Retrospective Study

Posterior Percutaneous Endoscopic Cervical Discectomy for Single-Level Soft, Huge Central Disc Herniation

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Background: Posterior percutaneous endoscopic cervical discectomy (PPECD) has been proven safe and effective for foraminal cervical disc herniation (CDH). However, central CDH has long been considered as the contraindication of PPECD, because the path is obstructed by the spinal cord and nerve root.

Objectives: To preliminarily assess the feasibility, safety, and effectiveness of PPECD for single-level soft, huge central CDH.

Study Design: A retrospective cohort study.

Setting: Zhejiang Provincial People's Hospital (Affiliated People's Hospital, Hangzhou Medical College).

Methods: Between 2017 and 2020, 31 patients diagnosed with single-level soft, huge central CDH were treated by PPECD. Primary outcomes included the measures of neck and radicular pain based on the numeric rating scale (NRS) and cervical neurologic status based on the Japanese Orthopedic Association (JOA) score. The global outcome was assessed using the Odom's criteria at one-year follow-up.

Results: Compared to the baseline, there was a constant and significant reduction of NRS-rated pain and improvement of JOA-rated cervical neurologic status postoperatively ($P < 0.01$). According to the Odom's criteria, 96.8% (30/31) of patients had satisfactory postoperative clinical improvement (excellent or good outcomes) at one-year follow-up. Complications included C5 nerve root palsy and spinal cord injury. The total complication rate was 16.5% (2/31), but these complications were temporary and not catastrophic.

Limitations: The limitations of this study include the volume of the sample, a short follow-up period, and the lack of a control group.

Conclusions: Our preliminary experience indicates that PPECD is a feasible and promising alternative for symptomatic single-level soft, huge central CDH.

Key words: Intervertebral disc displacement, minimally invasive surgical procedures, diskectomy, endoscopy

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For symptomatic cervical disc herniation (CDH), anterior cervical discectomy and fusion (ACDF) has been regarded as the gold-standard surgical treatment. However, with the increasing application of ACDF, some specific technique-related problems have been encountered, such as implant failures, graft subsidence, adjacent segment disease, and access-related complications (1,2). Technological advances

in recent decades have allowed the development of percutaneous endoscopic cervical discectomy (PECD) capable of achieving comparable clinical outcomes but with the advantages of lesser trauma and rapid rehabilitation (3,4). Currently, there are mainly two surgical approaches of PECD—namely, the anterior approach and the posterior approach. The anterior approach is more commonly used for central or paracentral CDH, while posterior percutaneous endoscopic cervical discectomy (PPECD) is more commonly used for foraminal CDH. However, the anterior transdiscal approach violates the anterior annulus and nucleus and ultimately reduces the stability of the disc. In addition, some special clinical situations are contraindicated for the anterior transdiscal approach, including severe discal calcification, a large anterior vertebral osteophyte, and a vertical intervertebral distance of less than 4 mm, which will lead to the difficulty of inserting a working sheath (5).

Another anterior approach, the transcorporeal approach, is more advanced, because it not only avoids the violation of the disc but also provides a better approach for resecting a migrated or sequestered lesion. However, the massive usage of fluoroscopy, the limited operative field of a narrow tunnel, and the risk of end plate collapse are concerns (6). Finally, the risk of injury to the anterior vessels, recurrent laryngeal nerve, trachea, and esophagus is the common greatest disadvantage shared by the 2 anterior approaches. With fewer significant structures, the posterior approach is safer and more favorable than the anterior approach (7). However, central CDH is usually considered as the contraindication of the posterior approach, because the path is obstructed by the spinal cord and nerve root. Removing the central CDH through PPECD is a great challenge. To the best of our knowledge, reports about treating soft, huge central CDH through PPECD are still lacking. Here we share our experiences through a case series of 31 patients with single-level soft, huge central CDH treated by PPECD.

Methods

Patient Population

We performed a retrospective study of 31 consecutive patients who underwent PPECD at our department of pain management between 2017 and 2020. The study was in compliance with the principles of the Declaration of Helsinki and approved by the institutional review board of our hospital (IRB No. ZJPPHEC 2022O-016). Written informed consent was obtained from all patients. The following were the inclusion criteria for PPECD: 1) radiculopathy or/and myelopathy consistent with preoperative magnetic resonance imaging (MRI)/computed tomography (CT), 2) single responsible level, 3) soft, huge central CDH (more than 50% cervical canal compromise on midsagittal MRI), 4) unsuccessful conservative treatment of more than 6 weeks or symptom aggravation to the extent of being intolerable, and (5) age older than 18 years. The exclusion criteria were as follows: 1) clear segmental instability or deformity, 2) severe vertebral posterior marginal osteophytes (ossification of posterior longitudinal ligaments or intervertebral disc calcification), 3) intolerance of a prone position for 2 to 3 hours, 4) inability to communicate and provide accurate feedback to the surgeon intraoperatively, 5) uncontrolled serious underlying diseases, 6) coagulation disorders, 7) systemic infection or local infection of the surgical area, 8) previous surgery at the same level, and 9) cranial sequestering of more than 1/3 of the vertebral body.

Operation Technique

All the operations were performed by the same chief pain physician with rich experience in PPECD. The patient was situated in a prone position. The head was placed on a sponge head ring with the neck in slight anteflexion, and 2 pillows were placed under the chest and abdomen. The arms and the head were fixed suitably to the surgical bed with tape. The patient received dexmedetomidine for sedation and auxiliary analgesia in a loading dose of 1μg.kg-1 for 10 minutes before the operation started, followed by a maintenance dose of 0.2~0.5μg.kg-1.h-1 intraoperatively. All of the operating instruments except for the high-speed drill and bipolar radiofrequency coagulator were supplied by Joimax (Joimax Inc., Irvine, CA). The skin entry point and the puncture path were defined on the preoperative computed tomography (CT) images. The straight line through the most medial border of the ipsilateral pedicle was selected as the puncture path. The intersection of this straight line and the skin was regarded as the skin entry point. The distance between the skin entry point and the midline could be measured on the CT images. Based on these designations, the skin entry point could be marked under the cervical anteroposterior fluoroscopy. After sterilization of the surgical field, an 18-gauge puncture needle was inserted through the skin entry point and advanced until the tip reached the medial border of the ipsilateral pedicle under the

cervical anteroposterior fluoroscopy. At the same time, 20 mL of 0.375% ropivacaine was injected along the puncture trajectory for local infiltration anesthesia. Next, the guidewire was placed, and the needle sheath was withdrawn, then an approximately 8 mm longitudinal incision was made. A bevel working sheath (outer diameter 7.5 mm) was introduced via the dilator after sequential dilation along the guidewire. After moderate blunt dissection of soft tissue on the surface of the lamina and facet joint using the working sheath, the endoscope was inserted. Further surgical steps were performed under visual control and continuous irrigation with normal saline solution.

Firstly, the soft tissue on the osseous surface was cleared up to expose the "V" point formed by 2 adjacent vertebral laminae and the facet joint using the forceps and a 40 cm bipolar radiofrequency coagulator with a flexible tip (Elliquence, Baldwin, NY). Then, the laminoforaminotomy was performed using a high-speed diamond drill (Chongqing Xishan Science & Technology Co., Ltd., Chongqing, China) and a rongeur (Kerrison, Jedmed, St. Louis, MO). Compared to the classical keyhole endoscopic technique for foraminal CDH, a wider range of lamina needed to be removed to increase the moving range of the spinal cord. Usually, a large part of the superior margin of the ipsilateral inferior lamina and a small part of the inferior margin of the ipsilateral superior lamina needed to be removed. In addition, a smaller range (usually approximately 30%) of the facet joint was removed except when the affected segment was C45 or in cases of intervertebral foraminal stenosis. After the physician finished the laminoforaminotomy and removing the ligamentum flavum, the dural sac and its outgoing nerve root could usually be exposed. Next, the bone located at the axillary region between the dural sac and nerve root was removed gradually by the bone chisel to create a channel to the ventral central area of the dural sac. Lastly, the posteriorly protruded nucleus pulposus could be removed using the forceps gradually. After the physician verified that the dural sac was decompressed enough and the patient was not bleeding, the working sheath was carefully pulled out, and the skin was closed with a single stitch. No drains were placed. Figures 1 to 5 illustrate a representative case.

Outcome Evaluation

Clinical data, including the intensity of neck and radicular pain evaluated on the numeric rating scale (NRS), the cervical neurologic status evaluated on the Japanese Orthopedic Association (JOA) score from preoperatively to 12 months postoperatively, the global outcome assessed by the Odom's criteria at the one-year follow-up, and the occurrence of complications, were collected. The removal of herniated nucleus pulposus was assessed through comparing the MRI or CT images preoperatively and on postoperative day one. Patients' lateral and dynamic cervical radiographs were obtained preoperatively and at the one-year follow-up. The intervertebral disc height (the average value of the anterior disc height

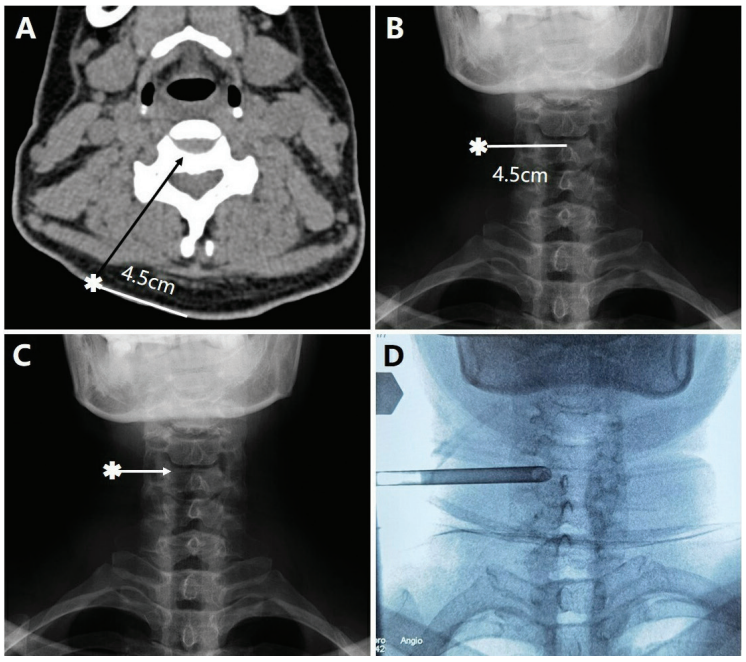

Fig 1. *A: The skin entry point and the puncture path were defined on preoperative CT images. The straight line through the most medial border of the ipsilateral pedicle was selected as the puncture path (black arrow). The intersection of this straight line and the skin was regarded as the skin entry point (white asterisk). The distance between the skin entry point and midline could be measured on the CT images (while straight line). B: According to the designed scheme on the preoperative CT images, the skin entry point (white asterisk) could be marked under the cervical anteroposterior fluoroscopy. C: The puncture path on the cervical anteroposterior fluoroscopy image (white arrow). D: Placement of the working channel on the cervical anteroposterior fluoroscopy image.*

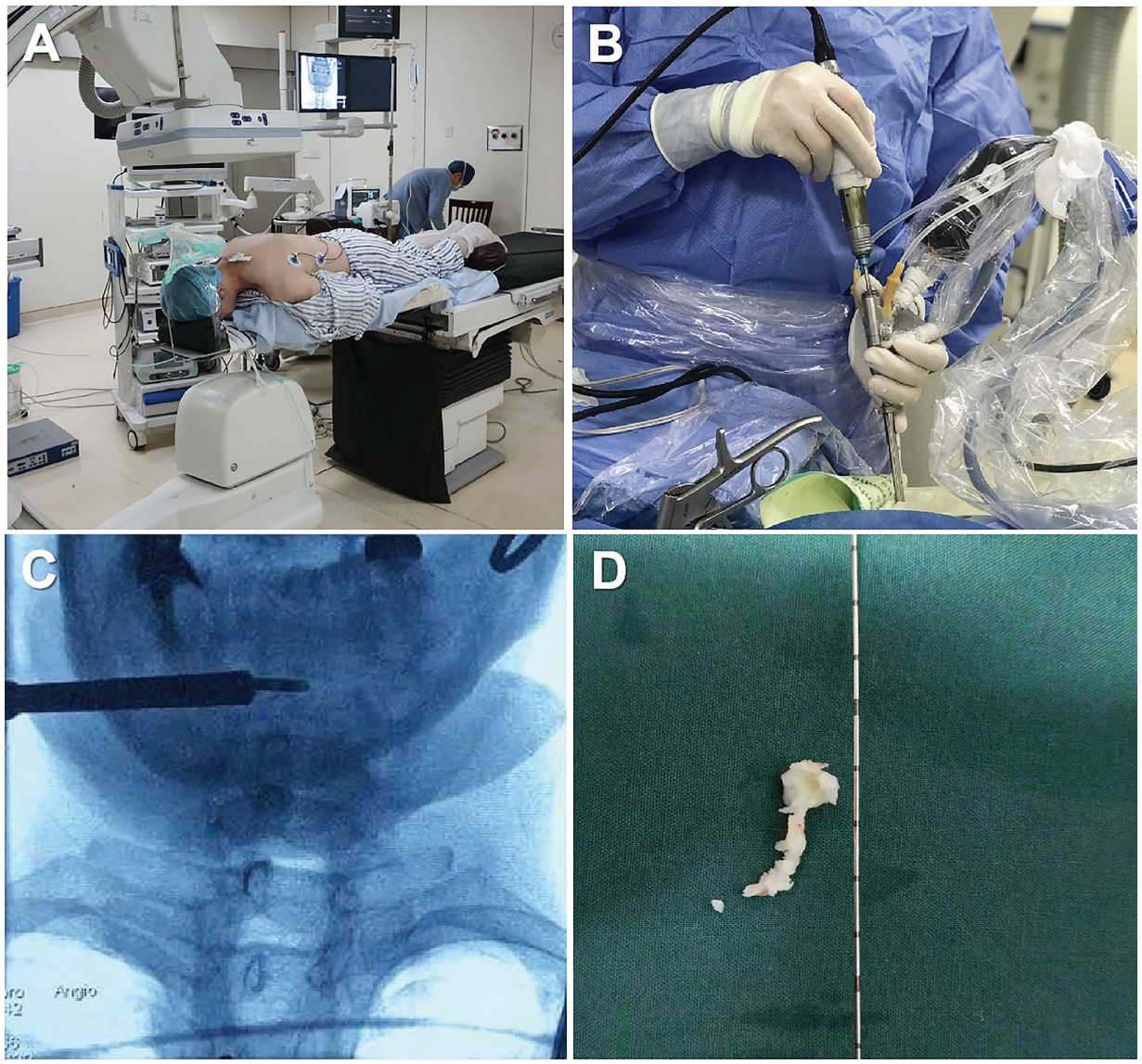

Fig 2. *A: Patient positioning. B: The surgical procedure. C: Intraoperative fluoroscopy showed the forceps could reach the central ventral area of the dural sac. D: The herniated nucleus pulposus resected.*

and poterior disc height) of the operative level and overall cervical curvature (C2-7, tangetial method) were measured on the lateral plane radiograph in the neutral position. Negative angles indicate lordosis.

Statistical Analysis

Statistical analysis was performed using SPSS 20.0 (SPSS Inc.). The Wilcoxon rank sum test and Friedman test were used for analysis. $P < 0.05$ was considered statistically significant.

Results

The demographic characteristics of the included patients are shown in Table 1. The mean total operative time was 100.5 minutes (range 95–150 minutes). There was no measurable blood loss. The courses of NRS-rated pain intensity and JOA-rated cervical neurologic status are shown in Table 2. Compared to the baseline, there was a constant and significant reduction of pain and improvement of cervical neurologic status postoperatively ($P < 0.01$). In addition, the JOA

score at month 12 postoperatively further improved significantly compared to scores at month one postoperatively ($P < 0.01$). According to the Odom's criteria, 96.8% of patients had satisfactory postoperative clinical improvement, including 16 excellent and 14 good outcomes, while one patient (3.2%) had a fair outcome at the one-year follow-up. There was no recurrence during the follow-up period. The total complication rate was 6.5% (2/31). C5 nerve root palsy (C5 palsy) occurred in one case (3.2%) immediately postoperatively, but the decreased deltoid muscle strength gradually recovered to normal from level III under conservative therapy and functional exercise in three months. Spinal cord injury occurred in another patient (3.2%). This patient complained of mild gait disturbance immediately postoperatively. After 80 mg of methylprednisolone was administered continuously for 3 days, gait disturbance made obvious improvements. Eventually, she recovered completely one month after surgery. Total and subtotal removal of herniated muclei pulposi were achieved in 28 and 3 patients respectively, according to the postoperative immediate MRI or CT images. Twenty-five patients underwent the neutral and dynamic cervical spine radiographs again at the one-year follow-up. The intervertebral disc height did not significantly change from 5.3 ±1.3 mm preoperatively to 5.3 ± 1.2 mm postoperatively ($P > 0.05$). Overall cervical lordosis significantly changed from -12.5 ± 8.4 degrees preoperatively to -17.5 ± 7.7 degrees postoperatively ($P < 0.01$). No cervical instability or increasing kyphosis was found.

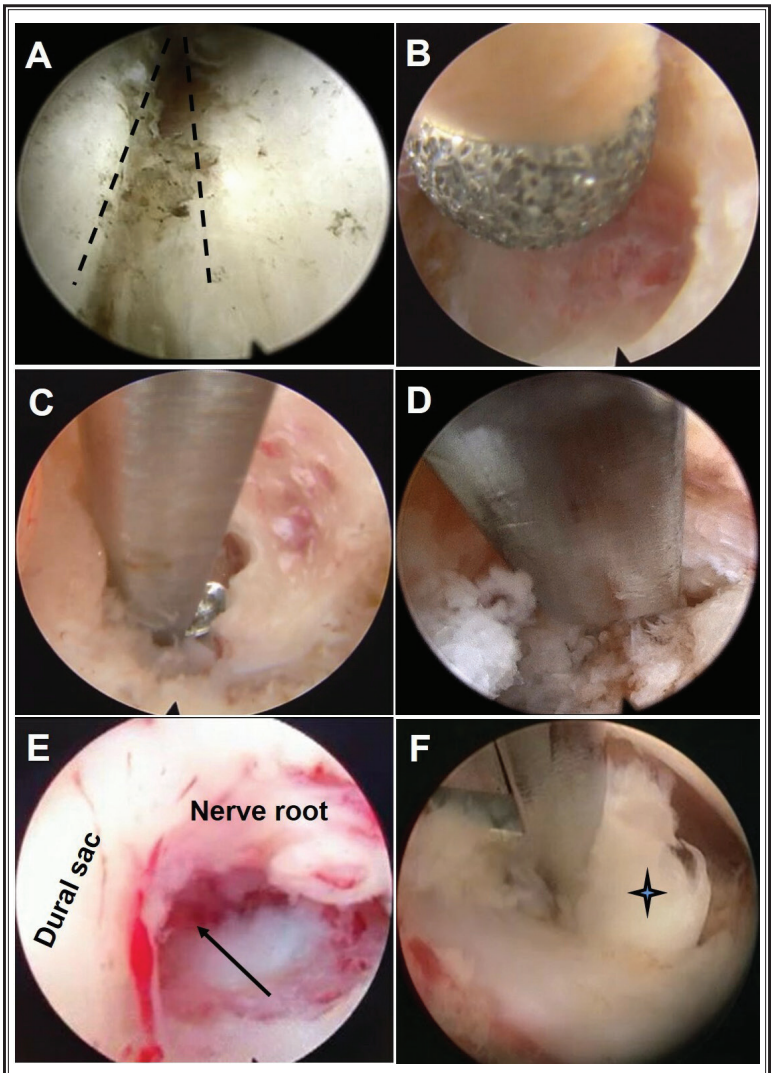

Fig 3. *A: The dotted line represents the V point formed by two adjacent vertebral laminae and the ipsilateral facet joint between them. B: Laminoforaminotomy with a high-speed drill. C: Resect the lamina with the Kerrison rongeur. D: Remove the partial vertebral posterior wall with a bone chisel to create a channel to the ventral central area of the dural sac. E: Exposure of the axillary region (black arrow) between the nerve root and spinal cord. F: Resection of the nucleus pulposus (asterisk).*

Discussion

Endoscopic techniques have become standard procedures in many areas of medicine. With the continuous evolution of techniques and instruments, PECD has more and more frequently been applied in the treatment of CDH, bridging the gap between conventional open surgery and conservative treatment. Different approaches to PECD are indicated for different axial locations of CDH. PPECD has been proven safe and effective for foraminal CDH (8-11). However, central CDH has long been considered inaccessible through the traditional PPECD, because the path is obstructed by the spinal cord and nerve root. We challenged this contraindication for the specific indication of symptomatic single-level soft, huge central CDH. Encouragingly, most patients were successfully treated through PPECD in the present study. Satisfactory improvement

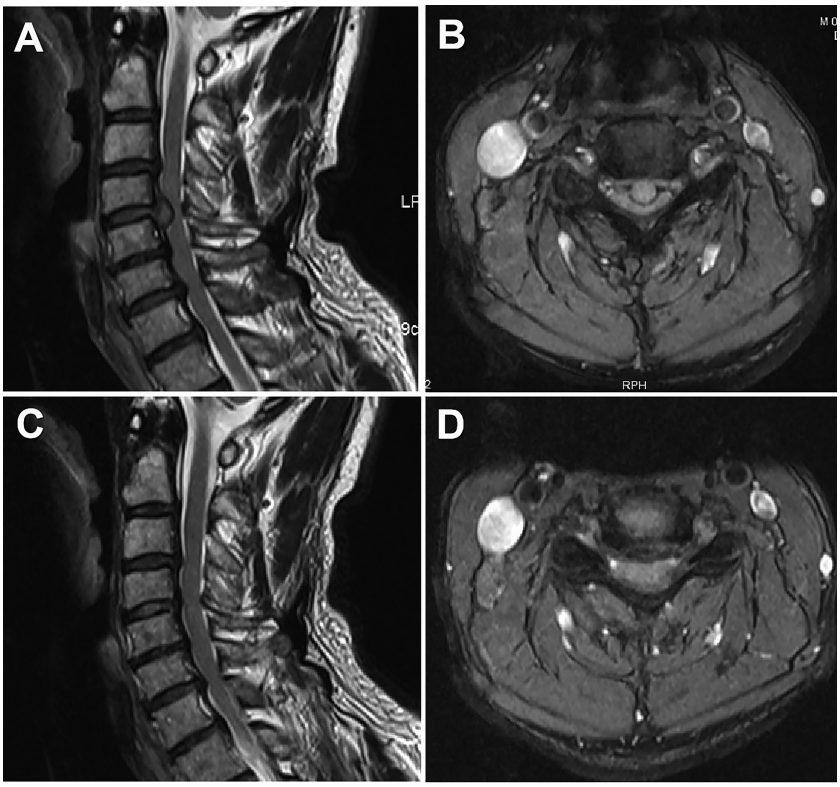

Fig 4. *A-B: Preoperative T2-weighted MRI showed a central herniated disc at the C45 level. C-D: Postoperative T2-weighted MRI showed that the herniated disc was resected successfully.*

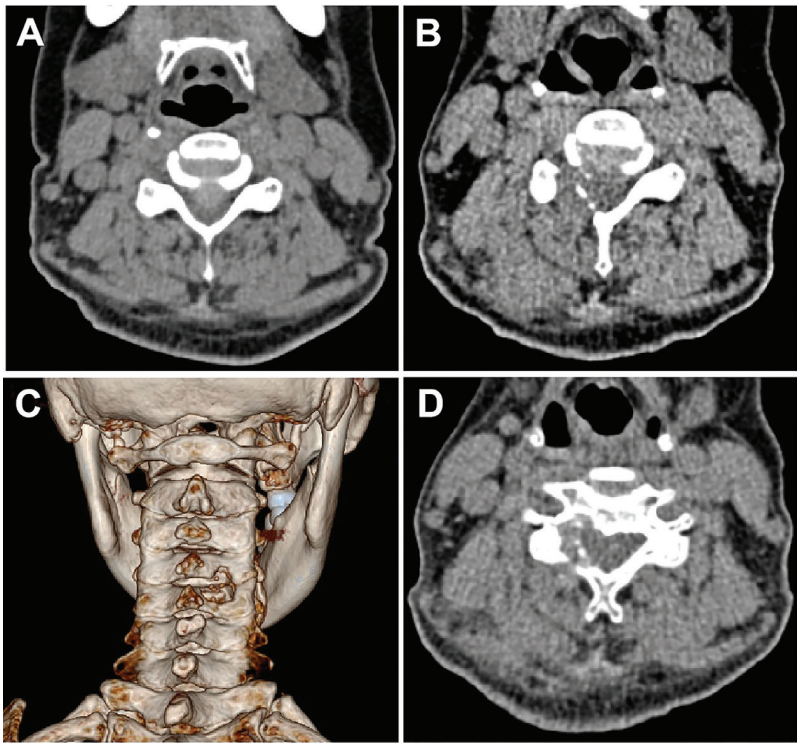

Fig 5. *A: Preoperative axial CT showed a soft, huge central herniated disc at the C45 level. B: Axial CT on postoperative day 3 showed that the herniated disc and the right inferior lamina of C5 were removed. C: CT three-dimensional reconstruction showed the medial edge of the facet joint, the superior edge of the inferior lamina, and the inferior edge of the superior lamina were removed. D: Axial CT on postoperative day 3 showed that the medial half-portion of the pedicle and part of the vertebral posterior wall of C5 were removed.*

of symptoms was obtained in 96.8% of patients and no permanent complications occurred. The direct comparison between PPECD and traditional ACDF could not be achieved in this present study due to the lack of a control group. However, it is well known that PPECD has the following advantages: excellent presentation of the anatomical structures due to amplification of endoscope and continuous fluid flow; good illumination and expanded visual field due to 30° optics; mobility due to lack of interbody fusion, reduced operative trauma, and rapid rehabilitation; reduced intraoperative bleeding; and no risk of anterior approach-related complications (8).

The greatest challenge for dealing with central CDH through PPECD is avoiding nerve root and spinal cord injury while sufficient decompression is achieved. The total complication rate in our study is 6.5% (2/31). However, these complications are transient, and the long-term therapeutic effects are not affected. C5 palsy is a common complication after cervical surgery. Patients with C5 palsy usually have paresis of the deltoid muscle and/or the biceps brachii muscle after surgery without any deterioration of myelopathic symptoms. Wang et al (12) reported that the incidence of C5 palsy is 6.3% for cervical surgery in a recent meta-analysis. The incidence is 3.2% (1/31) in our study, which is lower than that in Wang et al's report. Even though some mechanisms of possible explanations for this common complication have been proposed, it remains a controversial issue. The potential pathologic mechanisms are as follows: inadvertent injury to the nerve root during surgery; shifting of the spinal cord caused nerve root traction after surgery; spinal cord ischemia caused by decreased blood supply; segmental spinal cord disorder; and reperfusion injury of the spinal cord (12).

Although C5 palsy may place a serious burden on the patient's quality of life and finances in the short term, the prognosis is usually good. The patient with C5 palsy in this study recovered completely eventually. It is reported that foraminotomy and intraoperative neuromonitoring may help prevent C5 palsy (13). Spinal cord injury occurred in 3.2% (1/31) of patients in this present study. On the one hand, the long-term, extensive, and high compression on the spinal cord from the huge protruded nucleus pulposus significantly reduced its endurance to operative squeezing and stretching. On the other hand, the spinal cord is vulnerable to injury when the physician uses forceps to remove the nucleus pulposus located at the ventral central area of the dural sac.

The patient in this study complained of transient numbness and weakness of limbs intraoperatively when the nucleus pulposus was being removed. According to our experience, several key surgical skills below are beneficial for reducing the risk of spinal cord injury. Firstly, in contrast to the classical keyhole endoscopic technique for foraminal CDH, the working channel was placed obliquely rather than vertically toward the "V" point in our study. The posterolateral angle can provide a reasonable path to the ventral central area of the dural sac. Secondly, for the central type of CDH, more laminae need to be removed to increase the moving range of the spinal cord than for the foraminal type. Because the forceps will squeeze and stretch the spinal cord sometimes when picking the herniated nucleus pulposus, enough dorsal evasive space is an advantage for reducing the risk of spinal cord injury. Thirdly, when the dural sac and the outgoing nerve root are exposed, an access channel to the ventral central area of the du-

Table 1. *The baseline characteristics of patients.*

Characteristic	**(n = 31)**
Gender (men/women)	9/22
Age range [mean] (year)	30~84 (52.3)
Clinical diagnosis	
Radiculopathy	10
Myelopathy	18
Radiculopathy & Myelopathy	3
Treatment Level	
C3/4	6
C4/5	10
C5/6	15
Duration of symptoms [mean] (month)	0.67-96 (19.2)

Table 2. *The courses of NRS-rated pain intensity and JOA-rated cervical neurologic status.*

	Pre	**Month 1**	**Month 3**	**Month 6**	**Month 12**
Neck pain	3(2,4)	1(0,2)*	0(0,2)*	0(0,1)*	0(0,1)*
Radicular pain	4(2,5)	1(0,2)*	1(0,2)*	1(0,1)*	1(0,1)*
JOA	15(15,15)	16(15,16)*	16(16,17)*	16(16,17)*	17(16,17)*†

*Statistically significant changes compared to baseline ($P < 0.01$). † The JOA at month 12 postoperatively further improved significantly compared to that at month 1 postoperatively ($P < 0.01$).

ral sac from the axilla needs to be made to provide sufficient space for placing the instrument into the spinal canal safely without violating the spinal cord. According to the postoperative CT images, the medial portion of the pedicle and 3-5 mm deep vertebral posterior wall usually need to be removed. Fourthly, the loose nucleus pulposus located at the posterior part of intervertebral space should be picked first so the nucleus pulposus in the spinal canal will fall back naturally and become easier to pick. Lastly, local anesthesia is recommended, at least for the initial cases. Thus, the surgeon can obtain quick and accurate information about limb sensation and muscle strength changes from the patient by communicating with the patient intraoperatively. Once the signs of the spinal cord or nerve root injury appear, the harmful manipulation can be stopped timely and therapeutic drugs such as methylprednisolone can be used immediately.

Overall, our results are similar to those of the previous studies. Yu et al (7,14) first reported a specific method of treating central CDH by PPECD. They named this newly designed method the trench approach, also known as the transpedicular approach. The posterior trench approach begins with drilling a hole at the ipsilateral lateral mass, followed by drilling the 1/2 medial portion of the pedicle, and, finally, drilling a trench from the root of the pedicle to access the posteriorly protruded nucleus pulposus at the ventral central area of the dural sac under endoscopy (7). This technique can avoid damage to the facet joint, and the physical cost is only a few renewable bone tissues that can heal gradually over several months according to their postoperative radiographical follow-up. At the one-year follow-up, a majority of patients (29/30, 96.7%) showed satisfactory outcomes according to the modified MacNab criteria, and no severe complications occurred in one study (7). However, the steep learning curve is the major disadvantage of this technique. By contrast, our method is based on the traditional keyhole technique and is thus easier to master, especially for beginners. Although more bone tissues are sacrificed, the stability of the cervical spine is not affected according to the postoperative radiological assessment. It is well known that the resection of less than 50% of the facet joint does not affect the stability, and the lamina, pedicle, and vertebral posterior wall will heal gradually over time according to Yu et al (7). In addition, the resection of the lamina can provide indirect decompression of the spinal cord, and the wider osseous window can accommodate wider surgical tools and reduce the possibility of a residual herniated disc. Ran et al (15) reported a case series of 21 patients with single-level cervical spondylotic myelopathy treated by PPECD under intraoperative CT guidance. Finally, 19 of 21 patients (90.5%) achieved excellent or good outcomes according to the JOA recovery rate 6 months after surgery. No severe complications occurred except for transient C5 nerve root paralysis in one patient. Unlike our cases, in only 6 of the 21 patients, CSM was caused by soft central CDH, and in the other 15 patients, CSM was caused by both central CDH and osteophytes. A main defect of their technique may be the additional radiation exposure of patients due to the application of CT guidance. In this study, we included only cases with central soft CDH. Ran et al (15) and Wang et al (16) reported that the central osteophyte could be resected by a flexible high-speed drill. However, the use of a high-speed drill brings the risk of dural sac tear and nerve root injury, and the complete resection of the central osteophyte is very difficult (16).

Limitations

The limitations of this study include the volume of the sample, a short follow-up period, and the lack of a control group.

Conclusion

Our preliminary experience indicates that PPECD is a feasible and promising alternative for soft, huge central CDH. However, unfamiliar and incautious manipulation may lead to the spinal cord or nerve root injury. For this reason, it is suggested that only physicians with rich experience in endoscopic cervical surgery attempt to carry out this technique. Lastly, the effectiveness, safety, and reliability of this technique still require further confirmation from a comparative cohort study with a large sample size.

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