Acta Neurochirurgica (2024) 166:134
https://doi.org/10.1007/s00701-024-06030-0

HOW I DO IT

Biportal endoscopic transforaminal thoracic interbody fusion for the treatment of thoracic myelopathy

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Received: 14 February 2024 / Accepted: 28 February 2024

Abstract
Background Biportal endoscopic spine surgery independently controls two hands, similar to microscopic surgery, and utilizes a broader working space that is not disturbed by retractors under clear-magnified endoscopic vision. These advantages facilitate successful neural decompression and safe transforaminal interbody fusion, even in patients with thoracic spondylotic myelopathy.
Methods A wide laminectomy and precise total facetectomy, in conjunction with partial pediculotomy, establish a secure transforaminal space for cage insertion. Endplate preparation and cage insertion were performed without retracting the spinal cord under direct endoscopic vision.
Conclusion Biportal endoscopic transforaminal thoracic interbody fusion can be a feasible technique for treating thoracic spondylotic myelopathy at the thoracolumbar junction levels.

Keywords Transforaminal · Thoracic vertebrae · Fusion · Endoscopy

Relevant surgical anatomy

During the microscopic thoracic posterolateral approach, rib heads and self-retractors narrow the surgical corridor to the intervertebral disc space, including the neuroforamen. However, during the biportal endoscopic approach, a small endoscope reveals blind spots by closely examining the working space, allowing instruments to freely access the spinal canal without passing through retractors [1]. Wide laminectomy and ipsilateral total facetectomy should be performed to expose the disc space. Inclined drilling of the superior portion of the lower-level pedicle and superior articular process offers extra space for cage insertion [2]. The cage can be smoothly inserted into the disc space by sliding along the inclined bony surface. Unilateral biportal endoscopic transforaminal thoracic interbody fusion (UBE TTIF) overcomes anatomical limitations and enables efficient neural decompression and safe cage insertion without spinal cord retraction.

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Description of the technique

Surgical instruments

The usual biportal endoscopic systems, a tool-kit set for biportal endoscopic spine surgery, radiofrequency (RF) systems, and a scope retractor (MD company, South Korea) were used for this surgery [1, 3]. We inserted three-dimensional (3D)-printed titanium cages (PANTHER spinal cage, Mantiz, South Korea, 11 mm in width, 7 mm in height, and 24 mm in length), typically used for posterior lumbar interbody fusion (PLIF).

Position and making two portals

We performed the UBE-TTIF for the patient with thoracic myelopathy at the T11–12 caused by ossification of the ligament flavum and disc herniation (Fig. 1). UBE TTIF was performed with patients in the prone position on the Wilson frame under general anesthesia. Two-centimeter-sized longitudinal skin incisions were created on the lateral border of the pedicles, designated for percutaneous pedicle screw fixation (Fig. 2a). The incision for the working portal should include the disc space and pedicle, making it longer than the endoscopic portal [3, 4].

Published online: 12 March 2024

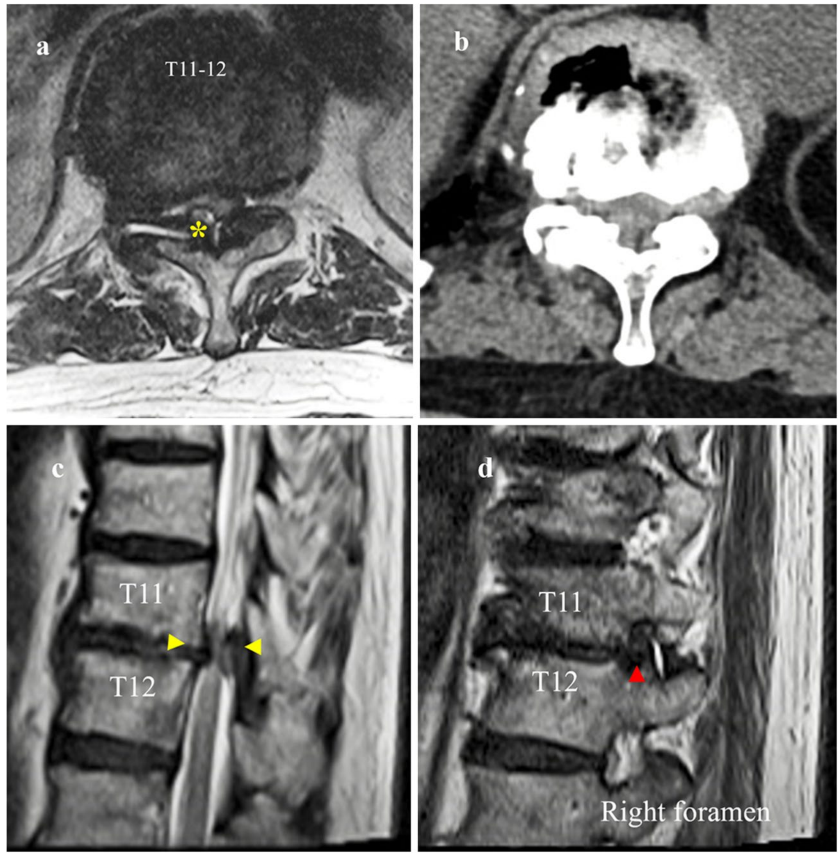

Fig. 1 Images from a 68-year-old man who presented with symptoms of thoracic myelopathy. **a**, **b** Preoperative axial magnetic resonance imaging (MRI) and computed tomography (CT) show a prominent facet cyst (yellow asterisk) with hypertrophied facet joint compression in the spinal cord at the T11–12 bilateral spinal canal. **c** A sagittal MRI reveals a severely compressed spinal cord between the herniated disc and hypertrophied ligament flavum (yellow arrowheads). **d** Severe stenosis of the right neuroforamen was observed on the oblique sagittal MRI (red arrowhead)

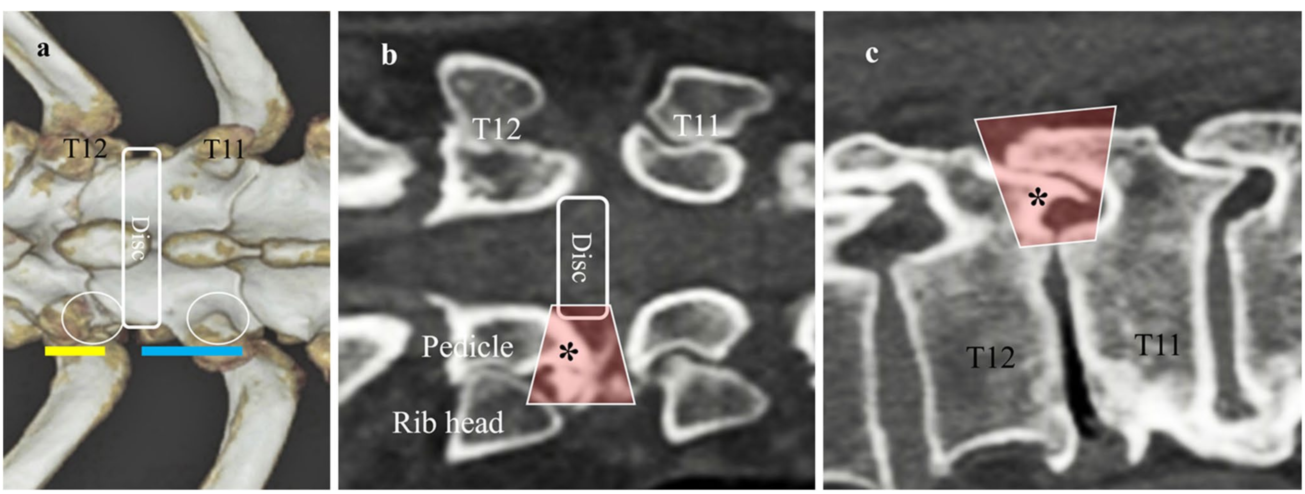

Fig. 2 Making portals and bony drilling are described with computed tomography (CT) images during the portal endoscopic approach for transforaminal thoracic interbody fusion at the T11–12 right. **a** Skin incisions for two portals in case of right-handed surgeon (yellow line, endoscopic portal; blue line, working portal). **b**, **c** Coronal and sagittal section of CT image at the neuroforaminal area. After ipsilateral total facetectomy, partially inclined drilling of the lower-level pedicle (asterisks) facilitates smooth cage passing into the narrow disc space

Unilateral total facetectomy and wide laminectomy (Videos 1 and 2)

The ipsilateral lamina and facet joint were exposed after soft tissue dissection. Firstly, we widely drilled out the bilateral lamina until exposing the bilateral superior articular process (SAP) and the craniocaudal ends of the ligamentum flavum. A secured flap of the ossified ligamentum flavum was carefully detached from the dura using the hook and scope retractor while the endoscopy visualized the epidural space (Video 1). Subsequently, the inferior articular process and SAP were serially removed using the endoscopic diamond drill until the proximal and distal ends of the neuroforamen were observed [3, 4] (Fig. 2b, c, and Video 2). The foraminal aspect of SAP and pedicle were obliquely drilled like a funnel to obtain extra space for endplate preparation and cage insertion [2, 5] (Figs. 2b, c, and 3a). After completing the bone work, the detached ligamentum flavum for the spinal canal and foraminal area was carefully removed using forceps [1, 6]. The disc space of the spinal canal and neuroforamen was exposed (Fig. 3b and Video 2).

Discectomy and endplate preparation (Video 3)

A customized blunt knife and a 3-mm diamond drill (NSK Primado, Japan) were used for annulotomy and expanding the entrance of the disc space [3, 4]. We separated the cartilaginous endplate from the osseous endplate using blunt dissectors under endoscopic guidance, while a scope retractor protected the dural sac. Curved instruments accessed the contralateral disc space with a shallow approach angle through the space created by total facetectomy. We should secure the sufficient entrance of disc space, including the spinal canal and neuroforaminal area, for smooth cage insertion (Fig. 3c).

Cage insertion (Video 3)

The serial size of trial cages was inserted into the disc space to determine the cage size and increase the disc height. During trial cage insertion, we meticulously confirmed the dural sac and exiting nerve root to ensure the cages did not excessively compress them. Bone chips and demineralized bone

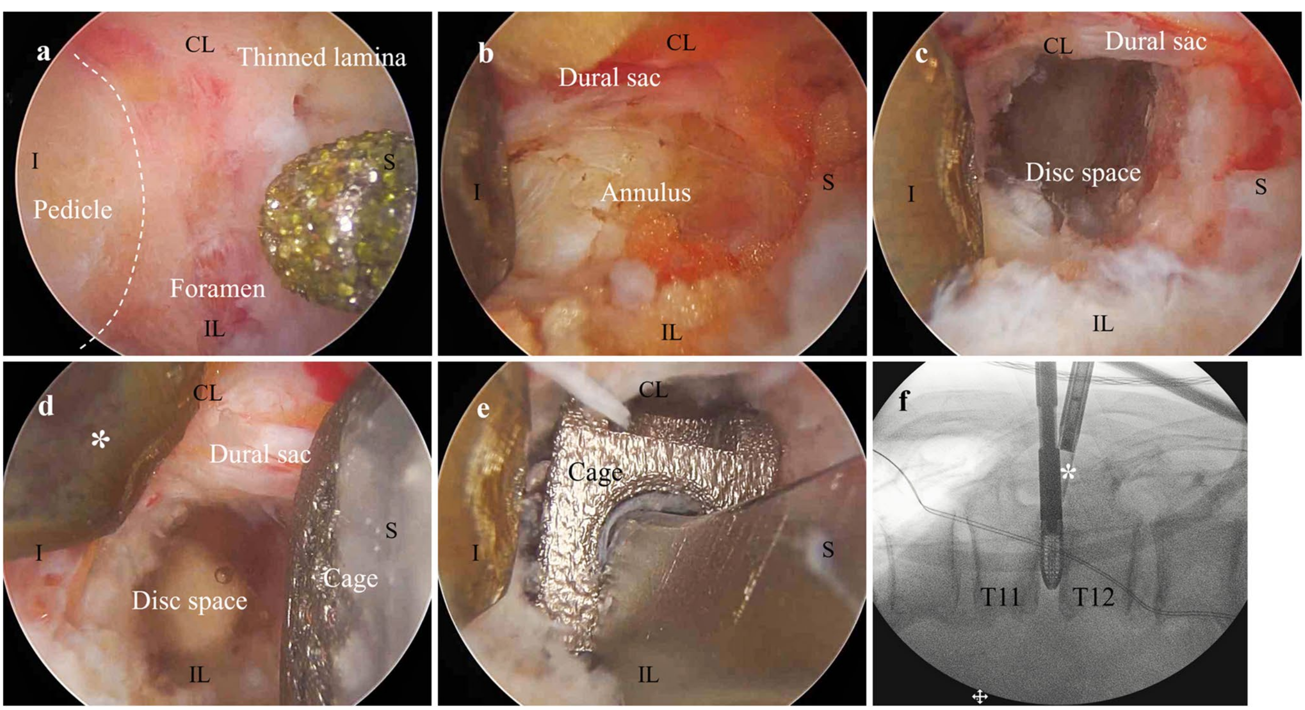

Fig. 3 Surgical steps are described with intraoperative photos and X-ray images during unilateral biportal endoscopic transforaminal thoracic interbody fusion at the T11–12 right. The ipsilateral lamina and facet joint were drilled out while maintaining the inner cortical bone. **a** Partial drilling of the lower-level pedicle offers a broad endoscopic view of the spinal canal and neuroforaminal area. **b** A sufficient surface of the annulus was exposed for discectomy and endplate preparation. **c** After completion of endplate preparation. **d** The cage was inserted into the disc space while protecting the dural sac with a scope retractor (white asterisk). **e** The cage smoothly passed the entrance of the disc space without compressing the dural sac. **f** The intraoperative C-arm image showed the step of cage insertion. The scope retractor (white asterisk) protects the spinal cord from a passing cage. Orientation: S, superior; I, inferior; CL, contralateral; IL, ipsilateral

matrix (DBM) blocks were inserted into the disc space [3]. Subsequently, we obliquely placed the 3D-printed titanium cage into the disc space while the scope retractor protected the spinal cord (Fig. 3d). The initial position of the cage could be adjusted as needed using cage impactors (Fig. 3e). All cage insertion procedures were carefully performed under endoscopic view and C-arm images (Fig. 3f). We inserted gel foam into the empty disc space to prevent bone chips and DBM loss. Drainage catheters were inserted after achieving hemostasis.

Percutaneous screw fixation

Skin incisions for the two portals were used for screw fixation. We made two additional skin incisions on the contralateral side and used them for percutaneous pedicle screw fixation [3, 4, 7]. After surgery, the patient recovered neurological functions, and postoperative images showed a decompressed spinal cord and an appropriate position of the cage (Fig. 4).

Indications

Excessive facet resection at the thoracolumbar junction is unlike midthoracic levels, which can induce postoperative segmental instability and kyphotic deformity. Postoperative kyphosis may cause delayed progression of compressive myelopathy in patients with adjacent-level stenosis, such as ossified ligamentum flavum or ossification of the posterior longitudinal ligament [8]. If patients have severe thoracic spondylotic myelopathy in the thoracolumbar junction and wide facet resection is inevitable, we recommend UBE-TTIF to prevent postoperative kyphosis.

Limitations

This technique should be considered at the thoracolumbar junction levels, including T10–11, T11–12, and T12–L1 levels, which can secure sufficient space for cage insertion without spinal cord injury. This technique should be performed for

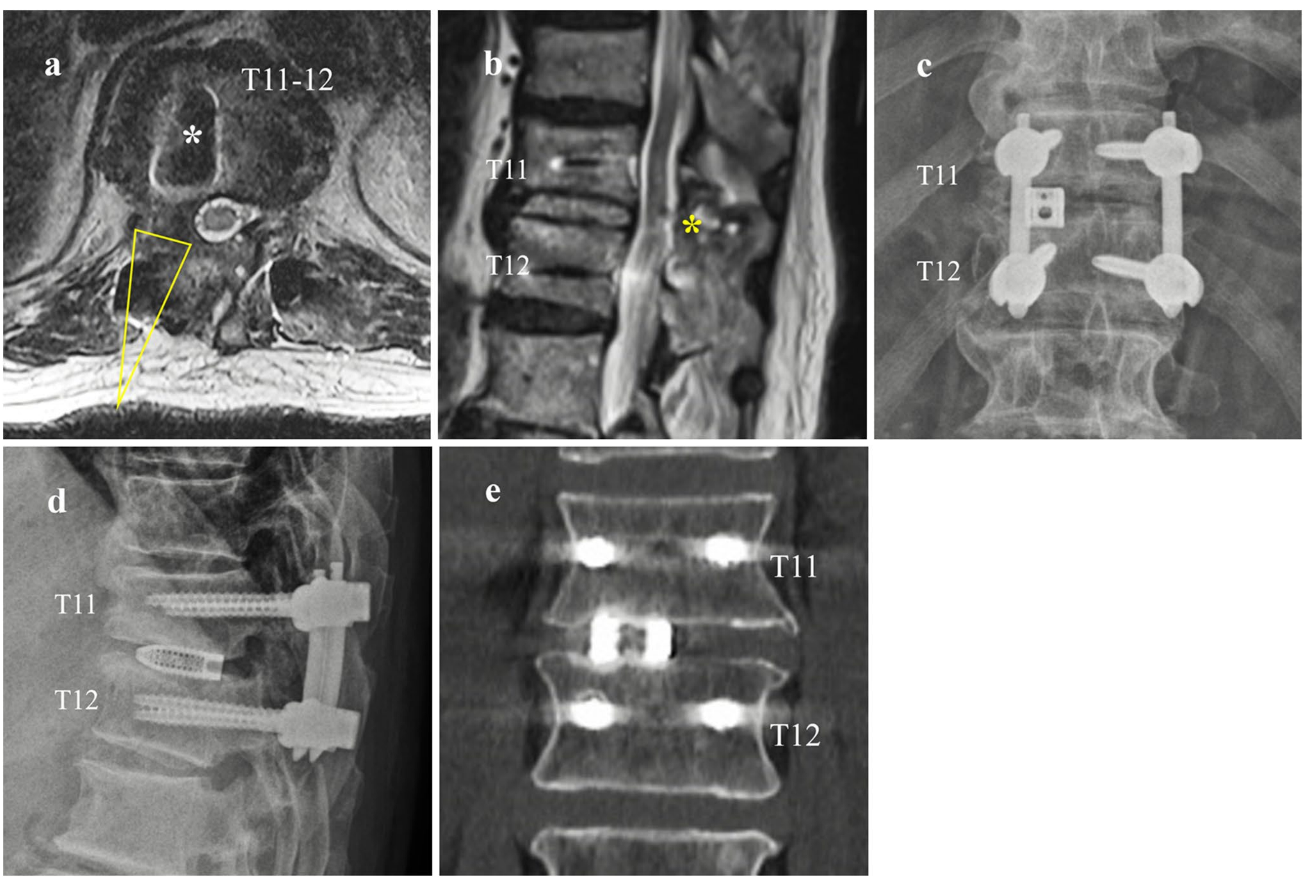

Fig. 4 Radiological result of the illustrated case. The patient underwent the biportal endoscopic posterior approach at the T11–12 right. **a**, **b** Postoperative axial and sagittal magnetic resonance images show a sufficiently expanded spinal canal (yellow asterisk). The cage (white asterisk) was successfully inserted through the space made by total facetectomy (yellow triangle). **c**, **d** The X-ray images of 6 months follow up. **e** Computed tomography at 6-month follow-up shows the process of interbody fusion through the 3-dimensional printed titanium cage

highly selective cases after obtaining abundant experience in microscopic thoracic and biportal endoscopic surgery.

How to avoid complications

The most crucial consideration is to avoid spinal cord compression during cage insertion. Total facetectomy commonly offers a disc space more than 11 mm in width in the thoracolumbar junction levels, and additional inclined pediculotomy facilitates smooth cage insertion through the funnel-shaped entrance of the disc space [2]. However, disc heights vary among patients. We recommend using bone blocks for interbody fusion in patients with disc heights less than the smallest cage.

Specific perioperative considerations

In patients with severely decreased disc space, cage insertion is not recommended due to the risk of spinal cord injury while impacting the cage into the collapsed disc space. In this case, we harvested the bone block by resecting the ipsilateral inferior articular process for inserting them in the disc space with the DBM block. Allobone graft could be a good option if auto-bone harvest is not sufficient.

Specific information to give the patient about surgery and potential risks

Although biportal endoscopic thoracic interbody fusion has advantages, there is a possibility of spinal cord injury due to insufficient space for cage insertion [9]. In this case, endoscopic surgery can be converted to open microscopic surgery.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s00701-024-06030-0.

Author contribution Corresponding author (SY Choi) conceived and designed the study, conducted data analysis and interpretation, drafted the manuscript, and critically reviewed it for important intellectual content.

First author (JY Kim) contributed to data collection, analysis, and interpretation, and critically reviewed the manuscript for important intellectual content.

Third author (KM Kim) contributed to study design, provided technical or material support, and critically reviewed the manuscript for important intellectual content.

Data Availability The data and materials used in this study are available upon request from the corresponding author.

Code Availability Applicable.

Declarations

Ethics approval This article does not contain any studies with human participants or animals performed by any of the authors.

Consent to participate Applicable

Consent for publication Applicable

Competing interests The authors declare no competing interests.

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