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ORIGINAL PAPER

"U" route transforaminal percutaneous endoscopic thoracic discectomy as a new treatment for thoracic spinal stenosis

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Abstract

Purposes To describe the rationale, surgical technique, and short-term follow-up results of a new minimally invasive treatment for thoracic spinal stenosis (TSS) caused by herniation, ossification of the ligamentum flavum (OLF), and/or ossification of the posterior longitudinal ligament (OPLL) with a "U" route transforaminal percutaneous endoscopic thoracic discectomy (PETD).

Methods Fourteen patients, including seven males and seven females, underwent "U" route PETD. Myelopathy was caused by OLF in 14 patients, OPLL in one, combined OLF-OPLL in ten, and intervertebral disc herniation (IDH) in five. Decompression was performed in one segment in 12 patients, and in two segments in two patients. The Japanese Orthopedic Association (JOA) scores, visual analog scale (VAS) scores, and complications were documented.

Results The JOA scores improved from 4.64 ± 2.31 pre-operatively to 7.07 ± 1.59 one day post-operatively and 11.79 ± 1.85 at final follow-up. The difference between pre-operation and post-operation was statistically significant ($P < 0.05$). Moreover, the VAS score was 6.07 ± 2.06 points pre-operatively, decreasing to 3.00 ± 1.24 points at one day post-operatively, and 1.14 ± 0.86 points at last follow-up ($P < 0.05$). Dural tear was observed in two cases during the intervention. No patient had transient worsening of pre-operative paralysis.

Conclusions This retrospective analysis shows that "U" route PETD for decompression may be a feasible alternative to treat thoracic spinal stenosis.

Keywords Thoracic spinal stenosis (TSS) · Percutaneous endoscopic thoracic discectomy (PETD) · Transforaminal · Novel technique · Surgical outcome

Introduction

The conventional surgical treatment for thoracic spinal stenosis (TSS) has evolved over several decades. At present, the main treatment methods for TSS are ossification of the posterior longitudinal ligament (OPLL) extirpation through thoracotomy [1, 2], laminectomy [3], posterior approach decompression [4], circumferential decompression, and front-side approach decompression. Although these approaches are established procedures and satisfying long-term results have been reported, some risks of transient neurological deterioration or permanent paraplegia with these methods are observed in many cases.

Several minimally invasive spinal procedures for the cervical and lumbar spine have been reported in recent years. It has been demonstrated that percutaneous endoscopic lumbar discectomy (PELD) is a relatively safe, minimally invasive procedure for lumbar spinal stenosis and lumbar intervertebral disc herniation with less tissue trauma and blood loss, shorter mean disability period, and less recovery time. Moreover, some scholars reported that their patients had thoracic ossification of the ligamentum flavum (OLF) that was completely removed using the microendoscopic technique. However, there are few reports of transforaminal percutaneous endoscopic thoracic discectomy (PETD) for thoracic spinal stenosis in the literature. With the development of cervical and lumbar

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spine mini-invasive surgery, we aimed to perform a "U" route PETD under local anaesthesia to treat 14 patients with severe TSS. We aimed to effectively expand the spinal canal while preserving most of the normal osteoligamentous anatomy of the thoracic spine. We thought that the patients would have neurological improvement, and we would simultaneously reduce the risk of post-operative complications. The purpose of our study is to evaluate the safety, feasibility, and efficacy of PETD for patients with TSS.

Patients and methods

Patients

After obtaining permission from The Third Hospital of Henan Province, the medical records of 14 patients (7 males and 7 females) who underwent "U" route PETD between June 2016 and January 2017 were retrospectively reviewed. Myelopathy was caused by ossification of the ligamentum flavum (OLF) in 12 patients, ossification of the posterior longitudinal ligament (OPLL) in one, combined OLF-OPLL in ten, intervertebral disc herniation (IDH) in five, the upper thoracic spine (T1–4) in ten, and the lower thoracic spine (T5–12) in two patients. Telephone interviews were conducted to complete a questionnaire as the final follow-up (Fig. 1).

Surgical procedures

Pre-operatively, we designed the operation puncture length and angle on a transverse computed tomography (CT) scan, as demonstrated in Fig. 2 (a, b).

Intra-operatively, all procedures were performed following the standard transforaminal endoscopic discectomy technique. With the patient in the prone position, all procedures were performed under local anaesthesia with continuous monitoring of oxygen saturation, heart rate, and blood pressure. For the relaxation and comfort of patients, sedation with dexmedetomidine hydrochloride was administered. Subsequent doses of dexmedetomidine hydrochloride were given as needed. The C-arm fluoroscopy technique was used to identify the lesion segment (Fig. 2. (1)).

The surgeon drew a straight line 6.5 cm in length from the posterior midline to the skin entry point at an angle of approximately 15°. After a routine disinfection procedure, the subcutaneous tissue and the trajectory tract were infiltrated with 1.0 to 1.5 mL of 1% lidocaine at the affected level. Following this, an 18-gauge needle was inserted to reach the facet joint under fluoroscopic guidance. We tilted the head back 10° with an inclination of 45° according to the puncture direction (Fig. 2 (2, a, b)).

Then, with a guide rod and another Kirschner wire guide rod replacement, the surgeon drilled directly into the bone cortex layers 1 to 2. After making three gradual expansion sleeve channels, the surgeon performed a sleeve soft-tissue expansion (Fig. 2 (3, c, d)).

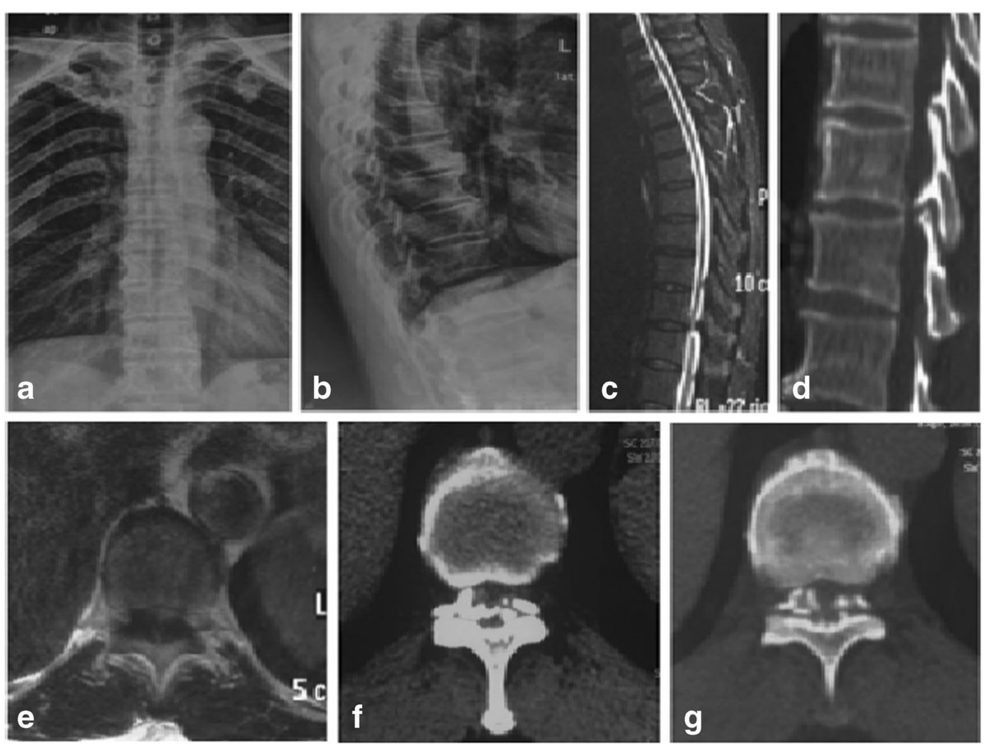

Fig. 1 Pre-operative anteroposterior (**a**) and right lateral (**b**) X-ray images of the patient revealed thoracic spine degenerative changes. CT scans (**c**, **e**, **g**) of the thoracic spine showed a mass of bone density in contact with the vertebral lamina of T10 on the right and protruded into the spinal canal. MRI (**d**, **f**) of the thoracic spinal cord in the sagittal section; T2-weighted sequence showed spinal cord compression by low-signal masses in contact with the neural arches of T9/10

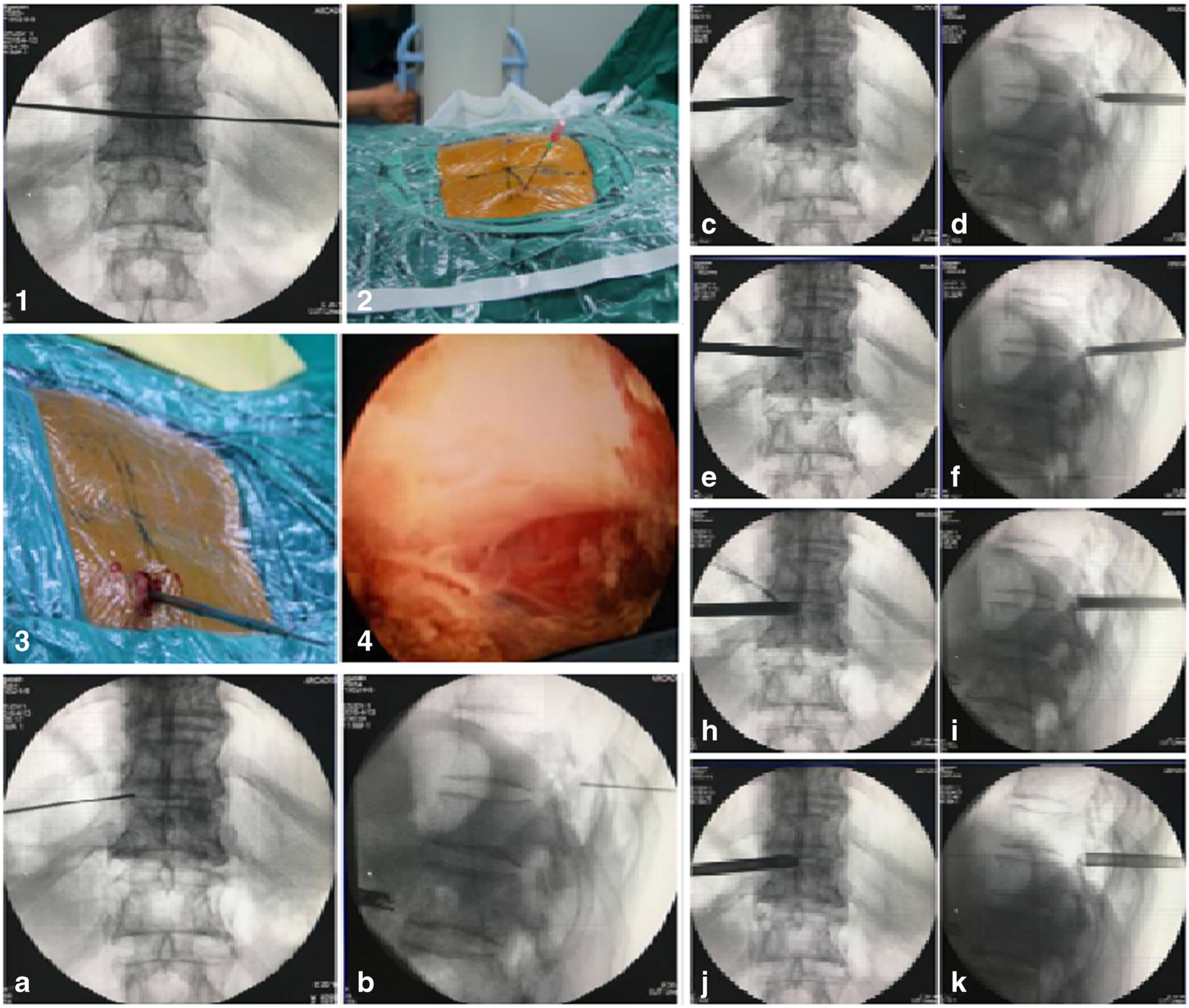

Fig. 2 We identified the lesion segment (1). An 18-gauge needle was inserted to reach the facet joint under a fluoroscopic guidance. According to the puncture direction of the head tilt back 10° inclination 45° (2, .a, b). It showed that after three gradual expansion sleeve channel, and then work sleeve soft. It showed that tissue expansion (3, c, d), the articular process or the lamina has been annulled by the ring saw (e, f, h, i). It showed that the working channel was rotated around the direction of the guide bar (j, k)

Then, three rings in addition to the bone, according to the backside of the eccentric ring, each ring with the bone as far as possible out saws. During the procedures, the application techniques is the so-called Acentric-saw technique. Key point is that right hand circular saw handle jammed left thumb finger against the lower edge of the handle, the thumb side of the force pushing forward the end of the ring saw, the other four fingers clenched left hand circular saw body, the little finger close to the skin of the patient, the little finger and ring finger abdominal push back trephine head end; we should be aware of circular saw and swing fall. When there is a sense of descent, it means that the articular process or the lamina has been annulled by the ring saw (Fig. 2 (e, f, h, i)).

The acentric saw was retreated. The working channel was rotated around the direction of the guide bar (Fig. 2 (j, k)), after insertion of the endoscope system was inserted, further drilling and herniated intervertebral discectomy were performed under percutaneous endoscopic thoracic discectomy system and continuous fluid flow with 0.9% saline solution.

Then, we inserted the spinal endoscope and removed the osteophyte and the ligamentum flavum by using pliers. Exploring inside and outside edge. Probe the end of the head to remove calcification. To expand the reduced pressure range, we use a power drill or ring saw. When you see the dural sac and the nerve root fluctuate, it means that the decompression is complete and the operation can be completed (Fig. 2. (4)). Besides, during the procedure, if the spinal canal was compressed by both sides osteoligamentous hypertrophy, we need to locate the target of the puncture to the junction of the spine and the lamina by adjusting the angle. If unilateral decompression, the target of the catheter is in the joint process or the upper and lower joint.

Finally, the operative field was copiously irrigated, and meticulous haemostasis was obtained; no drainage was placed. The incision was closed after the channel was removed.

Post-operative management

Post-operative bed rest for one to two days was recommended for all patients regularly receiving drugs such as anti-inflammation and nutritional nerve. Both thoracic MRI and CT findings were reviewed one day after surgery (Figs. 3 and 4). All patients generally were allowed to sit and walk with a orthosis for six to eight weeks for recovery.

Efficacy evaluation

The modified Japanese Orthopedic Association (m JOA) score (maximum score 17) was used to evaluate the neurological function, and recovery rates were calculated using the formula (RR = [post-operative score − pre-operative score]/[17 -pre-operative score] × 100%, which were ranked as follows: Excellent (recovery rate ≤ 75%), Good (50% ≤ recovery rate < 75%), Fair (25% ≤ recovery rate < 50%), Poor (recovery rate < 25%). The visual analog scale (VAS) was used to evaluate the degree of pain in the back and leg. Complications such as cerebrospinal fluid leakage caused by epidural tears were also recorded.

Results

The patients in our series were diagnosed with thoracic spinal stenosis, which was confirmed by post-operative X-ray, CT, and MRI. Fourteen patients (7 males and 7 females) with complete follow-up data were included in our study. These 14 patients were successfully operated upon by Li XC. Decompression was performed in one segment in 12 patients and in two segments in two patients. Bilateral decompression was performed in three patients. Clinical data are shown in Table 1.The operation time averaged 120 minutes (range 170–200 minutes) with the average intra-operative blood loss of 40 ml (range 20–90 ml). The mean hospital stay was four days.

The mean follow-up duration was 31.2 months. One or two days after the surgery, the lateral radiograph, CT scan, and MRI findings showed that the spinal cord was not compressed, low-signal masses, and the neural arches of T9/10 had been resected compared to the pre-operative results.

The JOA scale scores improved from 4.64 ± 2.31 pre-operatively to 7.07 ± 1.59 one day post-operation and to 11.79 ± 1.85 at the final follow-up with a mean recovery rate of 57.07 ± 15.30%. The difference between pre-operation and post-operation was statistically significant ($P < 0.05$) (Table 2). The excellent in one and good rate in ten were 71.42%, the fair rate in two was 92.85%.

The VAS score was 6.07 ± 2.06 in all patients pre-operative and improved to 3.00 ± 1.24 points at one day post-operation and to 1.14 ± 0.86 at the last follow-up (Table 2). The statistical analysis of the results showed a significant improvement in pain reduction at the final follow-up ($P < 0.05$) when compared to the pre-operative status.

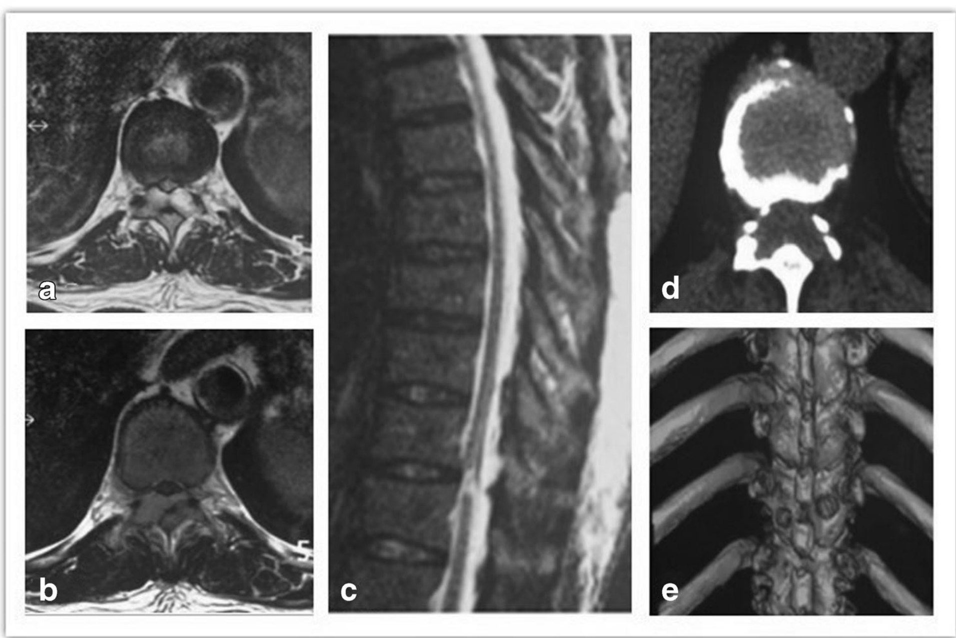

Fig. 3 Both the sagittal (**c**) and axial MRI (**a**, **b**) of the thoracic spinal cord T2-weighted sequence at 1-day post-operative showed no compression of the spinal cord, low-signal masses, and the neural arches of T9/10 had been resected compared with the pre-operative results despite the presence of oedema. CT scans (**d**) and 3-dimensional reconstruction (**e**) at 1-day post-operative of the thoracic spine indicating the stenosis. Bilateral were alleviated remaining two holes in the lamina at different level

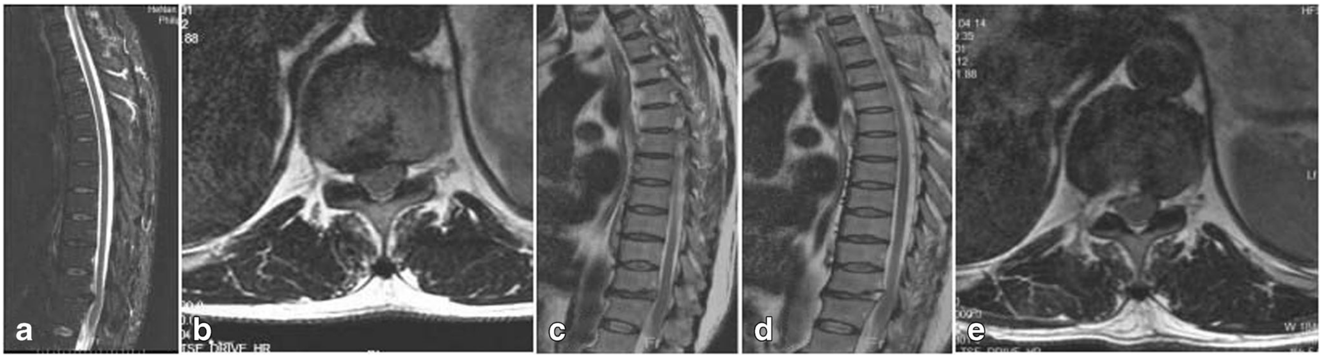

Fig. 4 Pre-operative MRI (**a**, **b**) of the thoracic spinal cord in the sagittal and sectional section; T2-weighted sequence showed spinal cord compression by herniated disc at T11/12. Both the sagittal (**c**, **d**) and axial MRI (**e**) of the thoracic spinal cord T2-weighted sequence at 1-day post-operative showed no compression of the spinal cord

Complication

In our present series, cerebrospinal fluid leakage occurred during the procedure in two patients (cases 1 and 2), but no patient had transient paralysis immediately after operation, and no patient developed persistent paralysis after decompression.

Discussion

Thoracic myelopathy is an uncommon disease caused by [5] herniation, ossification of the ligamentum flavum, or ossification of the posterior longitudinal ligament. These causes can be combined, also including vertebral osteophyte, hyperplasia of articular joint, kyphosis, and thickening of ligament [6]. More than 50% of the ossified ligaments are caused by ossification of the ligamentum flavum. In our patients, OLF account for 86%. The pathogenesis of OLF may be related to degeneration, abnormal bone metabolism, mechanical damage, and heredity [6]. More than 80% of thoracic spinal stenosis occurred at the T9-10 level or lower. The result in our cases was similar to that reported in the literature.

Researchers worldwide have used many surgical procedures to treat thoracic spinal stenosis, including laminectomy [3], OPLL extirpation through thoracotomy [1, 4, 7], and circumferential decompression [8, 9], and most patients have achieved satisfying clinical outcomes.

Recently, posterior foraminotomy appears to receiving much attention with the development of minimally invasive techniques [10, 11]. Alternatively, posterior foraminotomy

Table 1 Clinical data of patients

Case no.	Gender	Age	Segment	Period (month)	Pathogenesis	Complaint
1	M	64	T10–11	6	OLF + OPLL	Paraparesis
2	F	76	T11–12	4	IDH + OLF	Unstable walking, leg pain
3	F	41	T7–8	5	FH	Paraplegia
4	M	66	T1–2	7	OLF	Leg pain, band feeling
5	M	53	T10–11	10	IDH + OLF	Lower limb numbness, leg pain
6	F	50	T9–10	8	OLF	Unstable walking
7	M	41	T10–11	12	IDH + OLF	Unstable walking
8	F	66	T10–11	7	IDH + OLF	Lower limb numbness, leg pain
9	M	55	T10–11, T11–12	8	OLF	Paraparesis, band feeling
10	F	52	T8–9, T9–10	3	OLF	Paraparesis, leg pain
11	F	59	T11–12	36	OLF	Paraparesis, Leg pain
12	F	78	T10–11	7	OLF	Lower limb numbness
13	M	61	T11–12	4	IDH	Right lower limb numbness
14	M	33	T1–2	4	OLF	Right lower limb numbness

OLF, ossification of the ligamentum flavum; *OPLL*, ossification of the posterior longitudinal ligament; *IDH*, intervertebral disc herniation; *FH*, facet hypertrophy

Table 2 Comparison of clinical effectiveness between pre-operative and post-operative

Case. no.	F-up (month) (mean 7.5)	JOA			VAS			Neurological improvement
		Preop	Postop	Last F-up	Preop	Postop	Last F-up	
1	11	2	7	13	5	4	0	Good
2	6	3	9	12	8	3	1	Good
3	6	3	5	10	7	2	1	Good
4	15	7	8	14	7	3	2	Good
5	15	7	9	15	6	2	1	Excellent
6	5	5	7	13	6	4	0	Good
7	4	4	7	9	7	3	2	Fair
8	3	2	4	10	7	4	2	Good
9	4	3	6	12	3	2	1	Good
10	7	4	7	11	7	2	2	Fair
11	7	2	5	10	10	3	2	Good
12	9	7	9	12	2	1	0	Good
13	3	8	8	10	4	3	2	Poor
14	10	8	8	14	6	3	0	Good

VAS, visual analog scale; *JOA*, Japanese Orthopedic Association

using endoscopic is an approach to the cervical or lumbar spine that avoids many of the complications. Further avoiding fusion may preserve the normal motion in the spine. However, few reports are available on TSS using endoscopic systems. On the basis of these two advantages, we hypothesized that whether this technique could be applied in thoracic spinal stenosis. Based on this hypothesis, in 2016, we introduced the surgical procedure of posterior decompression for patients with OPLL, OLF, and TDH in TSS.

Our study showed the excellent and good cases were 11, the fair cases were two. Seichi Atsushi et al. [12] reported ten patients with myelopathy underwent laminotomy with medial facetectomy, and an image guidance system was used to remove the OLF. No neurological deterioration occurred, and postoperative CT revealed successful decompression and good preservation of the lateral parts of the facet joints with recovery rate of above 60%. Matsuyama Yukihiro et al. [13] and Li Z [3] also achieved satisfying clinical outcomes through a posterior and anterior approach for decompression and fusion with improvement rate of above 60%. Nie ZH [14–16] reported lamina osteotomy and replantation with miniplate fixation for thoracic myelopathy with a mean recovery rate of 67.8% ± 13.1%.

Post-operative paraplegia remains a major risk [4, 8, 13, 17] for these cases. Yong [18] reported that the incidence rate of acute neurologic deterioration after surgical treatment of TSS is 14.5%. Yamazaki M [19] reported a patient who underwent laminectomy and showed no further neurological deterioration post-operatively, but showed severe paraparesis over the next 18 h. After fusion, neurological deficits gradually recovered. A retrospective review reported by Takahata M [4] showed post-operative neurologic deterioration of about 33%, especially in patients with multiple level circumferential decompression of five or more vertebral levels, of which two patients had permanent paralysis. In addition, a multiinstitutional retrospective study conducted by Matsumoto M [17, 20] also revealed the frequent complications were deterioration of myelopathy immediately after surgery in 18 (11.7%) and dural injury in 34 (22.1%) patients. Therefore, some surgeons [21] like Eggspuehler A used multimodal intra-operative monitoring during decompression of thoracic spinal stenosis and concluded that this method is an effective method of monitoring the spinal cord during decompression. In our study, all the patients underwent local anesthesia, and the patients could sensitively respond to the stimulation due to the decompression, which improved the safety of the intervention. Neurologic deterioration was not observed in 14 patients.

In 2010, Liu [22] reported a 360° cave-in circumferential decompression that removes ventral and dorsal spinal compression from the posterior approach for 26 patients with TSS. It is a direct decompression procedure, which reduces the rate of post-operative paralysis. The literature reports are comparable to our results. None of the patients was paralyzed after surgery in our study. We think that this may be because we used the power grinding system in the operation, and the catheter was gently inserted into the spinal canal. This greatly reduced the stimulation to the spinal cord and nerve. Additionally, during the procedure of drilling of the superior and inferior articular process, cerebrospinal fluid (CSF) leakage occurred in two patients resulting from ossification of the ligament and dura mater adhesions, and even dural sclerosis. CSF leakage was reported to be 37.7% by Cho JY [23]. As a solution, we suspend the procedure for about five minutes by finger pressing on the outer mouth of the transforaminal endoscopic instruments. When seeing the flow rate of cerebral spinal fluid slowed down, we continued operations showing calcification and adhesion of the dural sac and the yellow ligament. Under the endoscope, the broken mouth was small, no suture was given, and the operation was continued. A drainage tube was placed after the operation; the patient's head was placed at a low position, and positive rehydration was applied to avoid the occurrence of low cranial pressure. The daily flow rate was about 100 ml, and the drainage volume was less than 10 ml on the third day after surgery. Nevertheless, the two patients did not have a headache, dizziness, nausea, fever, and other low cranial pressure symptoms postoperatively.

Numerous studies have shown that articular process or lamina debridement less than 50% does not affect the spinal stability [15, 24]. Based on this principle, we thought that the patients undergoing the surgery of transforaminal percutaneous endoscopic thoracic discectomy would not have a complication of spinal instability, because we only reduced the pressure by removing one third of the inferior articular process.

He [25] firstly reported the navigator-assisted spinal surgery (NASS) technique in transforamimal percutaneous endoscopic lumbar discectomy, and indicated that a definite trajectory significantly reduced pre-operative location time, puncture-channel time, and operation time, and minimized the fluoroscopy times. I suggest this technique can also be used for thoracic spinal stenosis, and may improve the safety of surgery and reduce the time of surgery and fluoroscopy.

The main disadvantages of our study were that the number of patients included was limited because thoracic spinal stenosis is rare in clinical setting. Let alone the cases combined with severe bone damage. Hence, despite good results, it was very difficult to assess the safety and efficacy of this approach by this study. Long-term follow-up and data collection will be required in the future.

Compliance with ethical standards

Competing interests The authors declare that they have no conflict of interest.

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