores, Japanese Orthopedic Association (JOA) scores, and the modified Macnab criteria. Radiologic follow-up included cervical computerized tomography (CT) and MRI evaluations.

**Results:** The diameter of the designed bone channel was about 7.5 mm, and the direction was from the upper edge of the lower endplate obliquely toward the disc protrusion. Through the designed surgical plan, 26 cases of discectomy were successfully completed. The average operation time was  $91.50 \pm 16.80$  min, and the average hospital stay was  $4.07 \pm 0.84$  days. All patients were followed for an average of  $19.61 \pm 4.04$  months. The postoperative VAS and JOA scores were significantly improved compared with the preoperative scores ( $P < 0.0001$ ). Clinical efficacy at the final follow-up was evaluated by the modified Macnab criteria, and the excellent and good rate was 92.31%. Postoperative MRI showed that the disc protrusion was completely removed, and CT showed no collapse of the vertebral body.

**Limitations:** This study has several limitations, including the lack of a control group, the small sample size, and the unavoidable nature of the single-center study design.

**Conclusions:** Based on the size and location of the disc protrusion on MRI, the diameter and direction of the bone channel are designed, which is conducive to have enough space under the full-endoscopic field of view to completely expose and remove the disc protrusion, to avoid residuals, and to ensure that PEATCD achieves good therapeutic results.

**Trial registration:** The study was registered at Chinese Clinical Trial Registry (ChiCTR1900027820).

**Key words:** Percutaneous full-endoscope, anterior transcorporeal approach, cervical discectomy, cervical disc herniation, minimally invasive surgery

**Pain Physician 2021; 24:E811-E819**

**C**ervical disc herniation (CDH) is a type of cervical spondylosis caused by degenerative or acute injury of the cervical disc; the nucleus pulposus in the disc protrudes and compresses the spinal cord or spinal nerve root to cause clinical symptoms. Surgical treatment is the most accurate and effective method when conservative treatment is ineffective or when the symptoms are severe. Anterior cervical discectomy and fusion (ACDF) is still the standard procedure for the treatment of CDH because of its excellent clinical treatment effect (1-4); however, as the number of procedures increases, there is an increased risk for fusion-related complications, such as the loss of mobility of cervical fusion segments, the degeneration of adjacent segments, nonunion of the bone graft, pseudoarthroses, and loosening of the metallic plates (5-8). To avoid these complications as much as possible, spine surgeons have explored and improved the technique of anterior cervical surgery.

In recent years, with the development of minimally invasive spinal surgery, full-endoscopic techniques have been applied for spinal degenerative diseases due to the advantages of less trauma, clear vision, and fast postoperative recovery (9-11). Endoscopic discectomy via the transdiscal approach for CDH was originally proposed by Bonaldi et al (12). However, the transdiscal approach inevitably damages the degenerated disc; some studies have reported a significant decrease of intervertebral disc height and accelerated degeneration of the intervertebral disc space (13-15). Deng et al (16) first reported the percutaneous full-endoscopic technique to establish a bone channel through the vertebral body for cervical discectomy in 2016. Du et al (17) reported the results of 1-year follow-up of 36 cases of CDH treated with percutaneous full-endoscopic anterior transcorporeal cervical discectomy (PEATCD). The symptoms of all the patients were significantly improved, and no complications related to surgery occurred. The clinical effect was satisfactory. Yu et al (18) reported 35 cases of CDH treated with PEATCD, and all the patients were followed up for 2 years, with good clinical results at the end of the follow-up.

The key technical issue of PEATCD is to establish a bone channel of suitable size and proper direction. If the bone channel is too large, it may lead to the collapse of the drilled vertebral body; if the bone channel is too small, the disc protrusion may not be completely removed. This study aimed to design the diameter of the bone channel by measuring the size of the disc protrusion on MRI, so that the disc protrusion can be

completely exposed and completely removed under the full-endoscopic field of view, while minimizing the damage to vertebral bone tissue. The surgical plan of PEATCD and its results are reported as follows.

## **METHODS**

### **Surgical Design**

Cervical MRI data from 40 patients with single-level central/paracentral CDH were selected at random, and the height and width of the disc protrusion were measured using IMPAX software (Version 6.3.1; AGFA, Mortsel, Belgium). On the most obvious MRI sagittal plane of the disc protrusion, the upper and lower intersections of the disc protrusion and the posterior longitudinal ligament were measured as the height; on the most obvious MRI axial plane of the disc protrusion, the left and right intersections of the disc protrusion and the posterior longitudinal ligament were measured as the width (Fig. 1). Based on the measured height and width of the disc protrusions, we designed the diameter of the bone channel to completely expose and completely remove the disc protrusion under the full-endoscopic field of view. Based on the precise location of the disc protrusion, the direction of the bone channel should be designed to minimize iatrogenic injury of the degenerated disc and the upper endplate (Fig. 2).

### **Patient Selection**

The study was approved by the ethics committee of Affiliated Hospital of Zunyi Medical University. Informed consent was obtained from all patients before enrollment. The inclusion criteria were as follows: 1) single-level central or paracentral CDH with soft protrusion, 2) symptoms not improved after 3 months of standardized conservative treatment, 3) symptoms confirmed by relevant imaging examination, 4) disc protrusion migration but no free, and 5) no cervical instability. The exclusion criteria were as follows: 1) lateral CDH, 2) lesions more than one segment, 3) disc protrusion calcification, osteophytes present behind the vertebral body, 4) symptoms not consistent with imaging examinations, 5) free disc protrusion in the spinal canal, 6) lesion segments with a history of surgery, and 7) osteoporosis. A total of 26 patients with central/paracentral CDH who underwent PEATCD through the designed surgical plan from October 2015 to September 2016 were enrolled in the retrospective study. The patients' characteristics are summarized in Table 1.

### Full-Endoscopic Instruments

The spinal endoscopy system (SPINENDOS GmbH., Munich, Germany) comprised a 4.3-mm working channel, an outer sheath with a 6.9-mm diameter, a 30°-angled scope with a continuous water irrigation system, a trephine (Joimax, Germany) with a 6.5 mm inner diameter and a 7.5 mm outer diameter. The drill was made by NOUVAG AG, Goldach, Switzerland.



Fig. 1. The measurement method of the height (a) and width (b) of the disc protrusion on MRI (white double arrow).

### Operative Technique

A gastric tube was inserted in all patients before surgery. After anesthesia via tracheal intubation, the patient was placed in the supine position with the neck slightly extended. The entire procedure was monitored using a C-arm. Injection of approximately 20 ml of iohexol into the gastric tube showed the esophageal trajectory under the C-arm, and the tracheal position was displayed under the C-arm after tracheal intubation. The lesion segment was confirmed, and the lower vertebra was located. The two-finger technique was used to touch the anterior edge of the vertebra, and the puncture needle was inserted. The starting position of the puncture needle was placed as close as possible to the lower edge of the vertebra, and then the posterosuperior edge of the vertebra was punctured (Fig. 3a). A transverse skin incision of approximately 8 mm was made at the center of the puncture needle, and the dilator-sheath system and operating cannula were placed along the puncture needle (Fig. 3b). The trephine was inserted and screwed gradually toward the posterosuperior edge of the vertebra; when the end of the trephine reached this point, the resected bone was removed with the trephine by gently shaking it (Fig. 3c). The full-endoscopic system was then placed into

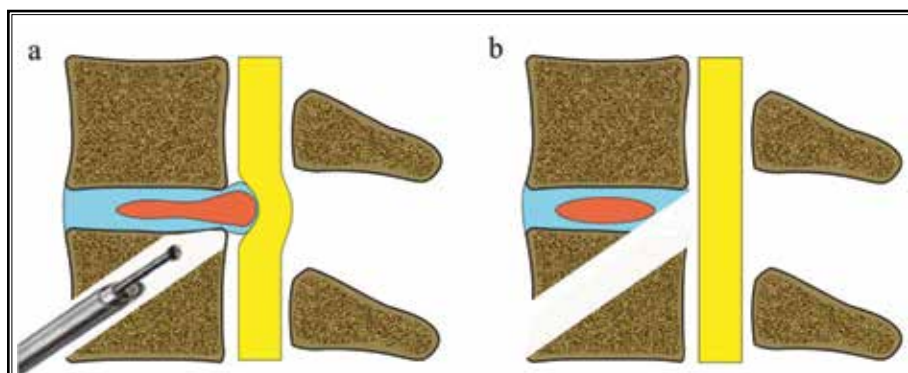


Fig. 2. Artistic illustration of bone channel establishment. The bone channel was established at the upper edge of the lower endplate of the target vertebra and was oriented obliquely toward the disc protrusion (a). Through the designed bone channel, the disc protrusion was fully exposed and completely removed to complete the decompression of the cervical spinal canal (b).

Table 1. Summary of Demographic Characteristics

Baseline Characteristic	Value
Gender, male/female	16/10
Age (range), years	49.14 ± 10.40 (33-72)
Symptom duration (range), weeks	23.8 0± 18.24 (1-60)
Indications for surgery	
Myelopathy	14
Radiculopathy	6
Myelopathy with radiculopathy	6
Treatment level	
C3/4	2
C4/5	12
C5/6	12
Follow-up duration (range), months	19.61 ± 4.04 (12-28)

the bone channel, and the residual bone of the bone channel was cleared using rongeurs and a high-speed diamond burr. If bleeding occurred during surgery, radiofrequency ablation was used to stop the bleeding. Nucleus pulposus forceps and a blunt hook were used to remove the disc protrusion tissue (Fig. 3d). The dural sac was evident after decompression (Fig. 3e). The bone channel was carefully explored; the full-endoscopic system was removed after determining that there was no bleeding, and all fluid was drained. The incision was sutured with one needle, and there was no need for the placement of a drainage tube (Fig. 3f). The incision was wrapped with a sterile dressing. For postoperative care, the patient could start eating 6 hours after the operation and could wear a cervical collar to get out of bed for protective activities 1 day after surgery.

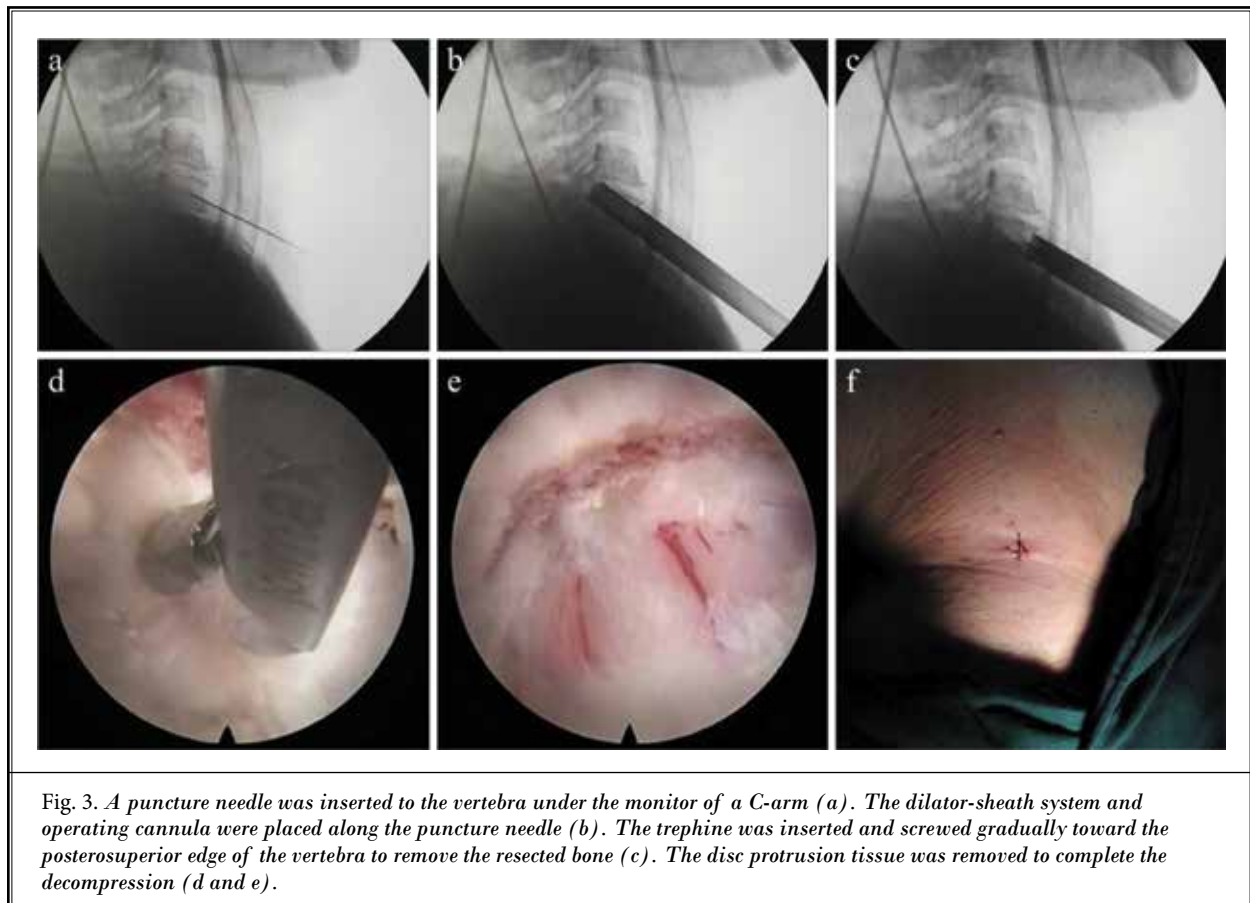
### Outcomes Evaluation

The Visual Analog Scale (VAS) scoring system was used to assess axial pain around the posterior neck or

suprascapular areas. The Japanese Orthopedic Association (JOA) scoring system was used to evaluate neurological function. VAS and JOA scores were recorded 1 day, 3 months, 6 months, and 12 months postoperatively as well as at the final follow-up and were then compared with preoperative scores. Clinical efficacy at the final follow-up was evaluated by the modified Macnab criteria (Table 2). Cervical MRI was conducted 1 week after the operation to confirm decompression, and cervical CT images were obtained to observe the healing of the bone channel 1 week and 12 months after the operation.

### Statistical Analyses

Statistical analyses were performed using SPSS software (Version 18.0; SPSS, Chicago, IL, USA). Data are presented as the mean  $\pm$  standard deviation (SD). Paired t test was used to compare preoperative scores with scores at each follow-up time point.  $P < 0.05$  was statistically significant.



**RESULTS**

**Outcomes of Surgical Design**

The average height of the 40 disc protrusions measured on cervical MRI was  $7.10 \pm 1.24$  mm (range 5.1-9.6 mm), and the average width was  $6.98 \pm 1.29$  mm (range 4.3-9.6 mm). The diameter of the designed bone channel was about 7.5 mm. The direction of the bone channel in the sagittal plane was from the upper edge of the lower endplate obliquely toward the disc protrusion. The direction of the bone channel on the coronal plane was adjusted based on the position of the disc protrusion.

**Clinical and Radiological Outcomes**

Through the designed surgical plan, the disc protrusions of 26 patients were completely exposed and completely removed under the full-endoscopic field of view, and the operation was successfully completed. The average operation time was  $91.50 \pm 16.80$  min (60-120 min). The amount of intra-operative blood loss was  $8.46 \pm 6.59$  ml (0-20 mL). The hospital stay was  $4.07 \pm 0.84$  days (2-5 days). All patients were followed up for  $19.61 \pm 4.04$  months (12-28 months).

The VAS score and JOA score of postoperative follow-up were significantly improved compared with preoperative scores, and the difference was statistically significant ( $P < 0.0001$ ). The average scores of the VAS and JOA during the follow-up period are shown in Fig. 4. The clinical efficacy was excellent in 21 cases, good in 3 cases, and fine in 2 cases at the final follow-up according to the modified Macnab criteria, with an excellent and good rate of 92.31%. Cervical CT and MRI data were available from all

patients 1 week after surgery. MRI showed that the disc protrusion was completely removed and that there was thorough decompression of the spinal canal (Fig. 5). CT

Table 2. *Modified Macnab Criteria*

Grade	Definition
Excellent	Completely disappeared of symptoms, recovery of original work and quality of life
Good	Slight symptoms, mild activity limitation that have no impact on work and quality of life
Fine	Symptoms relieved, activity limitations that influence work and quality of life
Bad	Symptoms have no difference before or after treatment, even worse

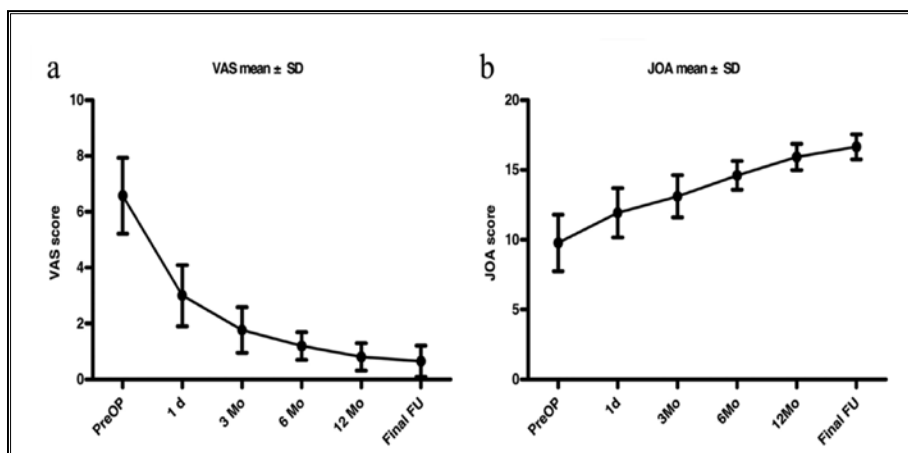


Fig. 4. Pre- and post-operative VAS scores (a) and JOA scores (b) (n = 26).

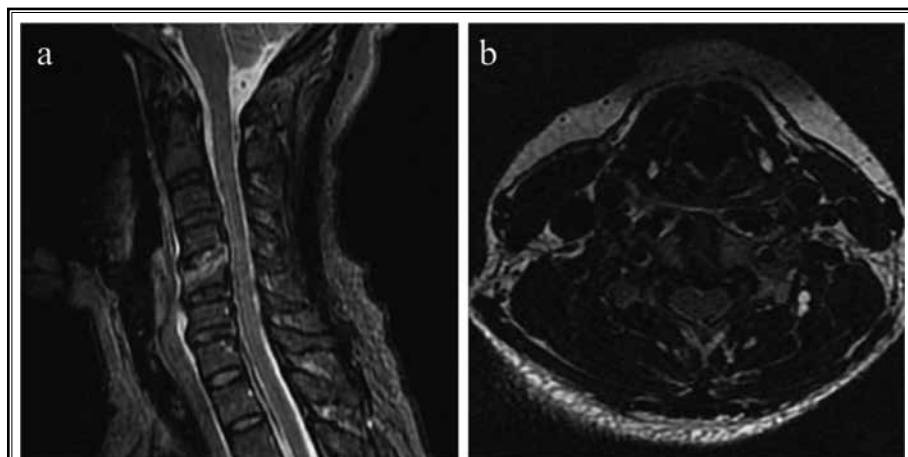


Fig. 5. Postoperative T2-weighted MRI in sagittal plane (a) and axial plane (b) showed that the disc protrusion was completely removed.

showed no collapse of the drilled vertebra. The bone channel almost completely disappeared 12 months after surgery (Fig. 6).

## DISCUSSION

Currently, the anterior surgical methods of CDH primarily include ACDF, artificial cervical intervertebral disc replacement, and anterior cervical corpectomy decompression and fusion. Among them, ACDF is a good clinical treatment for more serious and complex conditions such as multi-segment CDH, cervical instability, and free nucleus pulposus. Although ACDF is still the most common surgical procedure for the treatment of cervical disc disease (19,20), the complications related to bone graft fusion associated with long-term follow-up have had a substantial impact on its status for use as a standard treatment (21,22). With the clinical application of minimally invasive spinal surgery in recent years, low-trauma microsurgeries, especially full-endoscopic

anterior cervical discectomy, have been favored by spine surgeons (10,23,24); however, the transdiscal approach inevitably damages the degenerated disc and accelerates the loss of intervertebral height, and can even cause spontaneous bone fusion in the later stage.

George et al (25) first proposed an anterior transcorporeal approach for cervical spondylosis in 1993. This approach does not require removal of the disc or interbody fusion, which helps preserve the disc and cervical motion segments to the greatest extent, thus avoiding complications caused by interbody fusion; however, when the surgery is performed under traditional open conditions, substantial bone resection is required for the vertebral body, which increases the risk of both vertebral artery injury and collapse of the vertebral body. Nakai et al (26) reported the use of a microscopy-assisted technique to establish a relatively small bone channel around the center of the anterior surface of the vertebral body to avoid damage to

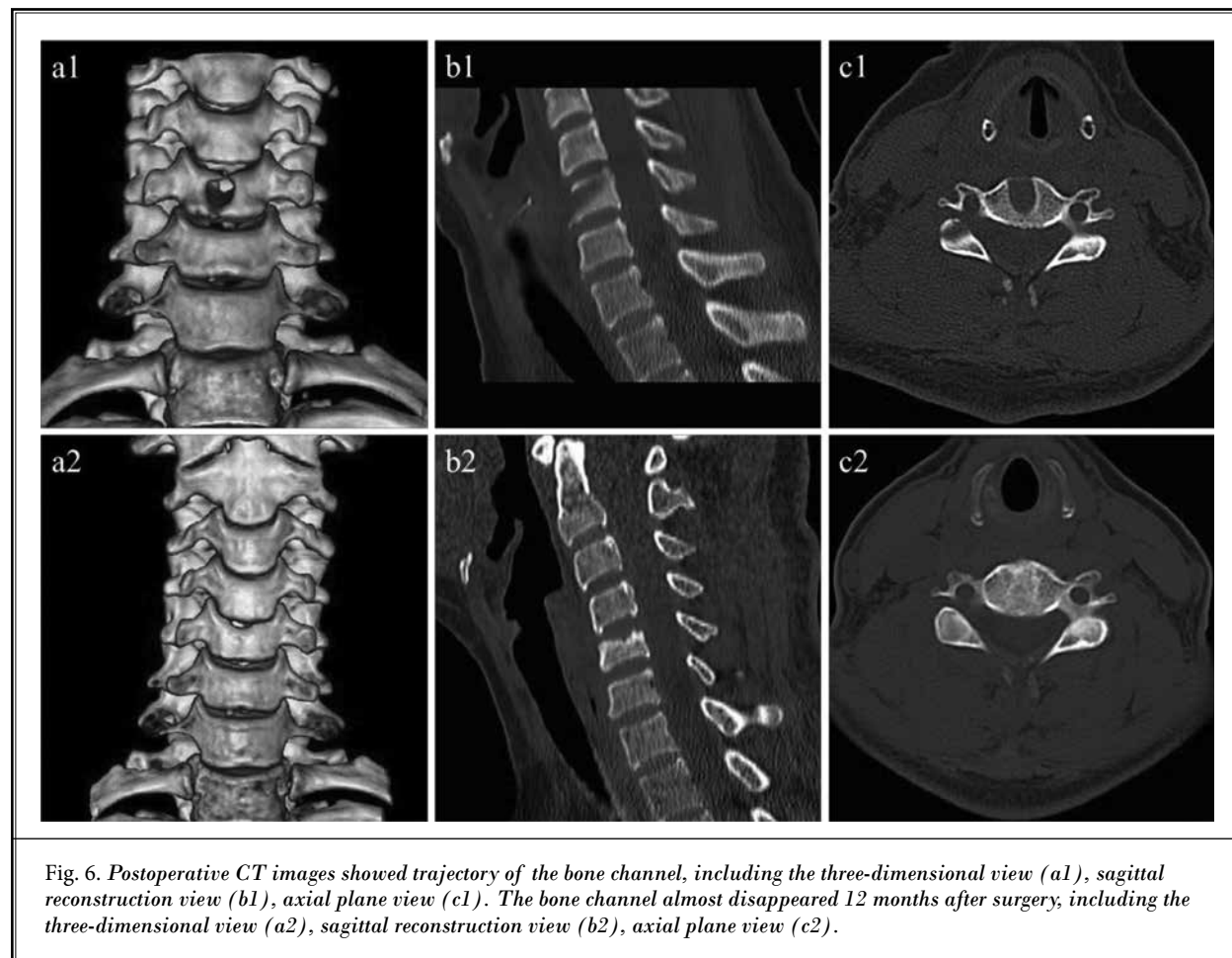


Fig. 6. Postoperative CT images showed trajectory of the bone channel, including the three-dimensional view (a1), sagittal reconstruction view (b1), axial plane view (c1). The bone channel almost disappeared 12 months after surgery, including the three-dimensional view (a2), sagittal reconstruction view (b2), axial plane view (c2).

the vertebral artery and cervical sympathetic nerves; however, due to the narrow field of view of the bone channel, it is still difficult to perform this operation even with microscope assistance, especially when active bleeding occurs during surgery. The full-endoscope has the advantage of small channel and large field of view. If bleeding occurs during the operation, radiofrequency ablation can be used to stop the bleeding in the enlarged field of view. At the same time, continuous saline lavage can promptly discharge bleeding to maintain a clear view and to reduce the risk of surgical infection compared with microscopic surgery with the use of air as a medium. Combined with the advantages of full-endoscopic technique and anterior transcorporeal approach, PEATCD has acquired good therapeutic effects. However, how to design a bone channel with an appropriate size and proper direction for surgery has not been mentioned in these previous PEATCD reports (16-18,27,28).

MRI has contributed to a better understanding of the physical characteristics and accuracy of disc herniation (29-32). MRI has largely replaced computerized tomography and myelography in the preoperative diagnostic and evaluation of CDH because it has higher resolution and is better able to detect the location and type of disc herniation. Nakashima et al (33) used MRI to measure cervical disc degeneration and protrusion in 1211 relatively healthy volunteers. Smuck et al (34) measured the intervertebral disc height of the lumbar on the MRI sagittal plane and the anteroposterior size of the disc protrusion on the MRI axial plane. In our study, the size of the disc protrusion removed during the operation was similar to the size of the disc protrusion measured on MRI. Therefore, cervical MRI can be used to relatively accurately evaluate the size of the disc protrusion to determine the diameter of the bone channel. Based on the location of the disc protrusion in the center or left or right side of the spinal canal, the corresponding bone channel is located in the center or left or right of the vertebral body. The diameter of the bone channel is usually limited to approximately 7.5 mm. This was a summary of the measured height and width of the 40 cases of the disc protrusions. This diameter allows for complete exposure and removal of the disc protrusion and allows for the endoscopic working cannula to pass smoothly. Therefore, it is also possible to select whether to perform the operation according to the measured range of disc protrusion before surgery. Overall, the diameter of the bone channel and the endoscopic field of view are limited. If the

disc protrusion is large or even free, it may not be able to be removed, resulting in the patient undergoing a second operation, which increases the patient's surgical trauma and financial burden.

The full-endoscopic working cannula used during the operation is 6.9 mm in diameter, and the required skin incision is only approximately 8 mm, which greatly reduces the traction damage to the neck tissue compared with open surgery. When positioning the puncture needle, due to the dense structure of the anterior cervical region, the first step is dynamic monitoring under the C-arm because the trachea and the gastric tube injected with iohexol can be clearly seen under the C-arm; this helps avoid damage to the esophagus and trachea as much as possible. The second step is to master the two-finger technique commonly used in minimally invasive surgery with the anterior cervical approach. The carotid artery is pushed to the outside by the left index finger, and the esophagus and trachea are pushed to the medial side with the middle finger to establish a safe puncture area of the anterior neck. The starting position of the puncture needle is usually selected on the upper edge of the lower endplate of the target vertebral body, and the direction moves in an oblique fashion toward the disc protrusion so that the iatrogenic injury of the upper endplate and intervertebral disc can be minimized when the bone channel is established along the puncture needle; at the same time, it is possible to avoid damage to the vertebral artery passing through the transverse process and the cervical sympathetic nerve running along the edge of the long neck muscles on both sides.

The bone channels established by some surgeons using diamond burrs and high-speed drills are irregular on the radiologic image (16,26,35-37). Therefore, trephine can be used to create a smooth and complete bone channel; it is easy to control the direction during surgery. This process requires close monitoring under the C-arm. When the trephine tip reaches the posterior superior edge of the vertebral body, it should be stopped immediately; otherwise, it may cause damage to the dura and even the spinal cord. The bone strip in the trephine is peeled off and removed by gently manipulating the trephine. If the bone strip is not successfully removed at one time, a second attempt is generally not performed, and the part can be positioned under the full-endoscope and removed with rongeurs and a high-speed diamond burr to create a smooth bone channel.

During removal of the disc protrusion, nucleus

pulposus forceps must pass through the upper endplate and the posterior edge of the disc. If the disc is displaced upward or downward, the corresponding upper or lower vertebral body is selected to establish a bone channel so that the upper endplate and the disc can be completely preserved. After the operation, we observed that the patient had a short period of swelling of the surgical site for approximately 2-4 hours, but this swelling did not cause compression of the trachea, blood vessels, or nerves. Combined with the characteristics of the anterior cervical anatomy and the surgeon's surgical experience, it was considered that the continuous saline lavage may have resulted in edema around the surgical site; the swelling gradually subsided after symptomatic treatment.

The results of this study show that the surgical design of bone channel of PEATCD is feasible and successful, and that PEATCD has the advantages of low levels of trauma and bleeding, few complications, and short lengths of hospital stay. PEATCD reduces the risk of injury to the esophagus, carotid artery, recurrent

laryngeal nerve, and vertebral artery. The successful application of this procedure requires strict selection of cases and a rigorous and meticulous surgical operation. The operator needs to have an extensive surgical experience in open cervical spine surgery. Due to the relatively small number of cases and strict selection criteria, this procedure should mainly be used for single-level central or paracentral soft protrusion. Additional large sample size study and long-term clinical follow-up are needed to better evaluate the procedure.

## CONCLUSIONS

Based on the size and location of the disc protrusion on MRI, the diameter and direction of the bone channel are designed, which is conducive to have enough space under the full-endoscopic field of view to completely expose and remove the disc protrusion, to avoid residuals, and to ensure that PEATCD achieves good therapeutic results.

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