

Clinical effectiveness of percutaneous endoscopic spinal surgery via transforaminal approach for single-level thoracic ossification of the posterior longitudinal ligament

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Research article

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Abstract

Background

Percutaneous endoscopic spinal surgery (PESS) was performed for a series of cases with single-level thoracic ossification of the posterior longitudinal ligament (T-OPLL). This study was to evaluate the clinical feasibility and effectiveness of percutaneous endoscopic spinal surgery via a transforaminal approach for T-OPLL.

Methods

15 patients with thoracic single-level ossification of the posterior longitudinal ligament (T-OPLL) were admitted to our hospital from October 2016 to October 2019 and treated with percutaneous endoscopic spinal surgery via transforaminal approach. There were 7 males and 8 females with an average age of (56.4 ± 8.4) years (range: 41 to 71 years). Computed tomography (CT) with 3-dimensional reconstruction and magnetic resonance imaging (MRI) were used to confirm the vertebral level of T-OPLL. Levels of T-OPLL: T7/T8 in 1 case, T9/T10 in 2 cases, T10/T11 in 6 cases, T11/T12 in 4 cases, and T12/L1 in 2 cases. The surgical index, neurological function, and clinical results were recorded in this study.

Results

All surgeries were successfully completed without any conversion to open surgery, no severe intraoperative complications such as dural sac tear, major vessel or spinal cord injury were reported in our study. The average operation time was 79.1 ± 29.4 min (ranged, 43 to 132 min). The amount of intraoperative blood loss was 62.3 ± 20.8 mL. The lengths of postoperative hospital stays were 4.1 ± 1.1 days. The follow-up rate was 93.3% (14/15). The follow-up time ranged from 13 to 32 months (mean, 20.3 ± 6.3 months). The satisfactory decompression was confirmed by the CT and MRI. The Visual Analog Scale (VAS) score improved from 5.9 ± 0.7 preoperatively to 2.1 ± 0.9 at the last follow-up ($P < 0.001$), and Oswestry Disability Index (ODI) improved from 46.9 ± 4.5 preoperatively to 9.9 ± 8.0 at the last follow-up ($P < 0.001$). Neurological function was evaluated by Japanese Orthopedic Association 29 (JOA29) score, which significantly improved from 16.0 ± 1.9 to 21.2 ± 1.1 ($P < 0.0001$). The good and excellent rates were 71.4% according to the modified MacNab criteria. No revision surgery was performed because of the residual nucleus pulposus or recurrent disc herniation.

Conclusion

As a minimally invasive spinal technique, PESS is a clinically feasible, safe and effective alternative approach to conventional procedures in the treatment of single-level T-OPLL.

Background

Thoracic ossification of the posterior longitudinal ligament (T-OPLL), as a process of fibrosis, calcification, and ossification of the OPLL, may lead to the thoracic spinal cord compression or thoracic spinal stenosis resulting in back pain, lower limbs numbness or weakness, cauda equina syndrome (CES) and permanent paraplegia[1]. At present, the treatment of T-OPLL is OPLL extirpation via thoracotomy, laminectomy and posterior decompression[2, 3, 4]. Percutaneous endoscopic spinal surgery (PESS), as a minimally invasive spinal surgery, has been emerged as an alternative approach to conventional procedures for cervical and lumbar degenerative disorders[5, 6, 7, 8, 9]. However, due to the anatomical differences between the thoracic and lumbar spine, limited thoracic spinal canal space and operating space as well as poor tolerance of thoracic spinal cord, the application of PESS for the treatment of single-level T-OPLL is rarely reported. In this study, the aim of this paper was to investigate the feasibility, safety and therapeutic effectiveness of PESS via a transforaminal approach for the treatment of single-level T-OPLL.

Methods

Patients

This study was approved by the Institutional Ethical Committee of local hospital, and all patients signed the informed consent. From October 2016 to October 2019, 15 patients with single-level T-OPLL were admitted to our hospital and underwent PESS via a transforaminal approach performed by a senior doctor. The general data of the patients shown in Table 1. Computed tomography (CT) with 3-dimensional reconstruction and magnetic resonance imaging (MRI) were used to confirm the vertebral level of T-OPLL. Of the 15 cases, 7 were males and 8 were females with an average age of (56.4 ± 8.4) years (range: 41 to 71 years). Levels of T-OPLL: T7/T8 in 1 case, T9/T10 in 2 cases, T10/T11 in 6 cases, T11/T12 in 4 cases and T12/L1 in 2 cases. 10 cases had thoracic back pain and their visual analogue scale (VAS) scores were 5 (4 cases), 6 (5 cases), and 7 points (2 cases), ODI index scores were 44.5, 42.2 (2 cases), 51.1 (2 cases), 48.9 (2 cases), 40.0, 53.3 and 46.7 points. 5 cases had lower extremities numbness and weakness. The Japanese Orthopedic Association 29 (JOA29) scores of 15 cases were 19 (2 cases), 18 (3 cases), 17 (3 patients), 16 and 14 points (6 cases). The spine stability of all patients was assessed prior to the surgery, and no thoracolumbar scoliosis, kyphosis or structural sagittal imbalance were found in all patients.

Surgical procedures

All the surgical procedures of PESS via the transforaminal approach were performed by the same senior doctor. Briefly, under local and intravenous combined anesthesia, the patient was placed in a prone position. During the procedure, dexmedetomidine was administered with initial bolus injection at 0.5 mg/kg and

continuous pumping at 0.1–0.5 mg/(kg*h) for relieving surgical related pain and improving the patient's intraoperative tolerance. The level of the pathologic vertebrae was confirmed by biplanar C-arm fluoroscopy. Then, a 1.5-cm incision was made at the intervertebral foramen of the pathologic side. Under C-arm fluoroscopy, a guide rod was penetrated along the posterolateral side of the thoracic vertebrae to the lamina of the superior vertebrae. After the guide rod was advanced along the outside margin of the lamina and the ventral part of the superior facet joint, then the guide rod reached the superior margin of the pedicle (Fig. 1A-B). During this whole process, the guide rod was "slid" into the intervertebral foramen using the "sliding technique" as mentioned previously[10]. Then the dilator and trephine cannula were inserted along the guide rod. Removed the guide rod, part of the superior facet joint and articular process was then carefully resected by using a trephine cannula for foraminotomy (Fig. 1C-D). The working sheath was then placed via the dilator, and then the position of the working sheath was confirmed by biplanar fluoroscopy (Fig. 1E-F). After removing the dilator, the percutaneous spinal endoscope system was connected. After the surrounding soft tissue was carefully cleaned out, a diamond high-speed burr (SPINE-NDOS Drill system, SPINENDOS GmbH, Munich, Germany) and an endoscopic Kerrison rongeur were used to remove the partial inferior aspect of the pedicle and the superior facet joint (Fig. 2A-B). And then the medial part of the pedicle and a minor portion of the posterior vertebral wall were drilled via the "trench approach" as we previously described[7], to create a groove for endoscopic manipulation and to fully expose the dural sac and base part of ossified posterior longitudinal ligament (Fig. 2C-E, Fig. 3F). Intraoperative bleeding was controlled by using low-energy bipolar radiofrequency (Ellman Trigger-Flex Probe, Ellman International, Hewitt, New York, USA). After the position of the working sheath was reconfirmed by fluoroscopy, the basal part of the ossified posterior longitudinal ligament was gradually isolated with high-speed burr and then removed by using an endoscopic Kerrison rongeur (Fig. 2F-G). After satisfactory and complete spinal decompression was achieved (Fig. 2H), surgery was halted.

After sufficient and careful hemostasis, the instruments were removed, and the incised wound was sutured. Postoperatively, the drainage tube was retained for 24 hours to avoid hematoma.

Statistical analyses

All statistical analyses were performed by GraphPad Prism 8.3.1 software (GraphPad Software, San Diego, California, USA). All data are expressed as the mean values \pm standard deviation (SD). The differences between the two groups were analyzed by nonparametric analysis using the Mann-Whitney U test. For more than a two-group comparison, one-way ANOVA was used. A *P* value < 0.05 was considered statistically significant. The clinical outcomes of therapeutic effectiveness were evaluated with the modified Macnab criteria, and VAS, ODI index and JOA29 scores were used to estimate the patient's neurological status and function.

Results

All surgeries were successfully completed without any conversion to open surgery, and no severe intraoperative complications were reported in our study. The surgical index, clinical outcomes and neurological function were recorded during this study. The spinal decompression outcomes were confirmed by postoperative CT and MRI examinations. A typical case with pre- and postoperative radiological examinations underwent PESS for OPLL was showed (Fig. 3A-F).

The surgical index, clinical outcomes, and neurological function were shown in Table 1. The operative time, defined as the time from the incision to suturing, ranged from 43 to 132 min (mean, 79.1 ± 29.4 min). The amount of intraoperative blood loss was 62.3 ± 20.8 mL. The lengths of postoperative hospital stays were 4.1 ± 1.1 days. Of the 10 cases with thoracic back pain, the VAS score improved from 5.9 ± 0.7 preoperatively to 4.0 ± 0.8 postoperatively ($P < 0.001$), ODI index decreased from 46.9 ± 4.5 preoperatively to 36.0 ± 4.4 postoperatively ($P < 0.001$). The JOA29 score of 15 cases improved from 16.0 ± 1.9 preoperatively to 17.3 ± 1.7 postoperatively ($P = 0.06, > 0.05$).

Of 15 patients, 14 patients completed follow-up and the follow-up rate was 93.3% (14/15). The follow-up time ranged from 13 to 32 months (mean, 20.3 ± 6.3 months). the satisfactory decompression was confirmed by CT and MRI. The VAS score and ODI index of the 10 cases with thoracic back pain improved from 5.9 ± 0.7 preoperatively to 2.1 ± 0.9 at the last follow-up ($P < 0.001$) and 46.9 ± 4.5 preoperatively to 9.9 ± 8.0 at the last follow-up ($P < 0.001$) respectively. Neurological function was evaluated by JOA29 score, which significantly improved from 16.0 ± 1.9 to 21.2 ± 1.1 ($P < 0.0001$). Clinical satisfactory results evaluated by the modified MacNab criteria were excellent in 3 patients, good in 7 patients and fair in 4 patients. The good and excellent rates were 71.4% according to the modified MacNab criteria.

Discussion

OPLL is a multifactorial condition caused by ectopic hyperostosis, calcification and ossification of the posterior longitudinal ligament and commonly presents with myelopathy and radiculopathy. However, the symptom of myelopathy in T-OPLL are more severe than cervical OPLL due to the narrow canal space, tenuous blood supply, and inability to withstand much compression. Conservative treatment is inefficacious for the symptomatic T-OPLL. Hence, surgical intervention is suggested according to the severity of clinical symptoms.

At present, the common surgical decompression procedures for the treatment of T-OPLL include anterior decompression[2, 11, 12, 13] via transthoracic approach, extrapleural anterolateral approach, and posterior decompression[1, 2, 14] via laminoplasty or laminectomy and fusion. Although the anterior approach could directly reach the ossified posterior longitudinal ligament and achieve targeted decompression of the ventral side of the dural sac, this approach is traumatic and surgical related complications including atelectasis, intercostal neuralgia et al are more severe[15]. The extrapleural anterolateral approach could penetrate deep into the anatomical space, which is also technically difficult and requires a long operation time, but it is better than other lateral and posterior approaches in exposing the ventral side of the spinal cord. Therefore, the posterior approach may be more safe and common but also demands higher requirements of the surgeons for the decompression of the ventral side of dural sac[16]. Above all, the conventional surgical procedures are more traumatic and have longer postoperative recovery duration and more surgical related complications.

Recently, several reports indicated that the surgical procedures via the above approaches using thoracoscopy or expandable channels could achieve thoroughly decompression and satisfactory clinical results for the treatment of thoracic spinal stenosis[17, 18, 19]. As the most representative minimally invasive spinal technique in recent years, PESS is based on targeted decompression, which is an important part of the stepwise strategy between conservative treatment and conventional interventions, and has advantages of a smaller skin incision, less trauma, reduced intraoperative blood loss, and fast postoperative functional recovery. A number of studies have shown that PESS with skillful manipulation of endoscopy and endoscopic instruments could achieve the same clinical outcomes as traditional surgeries for the treatment of cervical and lumbar degenerative diseases[20, 21]. In PESS, the whole procedure was performed under continuous fluid flow with a 0.9% saline solution, and hydraulic pressure could reduce most intraoperative bleeding and provide a clear, magnified and tridimensional endoscopic view of the targeted decompression area and neural structures. Moreover, post-procedural epidural adhesion may be a common complication in laminoplasty or laminectomy. The symptomatic postoperative epidural adhesion was not found in the 15 cases in our study because of the above advantage of the water-mediated procedure. Due to the narrow canal space and tenuous blood supply, the thoracic spinal cord may be more prone to being injured. Under local anesthesia, patients were conscious and could communicate to surgeons timely throughout PESS, which facilitated neurological function monitoring and contributed to surgical instrument adjustment during OPLL extirpation and reduced anesthesia-related complications and secondary spinal injury in elderly patients. Moreover, PESS under local anesthesia can provide patients who are intolerant to general anesthesia with opportunities for OPLL extirpation surgery.

With the continuous development of minimally invasive spinal surgery, PESS has been widely used for spinal degenerative diseases and has achieved good clinical outcomes[6, 9, 22, 23, 24]. Choi et al[25]reported the good clinical outcomes of PESS via transforaminal approach for the soft lateral or central thoracic disc herniation. Wagner et al[26]successfully performed the PESS via transforaminal approach for the thoracic disc herniation at T8/T9 level. In a recent study of 55 cases underwent uniportal decompression via interlaminar, extraforaminal or transthoracic retropleural approach for thoracic disc herniation and stenosis, Ruetten et al[27] reported the satisfactory clinical outcomes of PESS at 18 months follow-up. Above studies indicated that PESS via the transforaminal approach could achieve the targeted decompression of the thoracic spinal cord.

During PESS, part of the superior facet joint, the medial part of the pedicle and minor portion of the posterior vertebral wall were resected to fully expose the ossified posterior longitudinal ligament and dural sac, and resection of the above structures reduced the operative trauma and damage to the stability of the posterior spinal column compared with conventional posterior open surgeries including laminoplasty or laminectomy and fusion. Several studies[5, 22, 24] indicated that the risk of surgically induced instability was minimized via resecting a portion of the facet joint and medial part of the pedicle during the treatment of PESS for lumbar recess stenosis. Moreover, in our previous study[7, 8] on PESS for cervical disc herniation, postoperative bone healing was found in both the medial part of pedicle and the trench of the posterior margin of the vertebral wall with CT examinations at the 6-month follow-up.

In our study, the PESS for OPLL extirpation was performed under local and intravenous combined anesthesia via transforaminal approach, all procedures were successfully completed and the clinical outcomes at 32 months follow-up were good. During the procedure, dexmedetomidine was administrated with initial bolus injection at 0.5 mg/kg and continuous pumping at 0.1–0.5 mg/(kg*h) for relieving pain and improving the patient's intraoperative tolerance. Dexmedetomidine, as a highly selective alpha-2 agonist, has been safely and widely used for various diagnostic and therapeutic procedures to facilitate patients' comfort[28, 29]. Under local anesthesia, patients were conscious and could communicate to surgeons timely throughout the PESS, which facilitated neurological function monitoring and contributed to surgical instrument adjustment during OPLL extirpation. During the insertion of the guide rod, sliding the guide rod from the outside margin of the lamina and ventral part of the superior facet joint into the foramina using our "sliding technique" is recommended due to the potential of iatrogenic injury to the kidney or lung. When using the trephine cannula for foraminotomy, a thin layer of "eggshell" cortical bone is suggested to be left in order to avoid iatrogenic injury to the spinal cord. In our procedure, the medial part of the pedicle and a minor portion of the posterior vertebral wall were drilled via the "trench approach" to create a groove for endoscopic manipulation and fully expose the basal part of the ossified posterior longitudinal ligament and minimize the interference with neural structures.

Conclusion

In summary, our study examined the clinical effectiveness of PESS via a transforaminal approach for single-level T-OPLL. As a minimally invasive spinal technique, PESS can be a clinically feasible, safe and effective alternative approach to conventional procedures in the treatment of single-level T-OPLL.

Abbreviations

PESS
Percutaneous endoscopic spinal surgery
T-OPLL
thoracic ossification of the posterior longitudinal ligament
OPLL
ossification of the posterior longitudinal ligament
CT
Computed tomography
MRI
magnetic resonance imaging
VAS
Visual analog scale
ODI
Oswestry disability index

Declarations

Ethics declarations

Ethics approval and consent to participate: This study was approved by the Ethics Committee of the Second Affiliated Hospital of Chongqing Medical University. Written informed consent was obtained from all individual participants included in the study.

Consent for publication: Written informed consent was obtained from all individual participants included in the study for the publication of this study and any accompanying images.

Competing interests: The authors declare that they have no competing interests.

Availability of data and materials: The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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Author Contributions: Drs. QSY, LS, JSY, ZLD, LC, ZYK had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. Drs. QSY, JSY, LS, ZLD, LC and ZYK designed the study protocol. Dr. QSY and JSY managed the literature searches and summaries of previous related work. Dr. QSY wrote the first draft of the manuscript. Drs. QSY, JSY, LS, ZLD, LC and ZYK provided revision for intellectual content and final approval of the manuscript.

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Table

Table 1. The general data, surgical index and neurological function outcomes of patients in this study.

Case	1	2	3	4	5	6	7	8	9	10	11	12	
Age (Y)	54	62	59	51	48	64	52	71	43	56	58	41	
Sex (M/F)	M	M	F	M	F	F	M	M	M	F	F	F	
OPLL level (T6/T7 ~ T12/L1)	T11/T12	T10/T11	T10/T11	T9/T10	T6/T7	T11/T12	T12/L1	T10/T11	T9/T10	T11/T12	T9/T10	T10/	
Neurological deficits (P/W)	P	P	P	P	W	P	P	P	W	W	W	P	
Operative time (min)	43	52	55	62	59	75	57	83	66	95	104	85	
Intraoperative blood loss (mL)	34	41	37	48	49	64	36	72	59	84	64	78	
Postoperative hospital stays (day)	3	4	3	4	5	4	4	5	3	3	5	3	
Follow-up time (month)	27	13	17	21	15	32	25	/	23	30	19	16	
VAS scores	Pre-operative	6	5	7	6	/	5	7	6	/	/	/	6
	Post-operative	4	3	4	5	/	3	5	5	/	/	/	3
	Last follow-up	3	2	4	1	/	2	2	/	/	/	/	3
ODI scores (%)	Pre-operative	44.5	42.2	51.1	48.9	/	40.0	53.3	51.1	/	/	/	48.9
	Post-operative	26.7	35.6	42.2	40	/	35.6	37.8	40.0	/	/	/	33.3
	Last follow-up	6.0	6.7	31.1	8.9	/	8.9	6.0	/	/	/	/	8.0
JOA29 scores	Pre-operative	17	16	14	17	18	19	14	14	16	18	17	14
	Post-operative	19	16	15	18	19	19	15	17	18	19	18	17
	Last follow-up	20	21	20	22	23	22	22	/	21	22	21	21
Clinical results evaluated by the modified MacNab criteria were excellent in 3 patients, good in 7 patients and fair in 4 patients. The good and excellent rates													
P: thoracic back pain; W: lower extremities weakness; * Compare Preoperative, P < 0.0001													

Figures

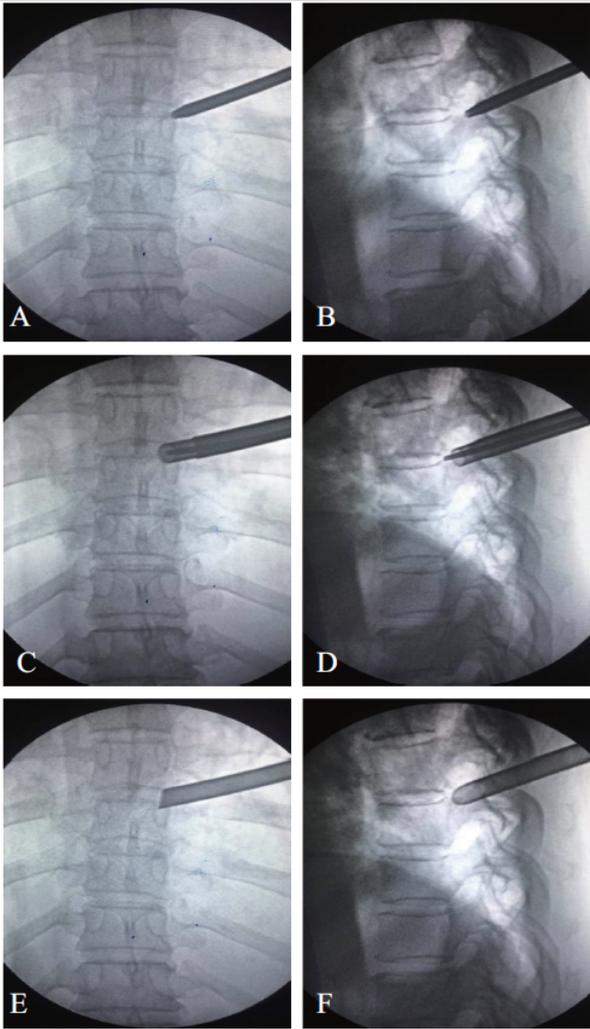


Figure 1

Intraoperative C-arm fluoroscopy during PESS. After the surgical level of thoracic vertebrae was confirmed by biplanar C-arm fluoroscopy, a guide rod was inserted and slid from the outside margin of lamina and ventral part of superior facet joint into the foramina by using “sliding” technique (A-B); foraminotomy was performed by using the trephine cannula with part of the superior facet joint and articular process resected (C-D); after the working sheath was inserted, the percutaneous spinal endoscope system was connected and the position was confirmed by biplanar C-arm fluoroscopy (E-F).

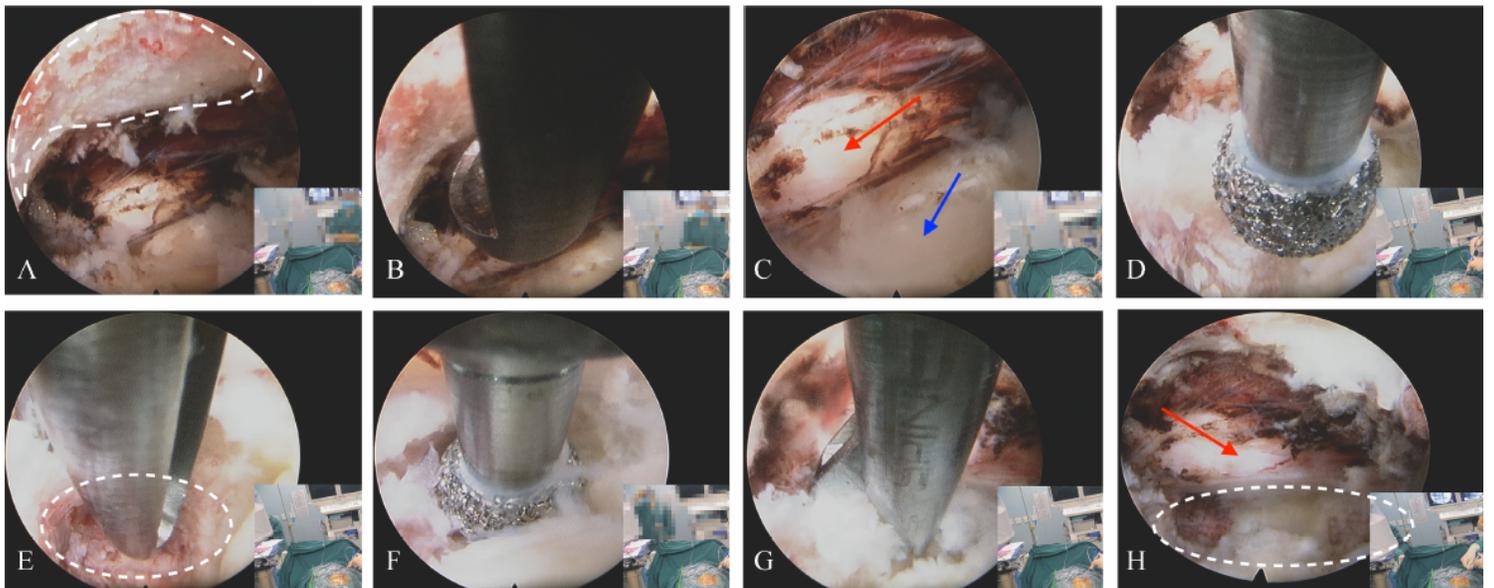


Figure 2

The endoscopic visualization during PESS procedure. After the surrounding soft tissue was carefully cleaned out, partial inferior aspect of the pedicle and the superior facet joint (A, white circle) were resected by Kerrison rongeur (B). The spinal cord (C, red arrow) and ossified posterior longitudinal ligament (blue arrow) were then exposed. A trench groove (E, white circle) was made by using the "trench" technique with the medial part of the pedicle and a minor portion of the posterior vertebral wall resected (D-E). After the basal part was gradually isolated with high-speed burr (F), the ossified posterior longitudinal ligament then removed by using an endoscopic Kerrison rongeur (G). Decompression of the spinal cord (red arrow) and the decompressed area (white circle) were confirmed (H) after the ossified posterior longitudinal ligament completely removed.

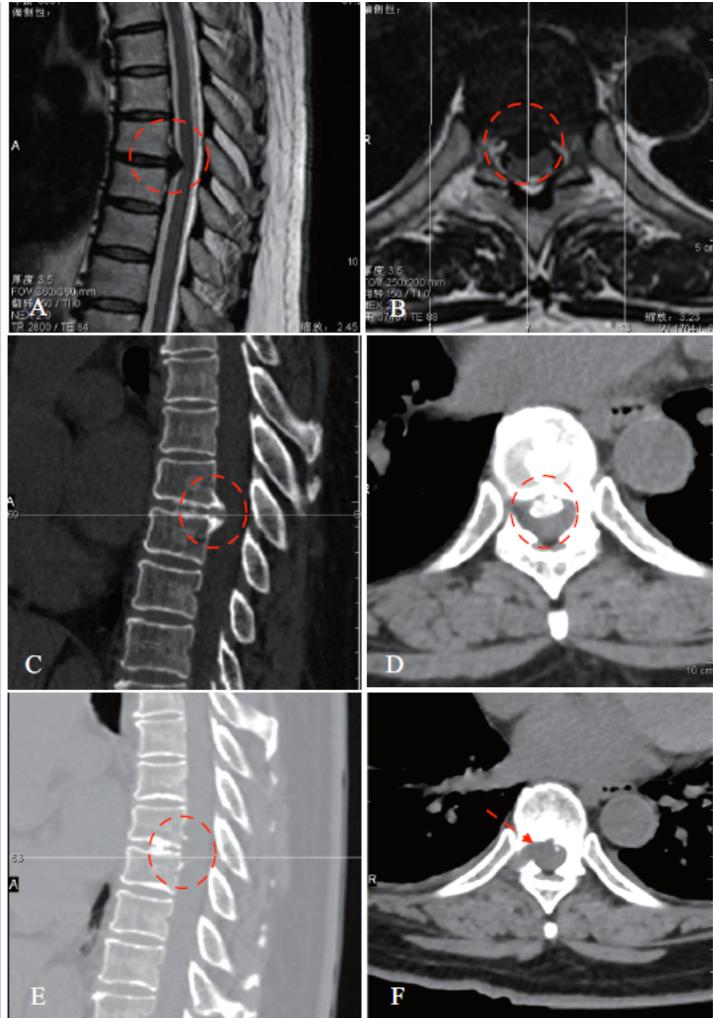


Figure 3

The pre- and postoperative radiologic examinations of a 60-year-old female who underwent PESS for T7/T8 OPLL. The preoperative MRI (A-B) and CT (C-D) examinations showed that the spinal cord was compressed by the ossified posterior longitudinal ligament (A-D, red circle), resulting in lower extremities weakness and cauda equina syndrome. The postoperative CT examinations (E-F) after PESS showed that the ossified posterior longitudinal ligament was completely removed via transforaminal approach by using the "trench" technique, and the trench groove was showed (red arrow).