AMPLIFY® SURGICAL

FALL SPINE SYMPOSIUM

featuring

dualPortal™ endoscopic and dualX® system

SEPTEMBER 24, 2022 | NEW YORK CITY, NY

WELCOME TO AMPLIFY SURGICAL'S FALL SPINE SYMPOSIUM 2022

On behalf of Amplify Surgical, welcome! We are so excited to see everyone in person. This year's meeting promises interesting and educational sessions with a hands-on cadaver lab for all participants with the goal of promoting and encouraging discussion on the latest advancements in the company and minimally invasive and endoscopic technologies for spine surgery.

We are pleased to have special speakers and faculty from South Korea joining us, collaborating with expert faculty from all over the US.

Thank you for taking time out of your busy schedules to join us at Amplify Surgical's Fall Spine Symposium 2022. We wish you an inspiring and enjoyable meeting.

THANK YOU TO OUR CORPORATE PARTNERS!

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MESSAGE FROM PROGRAM CHAIR

Dr. Yong H. Kim
Program Chair
NYU Langone Health

On behalf of all the faculty members, I'd like to welcome you to Amplify Surgical's Fall Spine Symposium featuring dualPortal endoscopic and dualX system - the first of its kind to be held in the Northeast.

We are truly privileged to have a distinguished faculty panel from Korea as well as from the States. They are the pioneers and experts in the field of dualPortal endoscopic spine surgery.

We have put together a very comprehensive series of lectures and hands-on workshops to maximize your learning experience today.

There are many different endoscopic spine surgical techniques. Not all endoscopic spine surgical techniques are the same. Some techniques have very steep learning curves and seemingly have very narrow indications. The dualPortal endoscopic technique is different. It is much easier to comprehend and seemingly has a less steep learning curve. It utilizes techniques that are very familiar to us. Its indications appear to be limitless from a simple discectomy to multi-level fusion with deformity correction. Many surgeons want to learn endoscopic surgical technique, however, they often give up due to the lack of comprehensive training opportunities. Thanks to Mr. Andy Choi and his team from Amplify Surgical, now we have comprehensive courses taught by the very best in the field.

I hope today is the beginning of your journey in the world of dualPortal endoscopic spine surgery. I am sure this symposium will be an eye-opening experience for you as it was for me when I visited Drs. Park and Heo in Korea this past summer watching them perform these procedures with such finesse and grace.

GENERAL INFORMATION

Exhibitor List

Cerapedics
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FACULTY | SOUTH KOREA

Dr. Cheol Woong Park
Daejeon Woori Hospital

Dr. Dong Hwa Heo
Seoul Bumin Hospital

Dr. Jae-Won Jang
Suwon Leon Wiltse Memorial Hospital

FACULTY | US

Dr. Kaku Barkoh
Orthopaedic Associates, LLP
Houston, TX

Dr. Brian Kwon
New England Baptist Hospital
Boston, MA

Dr. Yong H. Kim
NYU Langone Health
New York City, NY

Dr. Daniel Park
William Beaumont Hospital
Southeast Michigan

Dr. Don Young Park
UCLA Health
Los Angeles, CA

Dual Expanding Interbody Implant
Engineered for Spinal Fusion

Three Unique Implants fo

T/PLIF

- Heights 7mm* expanding to 17mm*
- Width 12mm expanding to 21mm
- Final Length 25mm
- 0°, 8°, 12° and 15° Lordosis*

TLIF

- Heights 7mm* expanding to 17mm*
- Width 12mm expanding to 21mm
- Final Length 30mm
- 0°, 8°, 12° and 15° Lordosis*

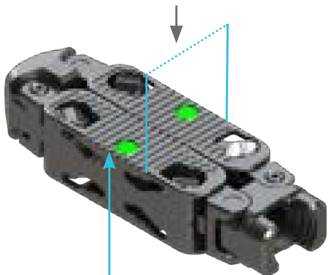
LLIF

- Heights 7mm* expanding to 17mm*
- Width 13mm expanding to 22mm
- Final Length 40 to 60mm
- 0°, 7°, 12° and 18° Lordosis*

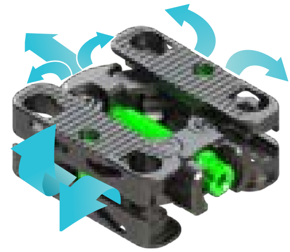
** Some lordotic angles available by request*

r Lateral, Transforaminal and Posterior Approaches

Collapsed width designed to reduce neural retraction

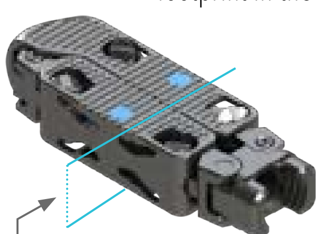


Open design allows bone graft to flow out to fill entire disc space

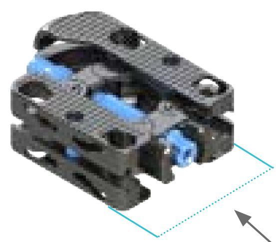


Coarse ridges assist with initial implant stability

Minimize subsidence with the largest footprint in the expandable cage market



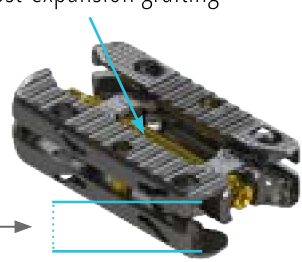
Low profile protects endplates during insertion



Lateral expansion establishes stable footprint

Multiple lordotic angles restore sagittal balance

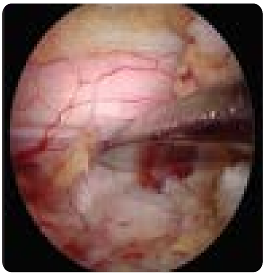
Large, center bone graft chamber for post-expansion grafting



Vertical expansion assists in direct and indirect decompression

dualPortal™

HOW TO GET STARTED



1. Endoscope System w/ Light Source & Monitor, 0-degree or 30-degree
2. Coblation Wand, 90-degree
3. Resection Bone Shaver with Cone Fluted Tip
4. High-speed Surgical Drill w/ Long, Angled Attachment, 3 or 4 mm Diamond Bur Tip
5. Kerrison Rongeurs, 2mm or 3mm
6. Woodson Elevator
7. Penfield Elevator, #2 & #4
8. Ball Tipped Probe, 90-degree
9. Nerve Hook Retractor
10. Curette, straight/angled, 3/0
11. Pituitary Rongeurs, straight/up, 2mm or 3mm
12. Micropituitary Rongeurs, straight/up, 1.5mm or 2mm
13. K-wire
14. Spinal Needle, 18G
15. Irrigation Pump (can also do gravity, 1 meter above the patient's back)
16. Closure System for Dural Tissue
17. Hemostatic Agent
18. Wilson Spine Frame on a regular Skytron OR table or OSI flattop
19. Tubular Retraction System (for initial tubes and instruments, can use as backup)
20. Drape for Endoscopic Procedure
21. Tissue Dissector or Sequential Dilator (back of scalpel handle can be used)
22. Amplify Surgical's dualX dualPortal Cannulas
23. Amplify Surgical's dualX dualPortal Hemostatic Agent Delivery Tube

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MEETING AGENDA

7:00 am - 7:45 am

Registration / Continental Breakfast

SESSION 1 — 7:45 am - 9:45am

7:45 am - 8:00 am

Welcome and Introductions

How I Started with dualPortal Endoscopic Spine Surgery

Yong H. Kim, MD

8:00 am - 8:15 am

dualPortal Endoscopic Spine Surgery - What is dualPortal Endoscopic Spine Surgery and how to get started; Discectomy: Equipment Needed, how to set up the OR

Brian Kwon, MD

8:15 am - 8:30 am

dualPortal Endoscopic Spine Surgery - ULBD: Principles, Anatomy, Workflow

Cheol Woong Park, MD, PhD

8:30am-8:45 am

dualPortal Endoscopic TLIF: Special Considerations

Dong Hwa Heo, MD

8:45 am - 9:00 am

The Marriage of dualPortal + dualX TLIF: Amplify dualLIF

Don Young Park, MD

9:00 am - 9:15 am

How to Avoid Intraoperative Complications with dualPortal Endoscopy

Jae Won Jang, MD

9:15 am - 9:30 am

MIS TLIF with dualX - Achieving Correction and Sagittal Balance While Avoiding Subsidence

Kaku Barkoh, MD

9:30 am - 9:45 am

MIS Small Portal Lateral Interbody Fusion with dualX LLIF - A Novel Lateral Fusion Procedure with Minimal Psoas Disruption

Daniel Park, MD

BREAK 9:45 am - 10:15 pm

SESSION 2, Lab #1 10:15 am - 12:30 pm

dualPortal / dualX Lab

Stations 1-3 to demonstrate:

- **dualPortal planning incisions, triangulating, getting started, discectomy**
- **dualPortal laminotomy, ligamentum resection, ULBD**
- **dualPortal TLIF**

STATION 1 - dualPortal

Lead: *Cheol Woong Park, MD, PhD*

Assist: *Yong H. Kim, MD*

STATION 2 - dualPortal

Lead: *Dong Hwa Heo, MD, PhD*

Assist: *Brian Kwon, MD*

STATION 3 - dualPortal

Lead: *Jae Won Jang, MD*

Assist: *Daniel Park, MD*

STATION 4 - MIS TLIF with dualX

Lead: *Kaku Barkoh*

ROUND TABLE LUNCH PANEL DISCUSSION — 12:30 pm - 1:30 pm

dualPortal Endoscopic Spine Surgery Cases

1. Upper lumbar levels (L1-3)
2. L5-S1
3. Foraminal decompression
4. Far Lateral disc herniation

Led by: *Yong H. Kim*

Panelists: *All faculty*

SESSION 3, Lab #2 — 1:30 pm - 5:00 pm

dualPortal / dualX Lab

Stations 1-3 to demonstrate:

- **dualPortal planning incisions, triangulating, getting started, discectomy**
- **dualPortal laminotomy, ligamentum resection, ULBD**
- **dualPortal TLIF**

STATION 1 - dualPortal

Lead: *Cheol Woong Park, MD, PhD*

Assist: *Yong H. Kim, MD*

STATION 2 - dualPortal

Lead: *Dong Hwa Heo, MD, PhD*

Assist: *Brian Kwon, MD*

STATION 3 - dualPortal

Lead: *Jae Won Jang, MD*

STATION 4 - MIS Small Portal Lateral Interbody Fusion with dualX LLIF

Lead: *Daniel Park, MD*

Kim et al. Journal of Orthopaedic Surgery and Research (2018) 13:22
DOI 10.1186/s13018-018-0725-1

Journal of Orthopaedic Surgery and Research

RESEARCH ARTICLE Open Access

Clinical comparison of unilateral biportal endoscopic technique versus open microdiscectomy for single-level lumbar discectomy: a multicenter, retrospective analysis

Seung-Kook Kim[1,2*], Sang-Soo Kang[3], Young-Ho Hong[4], Seung-Woo Park[2] and Su-Chan Lee[3]

Abstract

Background: The unilateral biportal endoscopic (UBE) technique is a minimally invasive procedure for spinal surgery, while open microscopic discectomy is the most common surgical treatment for ruptured or herniated discs of the lumbar spine. A new endoscopic technique that uses a UBE approach has been applied to conventional arthroscopic systems for the treatment of spinal disease. In this study, we aimed to compare and evaluate the perioperative parameters and clinical outcomes, including recovery from surgery, pain and life quality modification, patient's satisfaction, and complications, between UBE and open lumbar microdiscectomy (OLM) for single-level discectomy procedures.

Methods: This study included 141 patients with degenerative disc disease requiring discectomy at a single level from L2–L3 to L5–S1. A total of 60 and 81 patients underwent UBE and OLM, respectively. Analysis was based on comparison of perioperative metrics, operation time (OT); estimated blood loss (EBL); length of hospital stay (HS); clinical outcomes, including assessment using the Visual Analogue Scale (VAS) and Oswestry Disability Index (ODI); patient satisfaction (the MacNab score); and the incidence of reoperation and complications.

Results: The study cohort was 56.7% women, and the mean patient age was 50.98 ± 18.23 years. The mean VAS (the back and leg), MacNab score, and ODI improved significantly from the preoperative period to the last follow-up (12.92 ± 3.92) in both groups ($p < 0.001$). One week after operation, the back VAS score in the UBE group showed significantly more improvement than that in the OLM group. However, the 1-week, 3-month, and 12-month VAS (the back and leg), ODI improvement, modified MacNab score, and OT were not significantly different between the two groups. In the UBE group, EBL (34.67 ± 16.92) was smaller and HS (2.77 ± 1.2) was shorter than that of the OLM group (140.05 ± 57.8, 6.37 ± 1.39). However, OT (70.15 ± 22.0) was longer in the UBE group than in the OLM group (60.38 ± 15.5), and the difference was statistically significant. Meanwhile, the differences in the rate of surgical conversion and complications between the two groups were not statistically significant.

Conclusions: The UBE for single-level discectomy yielded similar clinical outcomes to OLM, including pain control, functional disability, and patient satisfaction, but incurred minimal EBL, HS, and postoperative back pain.
(Continued on next page)

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Full list of author information is available at the end of the article

(Continued from previous page)

Trial registration: *Not applicable.*

Keywords: Arthroscopy, Endoscopic spine surgery, Herniated lumbar disc, MISS, Lumbar disc, Minimally invasive spine surgery, BESS, UBE

Background

Lumbar disc herniation (LDH) is a clinically symptomatic condition caused by the compression of the spinal nerve root from a protruded disc material. Almost 70–85% of patients experience at least one episode of lower back pain with or without leg pain during their lives [1]. Some studies have reported that LDH can be naturally absorbed [2, 3]. However, surgery is required when symptoms refractory to medical treatment or combined neurological deficits, including sensory or motor problem, persist. The current standard surgery for LDH is open lumbar microdiscectomy (OLM) with partial laminotomy. However, OLM results in increased risks of postoperative spinal instability and chronic back pain [4]. This procedure is more invasive and is similar to open discectomy. OLM requires bone removal, entrance to the spinal canal, manipulation of neural and vascular tissues, and large fenestration to the annulus. Currently, the popularity of minimally invasive spine surgery for the treatment of LDH is growing. Percutaneous endoscopic discectomy is a minimally invasive spinal surgery (MISS) technique that has several advantages over OLM, including preservation of bony and muscular structure, shorter hospital stay (HS), and a smaller incision [5–7]. A new endoscopic technique that uses a unilateral biportal endoscopic (UBE) approach has been applied to conventional arthroscopic systems for spinal disease [8, 9]. The arthroscopic discectomy technique, as described by Kambin [10], is different from the other MISS procedures because it allows for extraction of the offending herniated fragments from the posterior intervertebral disc. Patient satisfaction was rated at 87% [11, 12], and the radiologic success rate was 16 out of 18 case series [11–13]. However, these reports were published before 2000, and a detailed analysis on pain and patient satisfaction over time is yet to be performed. High-definition (HD) endoscopic visualization has been available since 2007, allowing for better illumination and tissue identification compared with previous standard definition visualization [14, 15]. The clinical results of these techniques with respect to comparisons of various parameters have not been analyzed to date. To the best of our knowledge, this is the first report on the evaluation of the clinical results of these techniques since they were introduced.

Methods

This study aims to compare the differences in the 1-year postoperative clinical course in terms of perioperative parameters, such as pain control, quality of life modification, and patient satisfaction between biportal endoscopic and traditional microscopic techniques. This is a case control study conducted at Himchan Hospital, Incheon, Korea; Leaders Hospital, Seoul, Korea; and Barun-Sesang Hospital, Kyoungki, Korea. We enrolled 141 patients who underwent surgery for the treatment of LDH between May 2016 and October 2016; 60 consecutive patients were treated with UBE by three surgeons (Dr. S. Kim, Dr. S. Kang, and Dr. Y. Hong), while 81 consecutive patients were treated with OLM by two surgeons (Dr. S. Kim and Dr. Y. Hong). The inclusion criteria were (1) back or radiating pain related to LDH, (2) symptom persistence of more than 4 weeks, and (3) magnetic resonance (MR) images correlated to the symptoms. The exclusion criteria were as follows: (1) foraminal or extraforaminal disc involvement, (2) recurred LDH, (3) motion instability (defined as > 3 mm translation or > 5° angulation), (4) spondylolisthesis more than Meyerding grade II, (5) cauda equina syndrome, and (6) comorbid tumorous or infectious conditions. All participating institutions received approval from their respective institutional review board (KNUH7-1112), and all patients provided written informed consent. The data were collected starting from the preoperative period until 12 months postoperative. Pain intensity, patient satisfaction, and quality of life as analyzed using the Visual Analogue Scale (VAS), modified MacNab score, and Oswestry Disability Index (ODI), respectively, were investigated at 1-week, 3-month, and 12-month postoperative follow-ups.

Clinical outcomes were evaluated using the back and leg VAS (0–10) and the ODI (0–100%). Patient satisfaction was assessed via modified MacNab criteria (excellent, good, fair, and poor). Perioperative data (length of operation time (OT) and HS, estimated blood loss (EBL), and complications) were assessed via video records of the endoscopic and microscopic operation and clinical charts. Radiologic outcomes were evaluated using the pre- and 3-day postoperative MR images.

Surgical techniques

Unilateral UBE discectomy

The UBE was performed under epidural anesthesia with the patient in the prone position on a C-arm fluoro-radiolucent table. Conscious sedation with sedative analgesia and music listening was allowed, which enabled the surgeon to avoid injuring the neural structures.

During the procedure, we used 0° or 30° 4-mm rigid arthroscope (Hopkins® arthoroscope Storz, El Segundo, USA), 3.5-mm spherical burr (Dyonics® drill, Smith & Nephew, Andover, USA; Smith & Nephew, London, UK), 3.5-mm radiofrequency (RF) ablation probe (RF® Ablation system, Stryker, Kalamazoo, MI, USA), a pressure pump irrigation system (Smith & Nephew), and standard instruments for open laminectomy, such as hook dissectors, Kerrison punches, Rotating Kerrison punches (Osteo Rongeur, Koros, USA, CA, USA), and pituitary forceps.

The surgery proceeded as follows (see Additional file 1).

First, the two portal skin entry points were confirmed using preoperative axial MR images or plain anteroposterior (AP) radiographs to determine the optimal operation route. Then, the target disc was identified under the discographic images. In the left side approach, the insertion point for the endoscope (endoscopic portal) was 1–1.5 cm lateral to the midline in the lower margin of the upper lamina, while the upper margin of the lower lamina was the insertion point for surgical instruments (instrumental portal). The endoscopic portal was used for continuous irrigation and for viewing of the surgical procedure, while the instrumental portal was used for instrument manipulation and removal of the ruptured disc. After a serial dilator was inserted through the caudal portal, the muscle was dissected with an RF probe through the instrumental portal. The lower lamina of the upper lumbar spine and upper lamina of the lower lumbar spine were partially removed via an automated drill and Kerrison punches (partial laminotomy). The interlaminar ligament was then dissected using an RF probe and removed using rotating Kerrison punches. Annulotomy, disc fragment dissection, and ruptured fragment removal were performed using pituitary forceps and Kerrison punches. Decompressed root confirmation and disc space exploration were performed using a 90° hook dissector. The muscle and skin were sutured using a 2-0 absorbable suture (Vycryl®) and reinforced skin closure (Steri-Strip®, 3M, Inc.), Maplewood, MN, USA).

OLM

OLM was performed under general or spinal anesthesia. The surgical procedure followed the standard method using a tube or Caspar retractor system [16, 17]. The procedure was performed with the patient in a prone position on a radiolucent table. The incision point was at the inferior edge of the superior lamina of the lesion side in the AP view and parallel to the disc space in the lateral view. After creating a 3-cm incision in the midline, the fascia was dissected to the lateral edge of the inferior articular facet. Soft tissues, including the paraspinal muscles, were cleaned using a monopolar cautery system (Bovie® Medical, Inc., Purchase, NY, USA) to expose the ligamentum flavum. After partial laminotomy of the lower lamina of the upper lumbar spine and upper lamina of the lower lumbar spine, the ligamentum flavum was removed for disc discrimination. Then, the instruments were advanced to the epidural space and the dura margin, and the nerve roots were exposed. The root was retracted, and epidural dissection was performed. The protruded disc particles were found and removed with pituitary forceps and Kerrison punches. The mobility of the root was checked using a hook dissector after the pathologic disc particles were removed. Wound closure was performed using 1-0, 2-0, and 4-0 absorbable sutures (Vycryl®) and a skin stapler.

Statistical analysis

Statistical analyses were performed using SPSS for Windows (version 22.0; SPSS, Inc., Chicago, IL, USA). An independent sample t test (two sided) and Mann-Whitney test were used to compare numerical data between groups, such as VAS, ODI, OT, EBL, HS, postoperative complication, and follow-up duration. Fisher exact test and χ^2 test were used to compare categorical variables including sex, disc location, operation level, modified MacNab score, motor weakness, complication, and surgery conversion between groups. Changes in periodical variables from the preoperative period to each postoperative time were measured using Wilcoxon signed rank test and paired sample t test. A P value less than 0.05 was considered statistically significant.

Table 1 Patients' demographic data

		UBE (n = 60)	OLM (n = 81)	p value
Age (years)		46.60 ± 14.18	54.22 ± 20.21	0.121
Sex (%)	M	37 (61.7)	24 (29.6)	0.072
	F	23 (38.3)	57 (70.4)	
Symptom (%)	Pain only	18 (30.0)	25 (30.9)	0.531
	Pain and weakness	42 (70.0)	56 (69.1)	
Symptom duration (weeks)		4.67 ± 0.72	4.60 ± 0.71	0.591
Follow-up duration (months)		12.60 ± 1.03	12.84 ± 1.30	0.225
Disc location (%)	Central	11 (18.3)	18 (22.2)	0.565
	Paracentral	49 (81.7)	63 (77.8)	
Disc level (%)	L2–3	1 (1.7)	4 (4.9)	0.444
	L3–4	2 (3.3)	4 (4.9)	
	L4–5	34 (56.7)	36 (37.0)	
	L5-S1	23 (38.3)	37 (45.7)	

UBE unilateral biportal endoscopy, OLM open lumbar microscopy

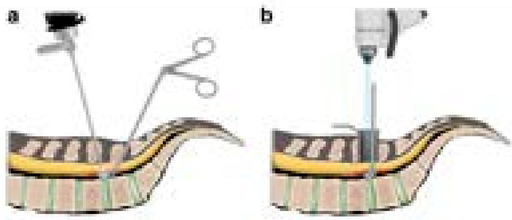

Fig. 1 Illustration of **a** unilateral biportal endoscopic discectomy and **b** open microscopic discectomy

Results

A total of 146 patients who underwent spinal surgery were enrolled in the present study. Two of the 62 patients who underwent UBE and three of the 84 who underwent OLM were excluded because they were lost to follow-up. Consequently, we enrolled 60 and 81 patients who underwent UBE and OLM, respectively. The patients' demographic and preoperative characteristics (Table 1) were not statistically different. The schematic differences between the two procedures are depicted in Fig. 1a, b.

The clinical outcomes and operative findings are shown in Table 2. In both groups, postoperative back and leg pain and ODI were significantly improved ($p < 0.001$, Fig. 2a–c). Improvements in back pain 1 week after operation were significantly different between the UBE and OLM groups (4.05 ± 1.6 vs. 1.25 ± 1.7, $p < 0.001$). The mean OT was significantly longer in the UBE group (70.15 ± 22.0 min, $p = 0.002$) than in the OLM group (60.38 ± 15.5 min, Fig. 2d). The mean blood loss in the UBE group was significantly less than in the OLM group (34.67 ± 16.9 ml vs. 140 ± 57.8 ml, $p < 0.001$, Fig. 2e). The mean HS was significantly shorter in the UBE group than in the OLM group (2.77 ± 1.2 d vs. 6.37 ± 1.4 d, $p = 0.005$, Fig. 2f). After the ruptured or protruded disc was dissected, the compressing materials were removed (Fig. 3a). A decompressed traversing root and thecal sac indicated completion of operation (Fig. 3b). Compared with preoperative MRI (Fig. 3c), postoperative (Fig. 3d) MRI indicated relieved pathologic condition (Fig. 3e) with limited muscle injury radiologically (Fig. 3f). The ruptured disc fragment was completely removed in all cases except in three cases of UBE that required conversion to OLM. The surgery was modified due to blurred field of view from the bone and epidural bleeding. Controlling bleeding in the microscopic view is important because the RF probe and bone can be difficult to manipulate due to vision disturbance. No serious complications, including cauda equine syndrome, were observed. Two cases of cerebrospinal fluid leakage occurred, which were treated with conservative treatment including bed rest and fluid replacement. Only one case of operative site infection occurred in the OLM group, which was controlled using 3rd-generation antibiotics, such as cefotaxime.

Table 2 Comparison of clinical outcomes of UBE and OLM for LDH

	UBE	OLM	*p* value
Pre-op VAS back	6.22 ± 1.5	6.33 ± 1.5	0.263
Pre-op VAS leg	7.93 ± 1.0	7.98 ± 1.0	0.808
Post-op VAS back	0.93 ± 0.7	0.85 ± 0.7	0.657
Post-op VAS leg	1.28 ± 1.0	1.27 ± 1.0	0.945
Pre-op ODI	70.15 ± 1.0	71.85 ± 8.4	0.815
Post-op ODI	14.5 ± 11.9	13.95 ± 11.5	0.549
Improvement of VAS back (1 week)	4.05 ± 1.6	1.25 ± 1.7	0.001*
Improvement of VAS back (12 months)	5.28 ± 1.83	5.28 ± 1.80	0.504
Improvement of VAS leg (1 week)	5.88 ± 1.6	5.60 ± 1.5	0.326
Improvement of VAS leg (12 months)	6.65 ± 1.5	6.70 ± 1.4	0.914
Improvement of ODI back (1 week)	45.67 ± 12.3	45.18 ± 12.8	0.824
Improvement of ODI (12 months)	57.90 ± 13.5	58.17 ± 15.6	0.792
Modified MacNab score (%)	75.35 ± 0.5	68.46 ± 0.5	0.082
OT	70.15 ± 22.0	60.38 ± 15.5	0.002*
EBL	34.67 ± 16.9	140 ± 57.8	0.001*
HS	2.77 ± 1.2	6.37 ± 1.4	0.005*
Complications (%)	3 (3.7)	2 (3.3)	0.640

UBE unilateral biportal endoscopy, *OLM* open lumbar microscopy, *LDH* lumbar disc herniation, *VAS* Visual Analogue Scale (0–10), *ODI* Oswestry Disability Index (0–100%), improvement, the difference between preoperative and postoperative results, modified MacNab (1, excellent; 2, good; 3, fair; 4, poor), *OT* operation time, *EBL* estimated blood loss, *HS* hospital stay (days)
*$p < 0.05$

Discussion

As a form of MISS, UBE demonstrated several advantages and one disadvantage in the present study. First, it showed superiority in terms of short-term back pain

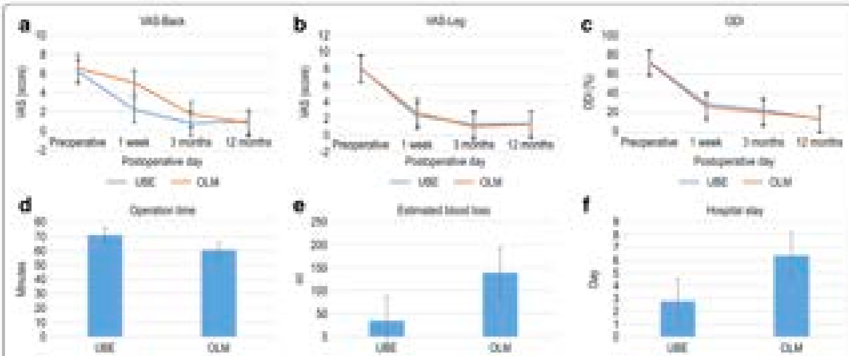

Fig. 2 Clinical outcomes during follow-up (1 week, 3 months, and 12 months) and perioperative data. Visual Analogue Scale (VAS) scores for back pain (**a**), VAS for leg pain (**b**), Oswestry Disability Index (ODI, %) (**c**), operation time (minutes) (**d**), estimated blood loss (ml) (**e**), hospital stay (days) (**f**)

recovery, a small volume of intraoperative blood loss, and less HS. Second, improvements in short-term leg pain and long-term back and leg pain, modification of the quality of life (ODI), patient satisfaction (modified MacNab score), and complication rate were similar to that of OLM. However, OT was longer in UBE than in OLM, but this is its only disadvantage in the present study. These results indicate that UBE can be used to minimize tissue damage, although several limitations, such as controlling bleeding, need to be overcome.

Although conventional open laminotomy and discectomy is an effective way for symptomatic herniation, muscle and ligament injury from surgery can lead to postoperative back pain and muscle atrophy [18]. Therefore, more time may be required for functional recovery and pain control after OLM. Postoperative back pain following mechanical trauma due to OLM has already been reported. Dvorak et al. reported that 70% of patients experienced back pain after conventional discectomy during long-term follow-up [19]. Parker et al. also reported that 32% of patients suffered back pain after conventional discectomy, and 9% of cases underwent fusion surgery for pain control [20]. Vodicar et al. reported that invasive procedures, including endplate perforation, decrease vertebral height and worsen back pain in the postoperative period [21]. Scarring of the epidural space can be problematic [22–24]. It may become clinically symptomatic and make revision surgery more difficult because of the connection of the thecal sac to the paravertebral muscle structures [25, 26]. As such, MISS techniques, such as transforaminal and interlaminar approach percutaneous endoscopic lumbar discectomy (PELD), have been developed to minimize injury to the posterior musculo-ligamentous structures [27, 28].

Uniportal transforaminal and interlaminar PELD are both good surgical methods. They can protect the posterior structures, such as the upper and lower laminas, ligamentous structure, and muscles, better than OLM. Although these procedures can remove soft disc herniation and ruptured LDH without foraminal obstruction, they have limited indications due to the restricted movements of the instruments and obstructed intervertebral foramen following degenerative changes. Microendoscopic discectomy is regarded as an alternative to OLM because it produces few traumas to soft tissues and results in rapid recovery and less intraoperative blood loss [29]. However, this technique requires the same exposure of muscle and bone and basic skills with that of conventional OLM, such as the use of a dilator and tubular retractor [29]. By contrast, UBE can achieve high-resolution visualization at only a small muscle dissection and use almost all laminectomy instruments without restriction. HD endoscopic vision makes disc dissection easier, and ruptured fragment removal and manipulation is possible as in the conventional technique. Because the same instruments are used while allowing for a more detailed view than in microscopic surgery, favorable radiologic outcomes can be achieved. UBE is a new method that combines the advantages of interlaminar endoscopy and microscopic surgery. The use of the uniportal system is limited because of the combined channel (viewing and instrumental) that limits the independent movement of instruments. By contrast, the UBE system uses independent channels for instruments; thus, movements are not restricted. Furthermore, instruments for both 0° or 30° arthroscopy for

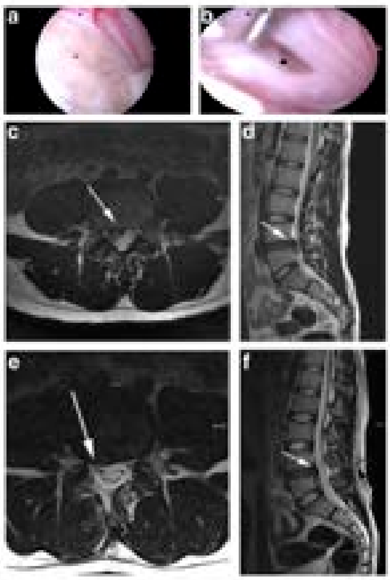

Fig. 3 Large disc herniation at the L4-5 level. Intraoperative imaging during unilateral biportal endoscopic (UBE) discectomy of a 28-year-old man presenting with severe back and right leg radiating pain. The herniated disc triangle compressing the thecal sac and traversing nerve root star (a), thecal sac, traversing nerve root star, and the posterior ligament circle were freely movable after disc fragment removal (b). Magnetic resonance (MR) axial image shows paracentral disc herniation and compression in the thecal sac and L5 traversing nerve root (white arrow) (c). Sagittal MR image shows down migrated disc compressing the thecal sac (white arrow) (d). After UBE discectomy, postoperative axial MR image shows decompressed thecal sac and traversing L5 nerve root (white arrow) (e). Postoperative sagittal MR imaging shows removed herniated disc (white arrow) and minimally invasive instrumental pathway for discectomy (black arrow) (f)

the knees and shoulders and standard laminectomy are used and additional devices are no longer needed. Moreover, the endoscopic trajectory is the same as that in conventional operation; thus, an experienced microscopic spine surgeon can achieve the necessary surgical skills without a steep learning curve [30].

Kambin et al. reported a high rate of 87% patient satisfaction for arthroscopic disc surgery [12]. The rating was based on pain reduction, medication changes, and lifestyle modifications. However, this study did not use universally accepted assessment scales such as VAS, ODI, and modified MacNab score. Casey et al. assessed the radiologic outcomes of arthroscopic discectomy and found that the success rates based on CT and MRI were 88.9% ($n = 18$) and 85.7% ($n = 12$), respectively [13]. However, this study did not perform a control analysis, and only radiologic outcomes were assessed. A recent study by Um et al. reported the outcomes of UBE after development of HD endoscopic vision [8]. The study showed that the ODI score decreased from 67.2 ± 1.7 to 24.3 ± 8.5, and the VAS for leg pain decreased from 8.3 ± 1.1 to 2.4 ± 1.1. This study showed favorable outcomes from UBE, which are consistent with our study. However, control group analysis was not performed, and the operation detail was not discussed. The present study is characterized by a detailed evaluation of the operation, analysis of controls, and evaluation according to the perioperative period. We also described the drawback of this surgery, which was prolonged OT.

Technical advances in the surgical techniques of LDH now permit a fully endoscopic procedure under continuous irrigation. This can provide optimal advantages for a MISS procedure [14] that became possible with more tissue-sparing techniques, which are being applied increasingly [31]. Compared with conventional OLM, UBE has the advantage of less intraoperative blood loss and postoperative back pain and relatively shorter HS due to the preservation of the back muscle and a smaller incision. These advantages extend the scope of lumbar spinal stenosis [30], degenerative diseases of the cervical spine, and even short-level fusion surgeries [8]. Through high-resolution video equipment, preserving the facet joint and ligament complex and lessening nerve traction is now possible. Another advantage is that UBE preserves the epidural vessel and discal tissues, avoiding anular incision with the knife. The combination of these advantages results in improved quality of life (ODI score). In terms of patient satisfaction, the modified MacNab score in UBE was equivalent to that in conventional OLM despite prolonged OT. This result may be due to the tissue-sparing nature of the procedure, rapid pain recovery, short HS, favorable pain outcomes, and improved quality of life.

Our results show that OT is longer in UBE than OLM primarily because most surgeons have been used to microscopic procedures for a long time. In UBE, only the right hand is in the instrument portal because the working portal is used only for the instruments; thus, the surgeon cannot use both hands, making it difficult to control bleeding and prolonging the OT. However, more surgical experience will reduce the OT.

The limitations of this study are its retrospective nature, small sample size, and short follow-up period. In addition, because of the nature of retrospective studies, selection bias seems to be intrinsic by patients' preferences and the surgeon's experience may be influenced the outcomes. However, the results show that UBE can be an alternative surgery to OLM based on the favorable clinical results and the convenience from the new endoscopic instruments. Adequate randomized prospective studies for UBE are required to verify the present results.

Conclusions

UBE can be an effective treatment modality for LDH. The anatomic trajectory and endoscopic view is similar to that of conventional discectomy. UBE for single-level discectomy has several advantages: the similar sufficient and direct fragmentectomy and discectomy to that in open microdiscectomy resulted in the same clinical outcomes, including pain improvement, functional disability, and patient satisfaction and minimal EBL, HS, and postoperative back pain, while preserving the spinal tissues. Considering the bleeding tendency and adequate indications, UBE is a highly feasible alternative to conventional microscopic operation.

Additional file

Additional file 1: Supplementary video clip. The supplementary video clip demonstrates the full process for the endoscopic unilateral biportal endoscopic (UBE) technique. (1) We performed unilateral partial laminotomy with automated drill. (2) Using a small laminotomy window, the interlamina was dissected with a radiofrequency probe. (3) Partial removal of the yellow ligament was performed with Kerrison punches. (4) Adhesion removal and disc dissection were done with hook dissector. (5) Ruptured disc removal and (6) disc space exploration and confirming the nerve root exposure were performed using a pituitary forcep and hook dissector. (MP4 104919 kb)

Abbreviations

AP: Anteroposterior; EBL: Estimated blood loss; HD: High definition; HS: Hospital stay; LDH: Lumbar disc herniation; MISS: Minimally invasive spinal surgery; MRI: Magnetic resonance; ODI: Oswestry Disability Index; OLM: Open lumbar microdiscectomy; OT: Operation time; PELD: Percutaneous endoscopic lumbar discectomy; RF: Radiofrequency; UBE: Unilateral biportal endoscopy; VAS: Visual Analogue Scale

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Availability of data and materials

All data generated or analyzed during this study are included in this published article and its supplementary information files.

Authors' contributions

S-KK 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. S-SK and Y-HH designed the study protocol. S-WP managed the literature search and summaries of previous related work and wrote the first draft of the manuscript. S-CL provided revisions for intellectual content and final approval of the manuscript. All authors read and approved the final manuscript.

Ethics approval and consent to participate

All participating institutions received approval from their respective institutional review board (KNUEF-1112), and all patients provided written informed consent.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Biportal Endoscopic Approach for Lumbar Central Stenosis

Hee-Seok Yang, Dong Hwa Heo, and Jeong-Yoon Park

Introduction

Lumbar central stenosis is a degenerative process that is frequent in the aging population. Lumbar spinal stenosis is a pathologic process where vertebral bodies, ligaments, and facet joints of the lumbar spine degenerate and overgrow, progressively compressing the neural and vascular elements in the spinal canal [1].

Recently, endoscopic techniques also have shown encouraging clinical results in the treatment of lumbar spinal stenosis [2]. Based on many studies and reports of successful decompression of the stenosis through uniportal and biprotal endoscopic approach, endoscopic spine surgery have evolved with less damage on normal structures and have demonstrated effective stenosis decompressions under direct visualization [2–5]. Recently, biportal endoscopic decompression is introduced. Uniportal endoscope uses single and same axis for endoscope and working channel, and it should have a close view. In addition, the instrument must be seen under close view and visual field during uniportal endoscopic surgery is narrow. On the other hand, biportal endoscopic spine surgery has a long and wide field of view, and the axes of the endoscope and working channel are separated. Therefore, the instrument can be used under a relatively long distance and wide field of view, and this unique feature of biportal endoscope made it easy to understand the anatomical orientation and to handle the surgical instruments. In biportal endoscopic spine surgery, endoscope and instrument approach angles are independent, and there is the freedom of vision and instrument angle during endoscopic spine surgery.

During biportal endoscopic spine surgery, we can use conventional retractor and instrument (drill, punch et al.) through a working portal and also can use the endoscopic cannula through endoscopic portal like uniportal endoscopic spine surgery. One of the main differences between biportal and uniportal endoscopic spine surgeries is that various general surgical instruments can be used during biportal endoscopic spine surgery because of independent working portal. In addition, we have to understand fluid dynamics during biportal endoscopic spine surgery and make cavitary water space, and there

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could be continuous flow between input and output channels. There were several papers about the behaviors of arthroscopic irrigation, and the authors recommend using an output cannula for biportal endoscopic spine surgery [6, 7]. In the text below, the surgical procedure for lumbar central stenosis using biportal endoscopic spine surgery will be described in detail.

Anesthesia and Position

The procedure is performed under general or epidural anesthesia. The patient is placed in the prone position with the abdomen free over the radiolucent frame in a flexed position to open the interlaminar space and foramen. A surgical drape designed to drain water well from the output channel can prevent the water leak from surgical field (Fig. 1).

Special Surgical Instruments

During the procedures, we used 3.5-mm spherical bur and diamond drill, 0° 4-mm-diameter arthroscope, 3.5-mm radiofrequency (RF) device, serial dilators, a specially designed dissector, and standard laminectomy instruments, such as hook dissectors, Kerrison punches, and pituitary for-

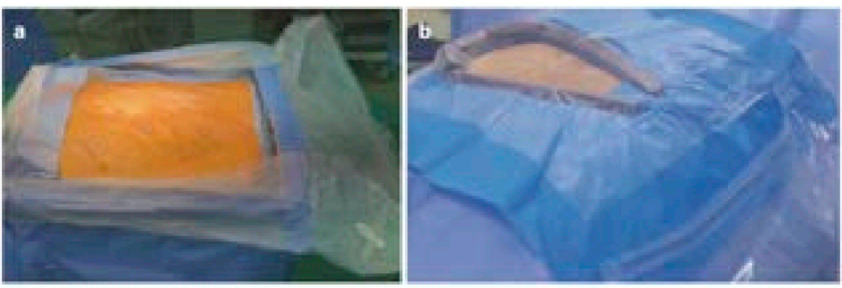

Fig. 1 Waterproof surgical drapes (A and B) for biportal endoscopic surgery

Fig. 2 Various kinds of surgical instruments of biportal endoscopic surgeries. 3.5-mm spherical bur and diamond drill (**a**), a specially designed dissector (**b**), 4-mm-diameter arthroscope (**c**), and semicircular cannula to keep proper outflow for working cannula (**d**). Clockwise from left. General spine surgical instruments were also available for biportal endoscopic surgeries

ceps (Fig. 2). The rest of the equipment uses the same endoscopy tower system. Instruments designed exclusively for biportal endoscopes are also available and could be more convenient. We use semicircular cannula to keep proper outflow through working cannula (Fig. 2d).

Surgical Steps (Illustration, Photos, and Video)

Skin Mark and Incision

Under image intensification, fluoroscopic confirmation of the level is made with a spinal needle inserted at the target area. Two portals are used: one portal was used for endoscope and the other working portal was used for instruments like drill, punch, and forceps. Skin entry points are determined according to the lesion site and the patient's anatomical variation. Because stenosis lesions differ from patient to patient and may combine central to lateral recess both side and foraminal lesions, portals should be created considering stenosis severity [8] and approach angles of instrument and scope to these combined lesions. Two standard entry points are made at 1 cm above and below the disc space for a posterior approach (Fig. 3). A 5-mm incision was given at the skin for the endoscope portal, and an 8-mm incision was given for the working portal along the skin crease. Docking point of two portals was over the lower portion of cranial laminae.

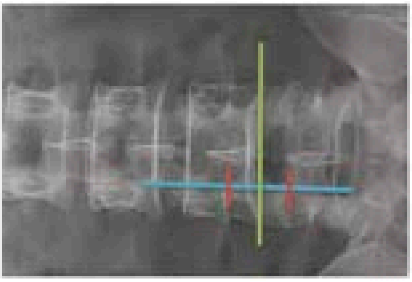

Fig. 3 Skin incision areas of biportal endoscopic lumbar surgery for L4–5 level. Anteroposterior X-ray view (**a**) and lateral X-ray view. From anteroposterior X-ray, draw line along the medical pedicle. From lateral X-ray, confirm the disc space. Two standard entry points are made at 1 cm above and below the disc space for a posterior approach. Upper portal was used for endoscope and the other working portal was used for instruments. Red lines are the skin incision

Two Portals (Biportal) Making

Serial dilators were then introduced to working portal and split the paraspinal muscles touching the spinous-laminar junction with minimal trauma. A 4-mm endoscope with trocar was then inserted into the endoscope portal, and a working sheath was inserted at the working portal (Fig. 4). RF device (for hemostasis and soft tissue dissection) was inserted into the working portal. A saline irrigation pump or just saline from 2 m height was connected to the endoscope and set to a pressure of 25–40 mm Hg during the procedure. Proper triangulation of the endoscope with the working instruments is vital for adequate visualization of the anatomical structures under keeping proper outflow with continuous irrigation of normal saline from endoscope to working portal. After exposing the lamina and the ligamentum flavum (LF), the levels are confirmed again with fluoroscopy.

Soft Tissue Dissection and Laminectomy

Muscle detachment using a dilator in the interlaminar space before inserting the endoscope helped secure sufficient visualization during the procedure. After triangulation with the endoscope and instrument, RF device and dissectors were used for bleeding control and detachment of the soft tissue remnants overlying the lamina and the ligamentum flavum.

Following complete exposure of the lamina and the ligamentum flavum in the targeted interlaminar space, an ipsilateral partial laminotomy was performed under magnified endoscopic vision. A laminotomy is performed using various burs initially to drill off the lower lamina of the cranial vertebra at the interlaminar space, similar to the decompression procedure with micro-

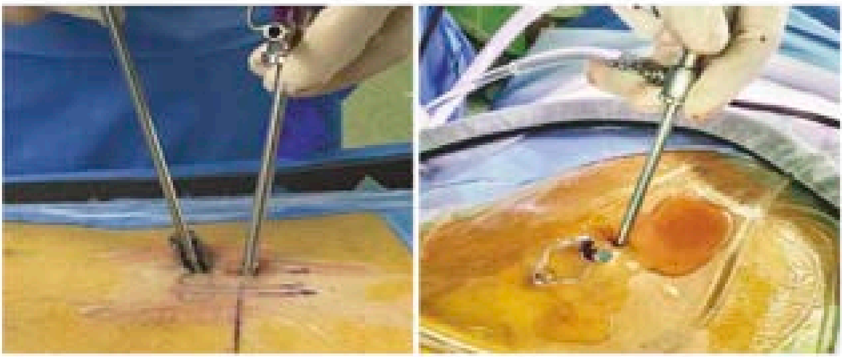

Fig. 4 Overview of biportal endoscopic surgeries. Endoscopic portal was used for only endoscopy and its trocar, and the other working portal was used for surgical instruments. Various kinds and sizes of working sheath were used for well drainage of irrigation fluid and smooth insertion of surgical instruments

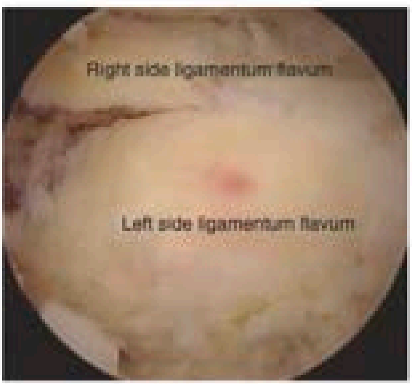

Fig. 5 Endoscopic view of unilateral laminectomy (left side approach). Ipsilateral ligamentum flavum as well as contralateral ligamentum flavum should be exposed after ipsilateral laminotomy

Fig. 6 Schematic illustration of the ligamentum flavum at lumbar area. Superficial layer was inserted over the caudal lamina. In contrast, deep layer was inserted below the caudal lamina

scopic approach with tubular retractor systems. Laminotomy of the upper laminar should be performed until exposure of proximal end of the ligamentum flavum. The upper lamina of the caudal vertebrae is partially removed using diamond drill and punches, continuing along the margins of the lateral recess and exposure of distal end of the ligamentum flavum. The thinned-off lateral recess and caudal laminar margin are then resected with the punch. In addition, midline spinous base area should be partially removed for exposure of contralateral ligamentum flavum (Fig. 5).

Ligamentum Flavum Removal and Decompression of Ipsilateral Traversing Nerve Root (Video 1)

Once adequate bony resection is achieved to the proximal and distal attachment of the ligamentum flavum, the superficial and deep layers of the ligamentum flavum are detached and removed. It may be removed with en bloc, but if adhesion is suspected due to severe stenosis, it may be necessary to separate and remove the superficial and deep layer (Fig. 6 and Video 1). In some cases, it is essential to check the lateral extent of the deep layer of the ligamentum flavum and remove to the lateral margin by using an angled curette [9]. A blunt hook dissector is used to identify the plane between the ligamentum flavum and the dura with saline irrigation, ensuring that it is free from adhesions. The ipsilateral ligamentum flavum was removed until full mobilization of the lateral border of the nerve root was achieved. The upper border of the lower lamina is removed for the ipsilateral foraminotomy as needed (Fig. 7).

Decompression of Contralateral Traversing Nerve Root (Video 2)

If bilateral decompression is required, the midline of the spinal canal must first be confirmed by resecting the base of the spinous process with a high-speed drill. The scope can then be adjusted medially. Usually, the base of the spinous process obstructs the placement of the scope; therefore, it may need to be partially resected to secure sufficient working space. Once exposed, the ligamen-

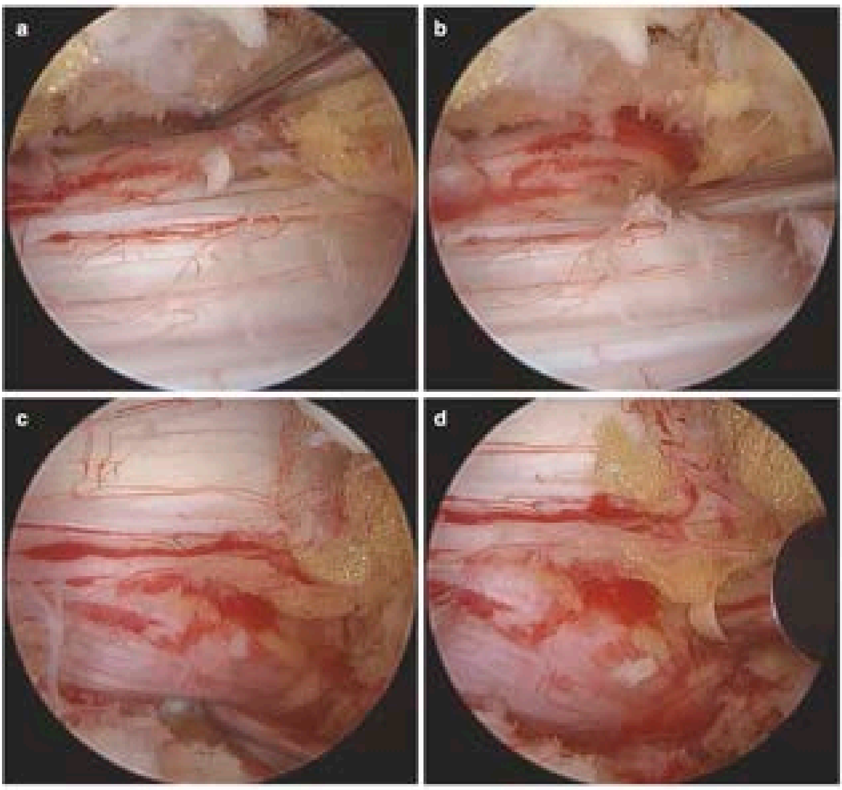

Fig. 7 Intraoperative endoscopic images showed complete decompression of bilateral traversing nerve roots. Medial margin of contralateral pedicle was checked for complete contralateral nerve root decompression of shoulder area (**a**). Also, axillar area of contralateral traversing nerve root was also checked (**b**). In addition, medical margin of ipsilateral pedicle (**c**) and ipsilateral axillar area (**d**) were carefully checked for complete decompression of ipsilateral nerve root

tum flavum can be detached from the contralateral lamina with angled curette and then undercut with a bur. After bony decompression, the thickened ligamentum flavum is resected with a curette and Kerrison punch to relieve the neural structures adequately. Contralateral decompression was performed until the contralateral traversing nerve root was identified and decompressed (Fig. 7).

Discectomy and Closure

If a patient is symptomatic and has ipsilateral disc herniation, it is possible to perform a discectomy under endoscopic view. The degree of neural decompression was assessed by normal respiratory-induced dural pulsation and confirmed with endoscopic viewing and use of a blunt probe. Bleeding is effectively controlled by the radiofrequency bipolar system under continuous irrigation. The skin incisions are closed after removal of the instruments and endoscope (Fig. 8). A surgical drain is inserted and kept for 24 h after surgery until spontaneous bleeding is controlled.

Illustrated Case or Cases

Case 1: A 79-year-old woman presented with a 1-year history of LBP and bilateral leg pain and numbness over the calf and dorsum of the foot.

Fig. 8 Wound image of biportal endoscopic approach for lumbar stenosis. Hemovac drainage catheter was inserted for prevention of postoperative epidural hematoma

No benefit was obtained from the use of analgesic or nonsteroidal anti-inflammatory medications. She could not walk for over 5 min due to the pain and weakness. Neurologic examination revealed weakness of the right great toe dorsiflexion (Grade III). Magnetic resonance imaging (MRI) documented bilateral lateral recess stenosis at L3–4–5 level (Fig. 9a–c). The patient underwent biportal endoscopic decompression surgery with left side approach under general anesthesia. Postoperative back and leg pain VAS scores were decreased from 7 and 8 preoperatively to 3 and 2 after the operation, respectively. Weakness of the right great toe dorsiflexion was also recovered gradually to Grade IV in 3 weeks after operation, and neurogenic intermittent claudication also improved more 30 min. Postoperative MRI revealed satisfactory decompression of bilateral lateral recesses at L3–4–5 (Fig. 9d–f).

Case 2 (Video 2): A 71-year-old male patient presented with severe radicular pain of both legs and neurological intermittent claudication. Preoperative MR images reveal severe central and lateral recess stenosis of L4–5 (Fig. 10). This patient was received left sided unilateral laminotomy with bilateral decompression by biportal endoscopic approach (Video 2). Intraoperative endoscopic image and postoperative MR images demonstrated complete decompression of central canal and lateral recess of L4–5 (Fig. 10). Postoperatively, his symptoms were significantly improved.

Complications and its Management

Bleeding

To reduce the occurrence of the technical complications, the most important factor is to keep the surgical field clear by blocking epidural bleeding. Fluent water flow and bleeding control from edge bone or epidural small vessels were ensured before processing with flavectomy or laminectomy especially on the contralateral side. A bleeding from the laminectomy bone edge was compressed by squashing a piece of bone wax on

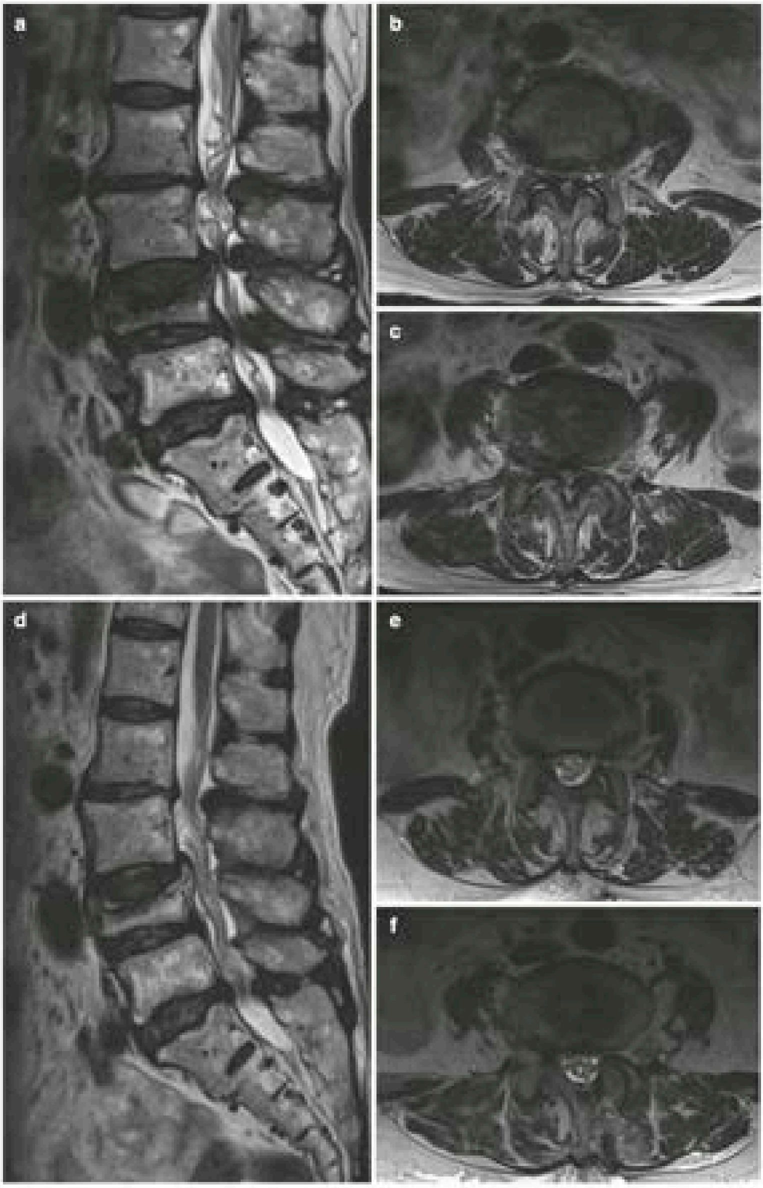

Fig. 9 Preoperative MRI showed severe central and lateral stenosis at L3–4–5 ((**a**) sagittal image; (**b**) axial image of L3–4; (**c**) axial image of L4–5). Postoperative MRI showed full decompression of lateral recess stenosis at L3–4–5 ((**d**) sagittal image; (**e**) axial image of L3–4; (**f**) axial image of L4-5). Clockwise from left

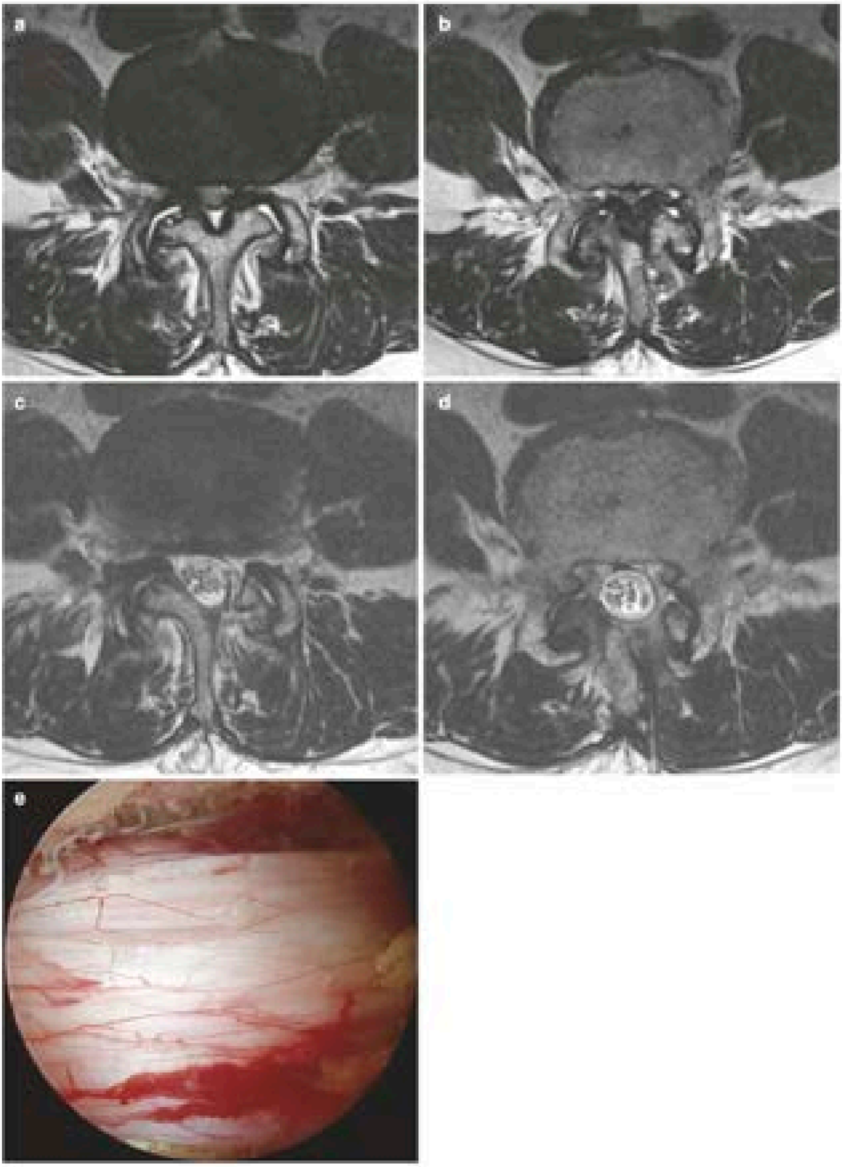

Fig. 10 Preoperative MR images show central and lateral recess stenosis of L4–5 (**a**, **b**). Postoperative MR images reveal complete decompression of central and lateral recess stenosis of L4–5 (**c**, **d**). Intraoperative endoscopic view image also demonstrated well decompression of central canal and bilateral traversing nerve roots (**e**)

the bleeding sites. A bleeding from the epidural edge just after flavectomy from the small epidural vessels could be coagulated using a small-sized RF device. If the bleeding cannot be controlled with these efforts, lowering the blood pressure to around 100 mm Hg can be helpful in some cases.

Dural tear

Several papers were reporting no differences in the incidence of complications between biportal endoscopic and microscopic groups [10]. The most common complication reported with a systematic review was a dural tear [11]. Biportal endoscopic spine surgery allows the surgical field to be viewed at high magnification, and the fluid from continuous pressure irrigation enables slight compression of the dura and widening of the contralateral epidural space during procedures. The risk of dural tear is reported to be increased in bilateral decompression procedures via a unilateral approach. Irrigation is continuous during biportal endoscopic surgery, which can make it difficult to confirm CSF leakage during the procedure. A significant dural defect should be repaired directly under the operative microscope, and small intraoperative durotomy can be resolved with the application of sealant materials and placing the patient on bed rest. The best treatment of dural tear is prevention with the exercise of several precautions. Aggressive surgical action to expose neural tissues through decompression may be harmful to the dural membrane. Instrumental manipulation of the narrow, invisible epidural space should be avoided. Keeping the cutting surface of the instruments (Kerrison punches and forceps) visible while removing structures identified by the endoscope also helps prevent dural tear.

Brief Discussion: Surgical Tip and Pitfall

For biportal endoscopic spine surgery, the axes of the endoscope and working channel are separated, making it easier for anatomical orientation and handling of instruments. The freedom of instrument angle is elevated and has made many technical advances, especially in the use of drills. Since biportal endoscopic spine surgery has a continuous water flow from the endoscopic portal to working portal, it is possible to maintain a clear view during bleeding.

From an anatomical perspective, the contralateral approach gives the most facile access to the lateral recess and intra-foraminal space. Using advantages of more freedom to manipulate instruments with biportal endoscopic spine sugery, endoscopic surgery for lumbar degenerative pathologies has been making rapid strides. Along with this, the efforts continue to find a useful and reliable classification system of lumbar spinal stenosis, which could be an index for preoperative evaluation and in determining the proper technique [12].

It was difficult to find the proper definition or criteria for the adequate decompression of spinal stenosis. The surgeon should perform surgery to keep the patient safe and to maximize the clinical results, and the spine surgeon must evaluate and take responsibility for the appropriate decompression, based on their experience and knowledge. The authors think the biportal endoscopic spine surgery has many advantages over the safety and stable outcome for the decompression of spinal stenosis.

The biportal endoscopic decompression method represents a viable option for lumbar spinal stenosis with good results. It was evolving with understanding other techniques and specialized in the benefits of the endoscopy. This biportal endoscopic technique is worth further developing and application.

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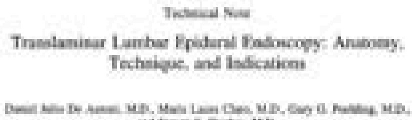
20 Percutaneous Biportal Endoscopic Decompression for Lumbar Central Stenosis and Foraminal Stenosis

Dong Hwa Heo and Choon-Keun Park

20.1 History of Biportal Endoscopic Spine Operation

In 1998, Dr. Antoni firstly presented biportal endoscopic approach named as lumbar degenerative disease (Fig. 20.1) [1]. Dr. Antoni performed translaminar lumbar discectomy through two channels using an epidural endoscopy. This approach was the first trial of percutaneous biportal endoscopic surgery. However, this approach did not become popular and developed technically in spine society and market. About 10 years ago, percutaneous biportal endoscopic approaches were attempted in South Korea. Firstly, percutaneous biportal endoscopic approach has been attempted for the treatment of lumbar central stenosis. Because endoscopic systems and radiofrequency systems were vigorously developed, biportal endoscopic surgeries can be achieved from cervical to lumbosacral area. Recently, many spine surgeons of South Korea have performed percutaneous biportal endoscopic surgery. Moreover, endoscopic lumbar interbody fusion can be achieved by percutaneous biportal endoscopic approach. Several articles related to percutaneous biportal endoscopic surgeries were published and presented [2, 3].


Technical Note

Translaminar Lumbar Epidural Endoscopy: Anatomy, Technique, and Indications

Daniel Julio De Antoni, M.D., Mario Lucas Claro, M.D., Gary G. Poehling, M.D., and Steven S. Hughes, M.D.

Fig. 20.1 The first published article of biportal endoscopic spine surgery. Dr. Antoni firstly presented biportal endoscopic surgery for lumbar degenerative disease 19 years ago (1998)

20.2 Concept of Percutaneous Biportal Endoscopic Approach

Percutaneous biportal endoscopic surgery was a minimally invasive approach and used two portals or two channels during operation. This approach is very similar to shoulder extracavitary arthroscopic surgery and percutaneous interlaminar endoscopic approach. One portal was used for endoscopy, and the other portal was used for working channel (Fig. 20.2). Spinal instruments were used through working portal. Two portals should be joined around working area such as lamina or foramen. For

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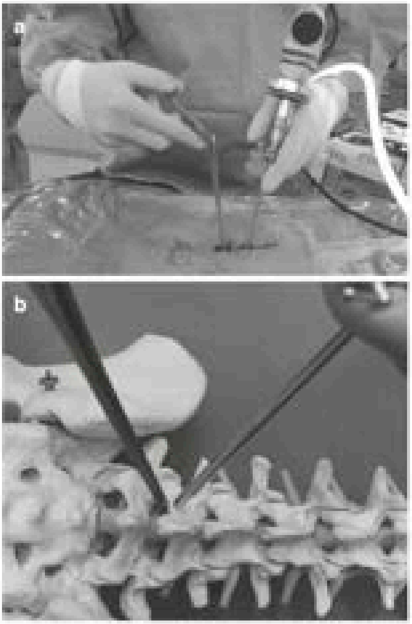

Fig. 20.2 Overview of percutaneous biportal endoscopic surgery (a and b)

the prevention of muscle injury, two portals should be made through loose epi-periosteal plane and inter-fascicular area (Fig. 20.3a). We have to make working space between muscle and bony structure (spinous process, lamina, and facet joint) for initiation of biportal endoscopic approach (Fig. 20.3b). Continuous irrigation fluid helps to make and maintain working space. As operation proceeded, extra-cavitary procedure was converted to cavitary procedure (intraspinal canal, Fig. 20.3c). The view of operation field was getting cleaner as operation proceeded.

Continuous irrigation system must be used for clearing of surgical field and bleeding control. Irrigation fluid was drained from endoscopic portal to working portal (Fig. 20.4). For the maintenance of pressure of irrigation fluid, irrigation fluid bag should be placed at about 170 cm height or used with irrigation pump system. Recommendation pressure of irrigation saline was 30–50 mmHg (height pressure control: 170 cm). Irrigation fluid should be continuously drained well via working channel during operation. If irrigation saline was not drained continuously, we checked patency of working portal and

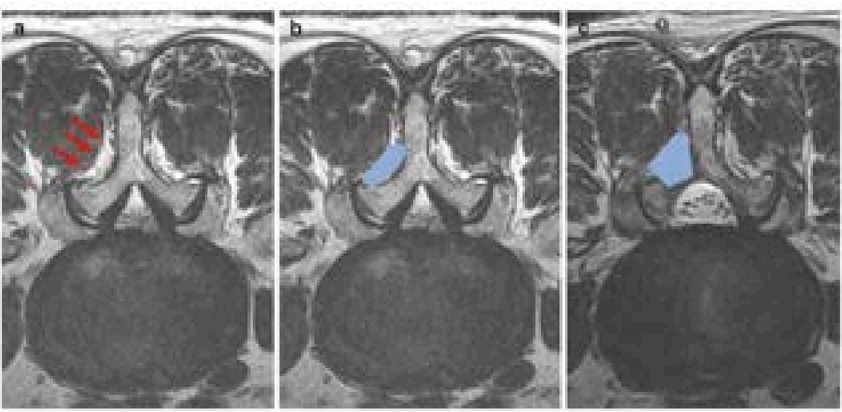

Fig. 20.3 Two channels were made via inter-fascicular area and epi-periosteal plane (a). Initial working space between lamina and muscle (b). Working space was increased and vision was clearer after laminotomy (c)

used a retractor for retraction of muscle and fascia.

We can use general spinal operation instruments such as Kerrison punches, pituitary forceps, hooks, and dissectors as well as endoscopic specialized instruments via working portal.

20.3 Operation Setting

Preparation and operation settings of percutaneous biportal endoscopic surgery are similar to knee or shoulder arthroscopic operation. We used a waterproof drape for shoulder arthroscopic surgery or percutaneous lumbar transforaminal or interlaminar endoscopic surgeries. An endoscope was used with a trocar for continuous fluid irrigation like arthroscopic surgery (Fig. 20.5). Zero degree 4 mm diameter endoscope was usually used. A 30° endoscope was helpful for contralateral sublaminar decompression. Radiofrequency systems were necessary for muscle dissection and bleeding control (Fig. 20.5). Endoscopic drill or shaver drill systems were used for laminotomy. We used a biportal endoscopic specialized tool kit set including serial dilators, laminar dissector, dissectors, and rotational Kerrison punches (Fig. 20.5).

- Endoscopic systems. 4 mm diameter zero degree and 30°
- Irrigation pump systems (or height pressure control)
- Endoscopic drill for interlaminar approach or shaver drill systems
- Radiofrequency systems
- Biportal endoscopy specialized tool kit set
- General spine operation instruments
- Suction line

20.4 Surgical Technique

We prefer general endotracheal anesthesia during percutaneous biportal endoscopic procedures. Epidural anesthesia was also available. We performed epidural anesthesia in patients who had morbidity or mortality related with general endotracheal anesthesia. Percutaneous biportal endoscopic procedures were performed under prone position.

20.4.1 Unilateral Laminotomy with Bilateral Decompression for Lumbar Central Stenosis by Percutaneous Biportal Endoscopic Approach

The patient was positioned in prone after anesthesia. Routine aseptic skin preparation was performed. And then, skin was covered by a waterproof drape (shoulder endoscope drape or spinal endoscope drape with U-shape cover) (Fig. 20.6). Two portals were made under C-arm fluoroscopic guidance. Two skin incisions were made at the medial border of pedicle ipsilateral in anteroposterior view (Fig. 20.7a, b). If patients did not have lateralizing symptoms, we prefer left-side approach in right-handed surgeon. In lateral fluoroscopic view, two skin incisions were made on upper and below 1 cm based on disc space. Upper skin incision was used for endoscopic portal, and lower skin incision was used for working portal. Firstly, we made working portal after 7–10 mm sized skin incision. Fascia was incised by a sharp knife or mosquito forceps. And then, serial dilators were inserted. We put in serial dilators under bone touching of spinous process and upper laminar (Fig. 20.7c). After insertion of serial dilators, we did laminar dissection using a specialized laminar dissector for the making of working space (hydrostatic cavity) over the laminar and interlaminar space. Following endoscopic portal about 5 mm sized skin incision was made at upper area. We put in a trocar after insertion of a small-diameter dilator. An endoscope should be met with spinal instruments such as micro-dissector or nerve freer around upper laminar area. If spinal working instrument was detected around upper laminar under endoscopic view, irrigation saline was drained continuously via working portal (Fig. 20.4). Ipsilateral partial hemi-laminectomy was done using Kerrison punches or drills. Base of spinous process was partially removed for contralateral sublaminar decompression. Partial hemi-laminectomy of upper laminar should be performed until exposure of proximal end of ligamentum flavum. Bone bleeding was controlled with bone wax and a radiofrequency probe. And then, we exposed and dissected upper portion of lower laminar using dissectors, curette, and radiofrequency probe. Ligamentum flavum consisted of two layers (superficial and deep layers, Fig. 20.8). Superficial layer of ligamentum flavum attached to the anterosuperior surface of the lower (caudal) lamina (Fig. 20.8) [4]. We removed superficial layer of ligamentum flavum firstly

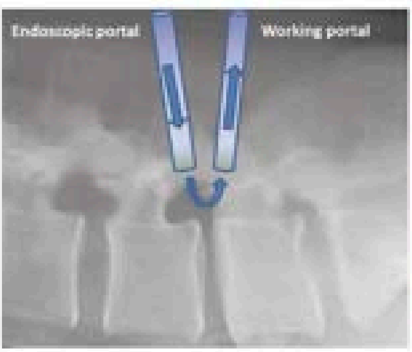

Fig. 20.4 Continuous irrigation systems of percutaneous biportal endoscopic surgery. Irrigation fluid was drained from endoscopic portal to working portal

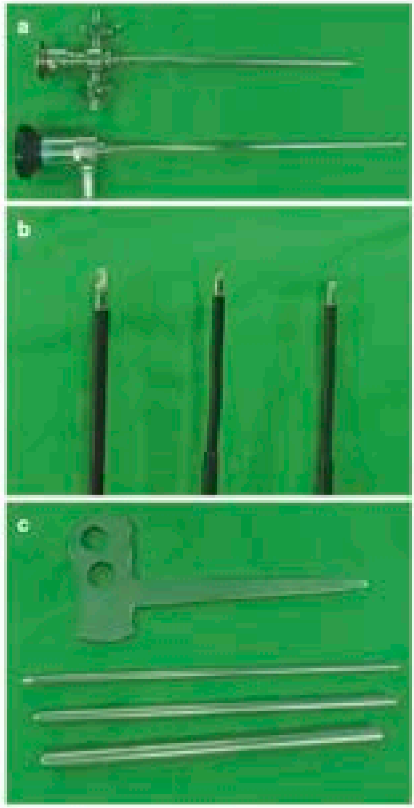

Fig. 20.5 An endoscope and its trocar (**a**), radiofrequency systems for biportal endoscopic surgery. VAPR, Ellmann, and Arthrocare systems were available (**b**). Serial dilators and dissector (**c**)

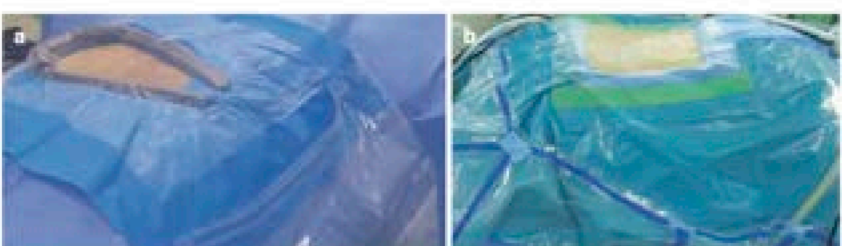

Fig. 20.6 A waterproof drape for percutaneous biportal endoscopic surgery. A U-shape drape (**a**) and a drape for shoulder arthroscopy (**b**)

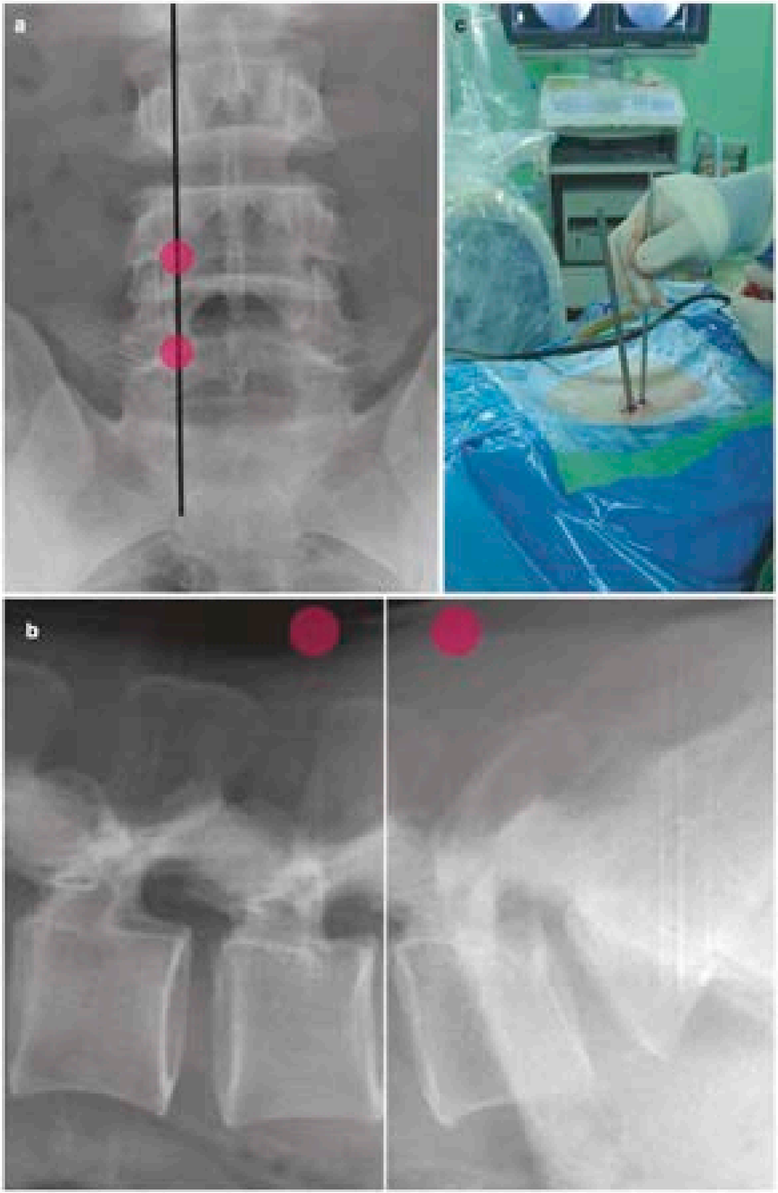

Fig. 20.7 Two skin incision points of biportal endoscopic surgery for central stenosis (**a**: anteroposterior view, **b**: lateral view). Intraoperative image of insertion of serial dilators for making two portals (**c**)

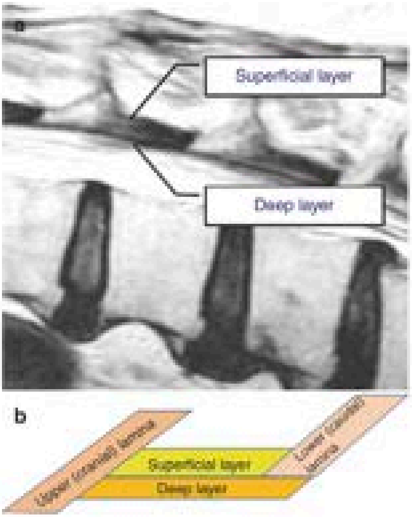

Fig. 20.8 Superficial layer of ligamentum flavum attached to the anterosuperior surface of the lower (caudal) lamina. Deep layer of ligamentum flavum was attached to inferior portion of lower (caudal) lamina. MRI image of ligamentum flavum (**a**), and schematic illustration of the anatomy of ligament flavum (**b**)

using Kerrison punch and pituitary forceps. Deep layer of ligamentum flavum was exposed after removal of superficial layer. Deep layer of ligamentum flavum was attached to the inferior portion of lower lamina (Fig. 20.10) [4]. Upper portion of lower laminar was partially removed for exposure of distal end of deep layer of ligamentum flavum. Deep layer of ligamentum flavum was adhered to dura sometimes. Dissection between deep layer of ligamentum flavum and dura must be performed using a hook dissector or Penfield dissector before removal of deep layer of ligamentum flavum. For the full decompression of central canal and traversing nerve root, ligamentum flavum should be completely removed from proximal to distal end. We did medial facetectomy and foraminotomy for decompression of ipsilateral traversing nerve root. If patients have concomitant disc herniation, we did discectomy after decompressive procedure.

We removed contralateral ligamentum flavum for decompression of contralateral traversing root. If an endoscope was slightly tilted, contralateral side was clearly demonstrated. Sometimes, we removed contralateral superior articular process and around osteophyte. Finally, we inserted a small-diameter drainage catheter for the prevention of postoperative epidural hematoma. We finished operation after full decompression of central canal and bilateral traversing roots (Fig. 20.9).

20.4.1.1 Case 1 (Video 20.1)

69-Year-old female complained of radicular pain of both legs and intermittent claudication. Magnetic resonance imaging (MRI) detected central and lateral recess stenosis of L4-5 (Fig. 20.9a, b). Intraoperative endoscopic image (Fig. 20.9c) and MRI (Fig. 20.9d, e) showed well-decompression status of L4-5. After operation, her pain and claudication were improved.

20.4.1.2 Case 2 (Video 20.2)

48-Year-old presented with intermittent neurologic claudication. Recently, her left leg pain was aggravated. MRI detected central stenosis with ruptured disc of L4-5 (Fig. 20.10a). Intraoperative endoscopic picture reveals stenosis of ruptured disc herniation of L4-5 (Fig. 20.10b). Postoperative MRI shows well-decompressive status of L4-5. Her symptoms were significantly improved.

20.4.2 Paraspinal Lateral Foraminotomy (Wiltse Approach) for Lumbar Foraminal Stenosis by Percutaneous Biportal Endoscopic Approach

This approach was similar to the paraspinal Wiltse approach. Two portals were made at 1 or

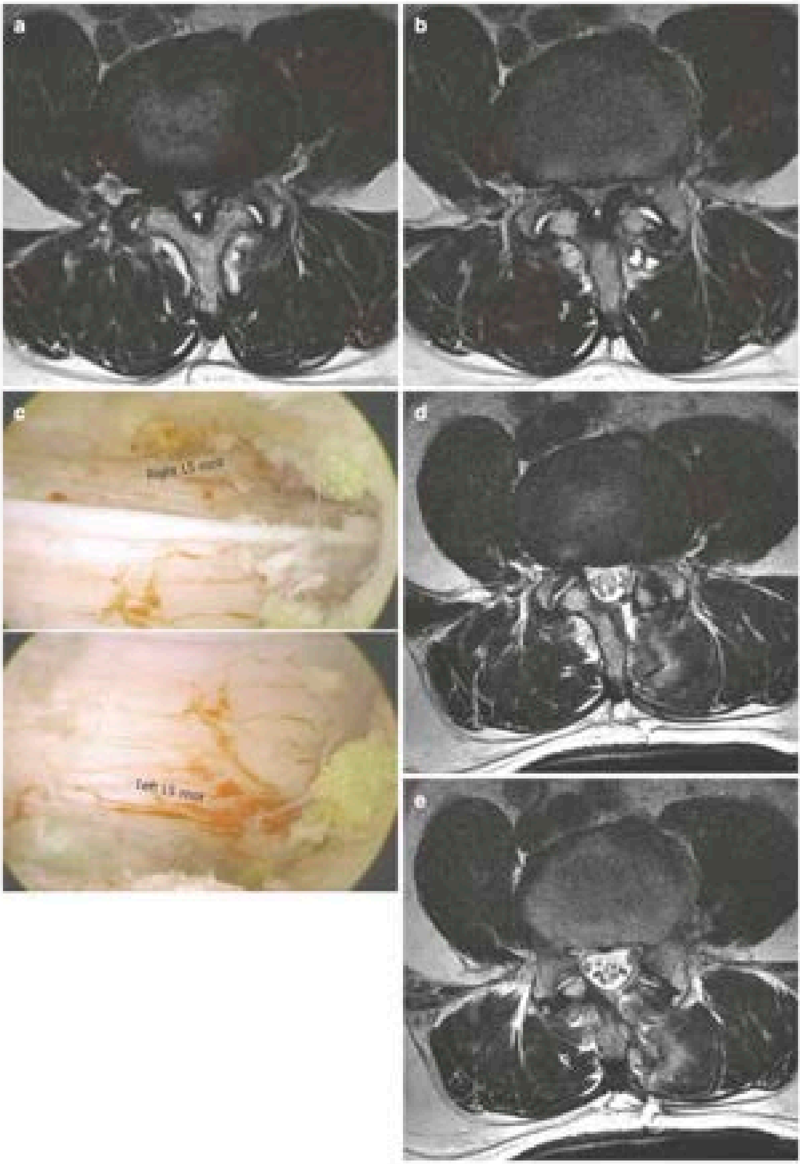

Fig. 20.9 Preoperative MRI images reveal central and lateral recess stenosis of L4-5 (**a** and **b**). Intraoperative endoscopic image shows complete neural decompressive status (**c**). Postoperative MRI shows good decompression status of the spinal canal of L4-5 (**d** and **e**)

2 cm lateral area from lateral border of pedicles in anteroposterior view (Fig. 20.11). In lateral view, two portals were made at 1 cm above and below area based on midportion of foramen (Fig. 20.11). Cranial endoscopic portal was usually made on the transverse process of upper vertebral body in the left-sided approach. And caudal working portal was made on the end plate of lower vertebral body. Serial dilators were inserted for making working channel after 7–10 mm sized skin incision. We percutaneously dissected transverse process, lateral border of isthmus, and lateral border of facet joint using a dissector under C-arm fluoroscopic guidance. The endoscopic portal was easily joined with working portal around transverse process of upper vertebral body or isthmus (Fig. 20.12). We could easily detect spinal working instrument under endoscopic view around transverse process of upper vertebral body. And then, we moved an endoscopy and instruments to the isthmus and facet joint. We removed lower margin of transverse process, and lateral margin of facet joint and isthmus partially using drill and punches. We exposed and identified the tip of superior articular process. Ligamentum flavum and inter-transverse ligament were easily removed after partial removal of superior articular process. Exiting root was exposed after removal of ligamentous structures. If the patient had foraminal or extraforaminal disc herniation, we did discectomy. We performed full decompression from preganglionic to postganglionic area. Especially, we removed inferior portion of ala in cases of L5 root entrapment for the full decompression of L5 root.

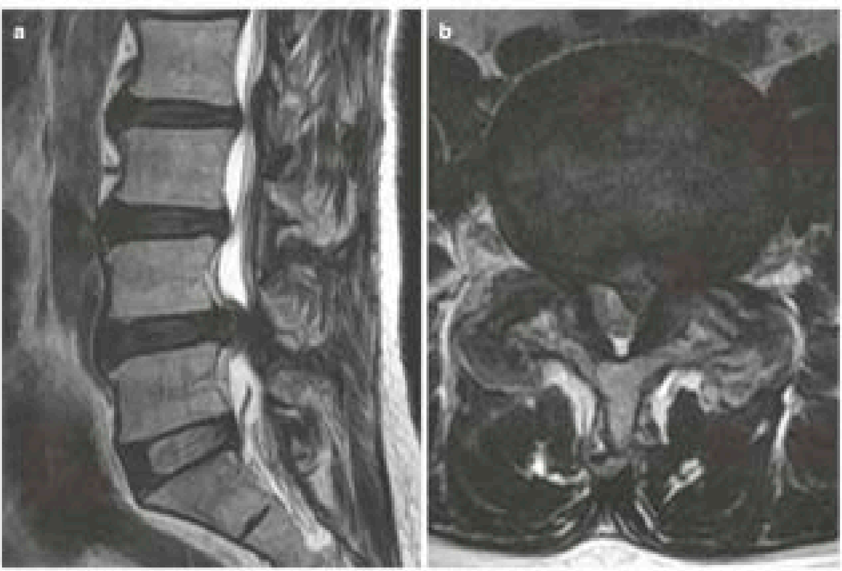

Fig. 20.10 Preoperative MRI shows central stenosis with ruptured disc of L4-5 (**a**). Intraoperative endoscopic image shows disc herniation with stenosis at the left side of L4-5 (**b**). Postoperative MRI reveals that spinal canal was well decompressed and disc particles were removed

Fig. 20.10 (continued)

20.4.2.1 Case 3 (Video 20.3)

62-year-old male presented with severe right leg pain refractory to conservative management. Preoperative MRI reveals right-sided foraminal stenosis with disc herniation of L3-4 (**a**, **b** and **c**). Postoperatively right side foraminal stenosis of L4-5 was well decompressive (**d**: intraoperative endoscopic view, **e** and **f**: postoperative MRI) (Fig. 20.13).

20.4.2.2 Case 4 (Video 20.4)

61-Year-old male complained of severe radicular pain and tingling sensation of left leg. Preoperative MRI (a) and CT (b) show extra-foraminal stenosis below ala and ruptured disc at l L5-S1 area. After operation, L5 nerve root was well decompressed (c and d). His leg pain disappeared postoperatively (Fig. 20.14).

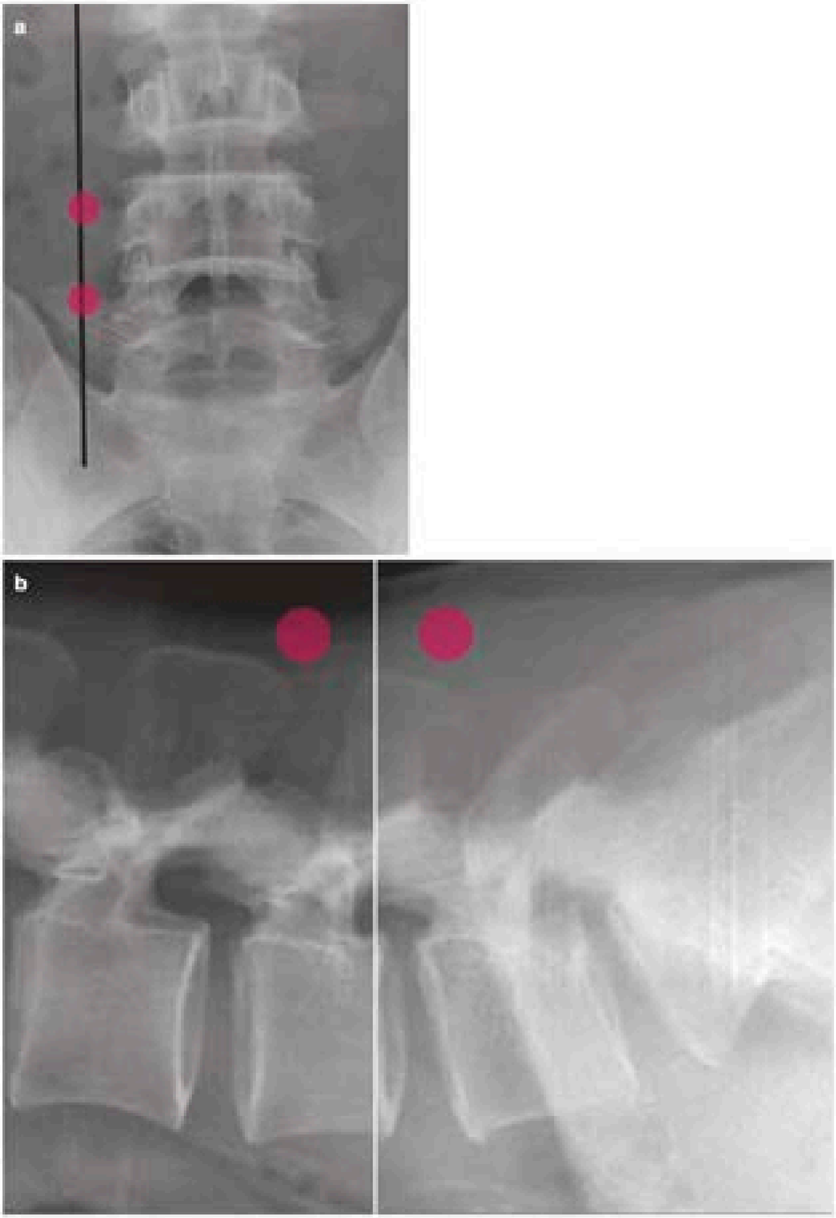

Fig. 20.11 Two-skin-incision points of percutaneous biportal endoscopic surgery for paraspinal approach

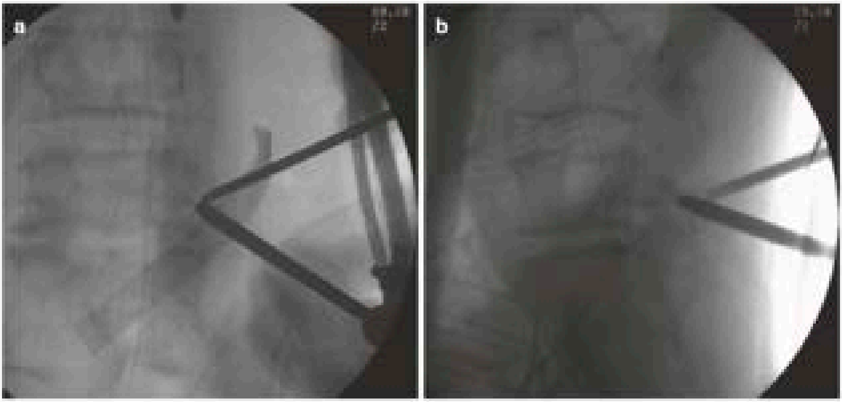

Fig. 20.12 Intraoperative fluoroscopic images of paraspinal approach (**a**: anteroposterior view, **b**: lateral view). Target point is isthmus and foramen

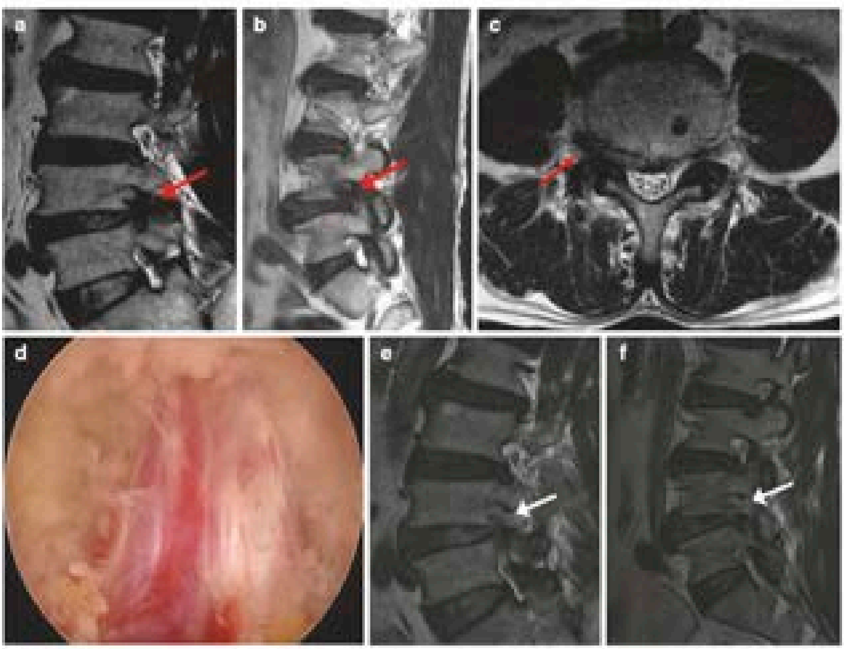

Fig. 20.13 Preoperative MRI images show foraminal stenosis with ruptured disc of right foramen of L4-5 (**a**: foraminal image, **b**: parasagittal image, **c**: axial image, arrows). Intraoperative endoscopic image depicts complete decompression status of right L4 exiting root (**d**). Postoperative MRI images (**e** and **f**) demonstrate well-decompressive status of right L5 root and around foramen

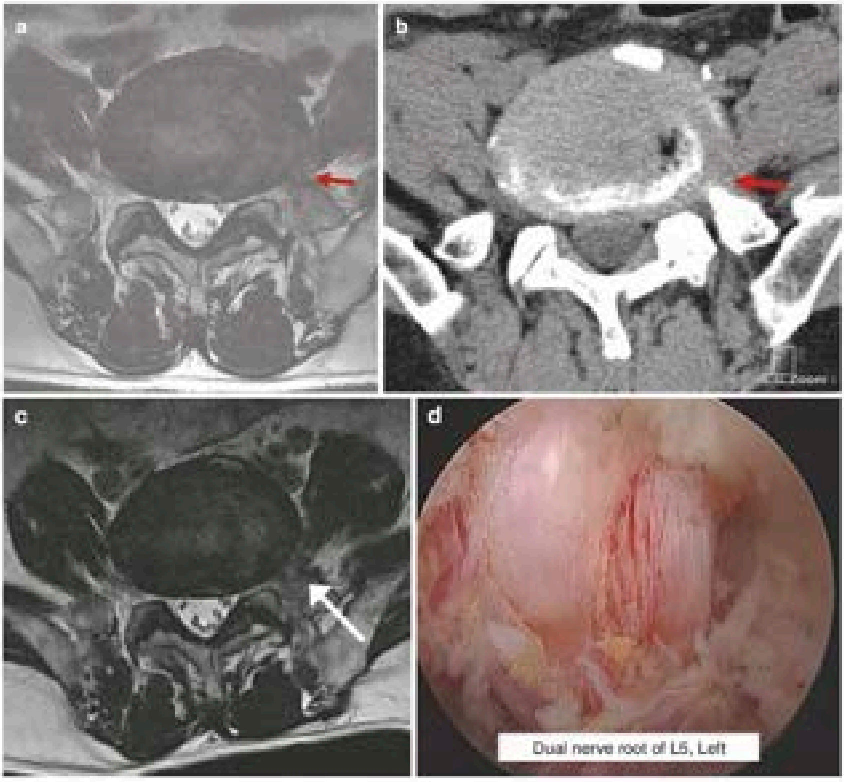

Fig. 20.14 Preoperative MRI (**a**) and CT (**b**) show that left L5 nerve root was entrapped by hypertrophied ala and rupture disc at extra-foraminal area of left L5-S1 (arrows). Postoperative MRI depicts that ala was partially removed and ruptured disc particles were removed (arrows) (**c**). Intraoperative endoscopic picture shows full decompression status of L5 nerve root. Dual-nerve roots of L5 were detected intraoperatively (**d**)

20.5 Complication

1. Postoperative headache: Continuous irrigation fluid may affect intracranial pressure. Use of large amount of irrigation fluid and long duration of operation time may induce postoperative headache or neck pain [5]. The irrigation fluid must be continuously drained via the working portal during operation. And, pressure of irrigation fluid should be controlled under 50 mmHg.
2. Dura injury (Fig. 20.15): Like conventional spinal operation, incidental durotomy or dura injury may occur during endoscopic procedures. Direct dura repair may be difficult during endoscopic surgery. If continuous fluid irrigation may directly increase intracranial pressure in case with dura tear, seizure attack may occur postoperatively. If dura defect or large size of dura tear occurred in early period of biportal endoscopic operation, we recommend converting endoscopic surgery to open

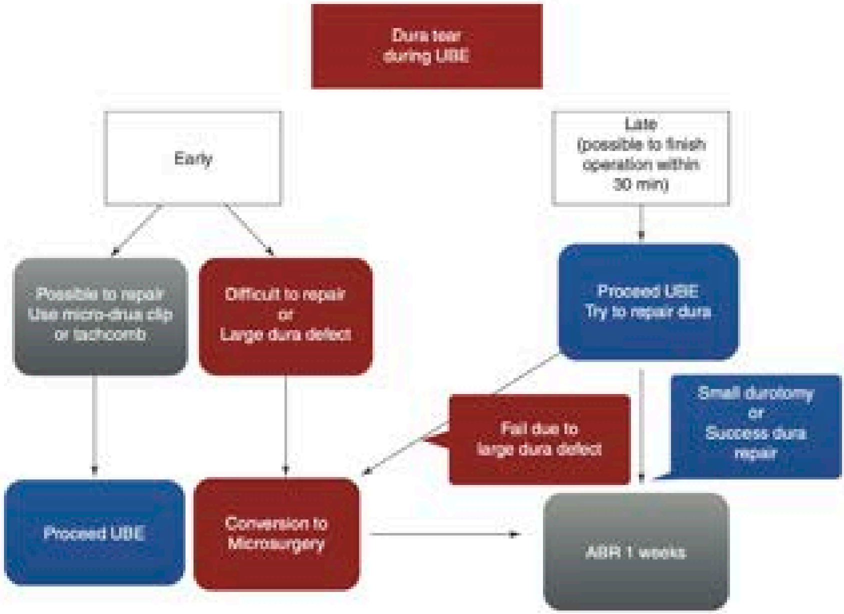

Fig. 20.15 Diagram of management of dura tear during percutaneous biportal endoscopic surgery in lumbar area

microsurgery for the direct dura repair. If small durotomy occurred, we have tried to direct dura repair using dura-sealing materials (Tachcomb) or dura clip or proceeded biportal endoscopic procedure without dura repair.

Dura tear usually occurs during flavectomy. Meticulous dura and ligamentum flavum dissection should be done before flavectomy. Moreover, we did not remove full layer of ligamentum flavum but did a layer-by-layer pattern for the prevention of dura injury. Firstly, we removed superficial layer of ligamentum flavum, and subsequently removed inner deep layer of ligamentum flavum for the prevention of dura injury during flavectomy (Fig. 20.8). We recommend bed rest for 7 days in patients who had dura injury.

3. Postoperative epidural hematoma: Epidural hematoma can occur like conventional spine surgery. Meticulous bleeding control was important for prevention of postoperative epidural hematoma. We inserted a small-diameter drainage catheter routinely. Keeping of drainage catheter may be effective for the prevention of epidural hematoma. In our large experience, the incidence of symptomatic epidural hematoma may be very low.

20.6 Conclusion

We suggest that percutaneous biportal endoscopic approach may be an effective treatment for lumbar central or foraminal stenosis. We can achieve full neural decompression using biportal endoscopic surgery like conventional open surgery. Short learning curve and familial surgical anatomy are other merits of biportal endoscopic surgery.

Percutaneous biportal endoscopic surgery is still in development status, and instruments for biportal endoscopic approach should be developed.

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Review and Technical Note

Technique of Biportal Endoscopic Transforaminal Lumbar Interbody Fusion

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Biportal endoscopic transforaminal lumbar interbody fusion (TLIF) may have advantages of minimally invasive fusion surgery as well as those of endoscopic surgery. The purpose of this study was to present the biportal endoscopic TLIF technique along with video presentations and a review of the literature on this technique. Basically, the biportal endoscopic TLIF technique is similar to minimally invasive TLIF with a tubular retractor. There were 2 options in the biportal endoscopic TLIF procedures. The first was the insertion of one long TLIF cage and the other was the insertion of 2 short posterior lumbar interbody fusion (PLIF) cages. After the interbody fusion procedures, percutaneous pedicles screw fixation was performed. Biportal endoscopic TLIF achieved complete neural decompression through laminectomy and facetectomy like conventional TLIF. Endplate preparation was performed completely under a clear and magnified endoscopic view. It was also feasible to insert a large TLIF cage or 2 cages for PLIF without exiting nerve root injury. Biportal endoscopic TLIF might have the advantages of endoscopic surgery as well as minimally invasive fusion surgery. Direct neural decompression, endplate preparation under endoscopic guidance, and the insertion of a large TLIF cage or 2 PLIF cages may be the merits of biportal endoscopic lumbar fusion procedures.

Keywords: Endoscopy, Fusion, Lumbar, Minimally invasive surgery

INTRODUCTION

Minimally invasive (MIS) spine surgery has the advantages of early recovery and the preservation of normal structures.1 MIS spine procedures include percutaneous pain procedures, endoscopic spine surgery, microsurgery with tubular retractor systems, lateral lumbar interbody fusion surgeries, and transforaminal lumbar interbody fusion (TLIF) surgeries.[1] Recently, endoscopic lumbar interbody fusion procedures have been attempted for lumbar degenerative disease and instability.[2-4] Regarding the instrumentation systems, there are 2 kinds of endoscopic lumbar interbody fusion surgeries. The first is uniportal endoscopic lumbar interbody fusion and the other is biportal endoscopic lumbar interbody fusion.[5-8] With regard to surgical approaches or corridor, one approach is a trans-Kambin approach using uniportal endoscopic surgery[9,10] and the other is a posterolateral approach like MIS TLIF using uniportal or biportal endoscopic surgery.[5,11,12] The trans-Kambin approach is similar to transforaminal endoscopic lumbar discectomy via the Kambin triangle. And, the technique of posterolateral endoscopic TLIF is similar to MIS TLIF involving tubular retractor systems.[4,11,12]

Although endoscopic TLIF by the trans-Kambin approach may be less invasive than the posterolateral approach, the trans-Kambin approach might exhibit a higher possibility of exiting nerve root irritation or injury and limitations in direct neural decompression compared to the posterolateral approach.[7,13] The biportal endoscopic TLIF technique uses a posterolateral approach similar to MIS TLIF involving tubular retractor systems. Through biportal endoscopic procedures, it was feasible to perform direct neural decompression through a laminectomy, contralateral sublaminar decompression, discectomy, foraminotomy, and facetectomy as well as indirect decompression by disc space restoration, and the reduction of spondylolisthesis.[illegible] Also, the endoscopic approach is the least invasive and may preserve the normal structure.[illegible] Biportal endoscopic TLIF is hypothesized to have advantages of minimally invasive fusion surgery as well as those of endoscopic surgery.[illegible] Herein, we present the biportal endoscopic TLIF technique along with a video presentation and review of the literature on this technique.

SURGICAL PROCEDURES

We present 2 illustrated cases with surgical videos. The lumbar interbody fusion procedures were performed by biportal endoscopic surgery[illegible] (Fig. 1). There were 2 options of biportal endoscopic lumbar interbody fusion surgical procedures performed. The first was a cage insertion procedure (Supplementary video clip 1) and the second was a 2-cage insertion procedure (Supplementary video clip 2).

Fig. 1. Overview of biportal endoscopic lumbar interbody fusion. Usually, the dominant hand was used for the working portal and the nondominant hand was used for the endoscopic portal.

1. Surgical Instruments

The biportal endoscopy systems include a console, camera, endoscopy irrigation equipment, and tool kits, which are essential for the surgery. A waterproof surgical drape is essential for endoscopic spine surgeries and must be prepared. Also, a radiofrequency (RF) console and RF probes should be prepared for tissue cauterization and bleeding control. General spinal operation instruments for MIS TLIF were used. Angled curettes are helpful for endplate preparation of the contralateral side. A long straight TLIF cage (width, 11 mm; length, 34 mm; height, 9–18 mm) was usually used for interbody fusion, and short-length PLIF cages (width, 11 mm; length, 25 mm; height, 9–18 mm) are available. After the interbody fusion procedures, percutaneous pedicle screws were inserted under C-arm fluoroscopic guidance.

2. Anesthesia and Position

We prefer general endotracheal anesthesia. Epidural anesthesia with intravenous sedation is also available for single-level fusion. The patient is in a prone position during the interbody fusion procedure and insertion of the percutaneous pedicle screws. A Jackson table or a Wilson frame is used for this procedure.

3. Surgical Procedures

First, we make 2 skin incisions over the ipsilateral pedicles for

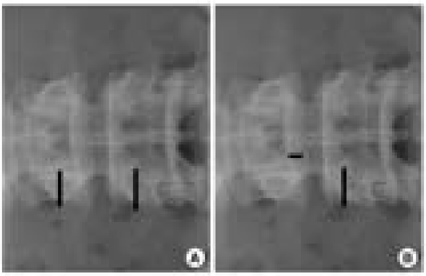

Fig. 2. Two skin incision points for biportal endoscopic transforaminal lumbar interbody fusion. (A) Ordinary skin incision points were made over the pedicle area in the anteroposterior x-ray view. (B) Modified skin incision points. (B) An endoscopic portal incision was made near the intervertebral space for good visualization of the superior and inferior endplates.

decompression and insertion of the cages under C-arm fluoroscopic guidance (Fig. 2). If the dominant radicular pain site was in the leg or buttock, biportal endoscopic approaches are tried at the dominant pain side. Modified skin incisions, different from routine incisions, were used. Typically, a 5-mm-long skin incision for an endoscopic portal is made close to the disc space of the medial pedicular line and the other skin incision is made on the working portal over the pedicle (Fig. 2B). These 2 skin incisions are also used for ipsilateral percutaneous pedicle screw insertion. A small-sized endoscopic portal is used for passing a drainage catheter. The purpose of the modified skin incision is to achieve optimal visualization of the superior and inferior endplates during endplate preparation.

Serial dilators are inserted through the working portals. The lower portion of the cranial lamina is gently dissected using a dissector under C-arm fluoroscopic guidance. The docking point of the endoscopic and working portals is over the lower portion of the cranial lamina. Ipsilateral unilateral laminotomy with an ipsilateral facetectomy is performed. Ipsilateral laminotomy of the upper and lower laminae is performed until full exposure of the ligamentum flavum from the proximal end to the distal end. The unilateral inferior articular process is removed using Kerrison punches and osteotomes. The superior articular process is partially removed. In cases with foraminal stenosis or foraminal disc herniation, the superior articular process is removed for decompression of the exiting nerve root. Facet and laminae bone chips are collected for fusion materials.

The ligamentum flavum is removed for ipsilateral traversing nerve root decompression (Fig. 3A). The contralateral side of the ligamentum flavum is completely removed for decompression of the central canal and contralateral traversing nerve root (Fig. 3B, C). The medial portion of the contralateral facet joint is fully released for the reduction of spondylolisthesis or distraction of the intervertebral disc space. Annulus fibrosus of the disc is incised using a blunt knife or an RF probe with a small diameter. The disc materials are removed using pituitary forceps and shavers. We perform complete endplate preparation under the endoscopic view. A small-diameter shaver is inserted and rotated in disc space. Larger shavers are used serially for endplate preparation. The endoscopy of biportal endoscopic systems can be inserted into disc space. The dissection plane between the cartilaginous endplate and osseous endplate is explored under a clear, magnified endoscopic view. The cartilaginous endplate is separated from the osseous endplate using angled dissectors and curettes (Fig. 4A). Only the cartilaginous endplate can be completely removed from the osseous endplate under a clear endoscopic view

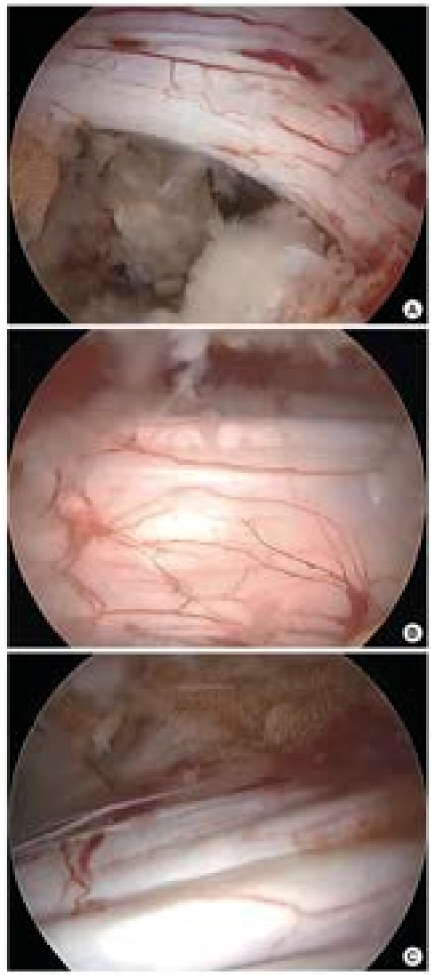

Fig. 3. Biportal endoscopic view after neural decompression. (A) Ipsilateral traversing nerve root. (B) Central canal. (C) Contralateral traversing nerve root.

(Fig. 4B). The intervertebral disc space is distracted by serial insertion of cage trials or serial dilators. The contralateral side of endplate is prepared using angled curettes and an upward angled

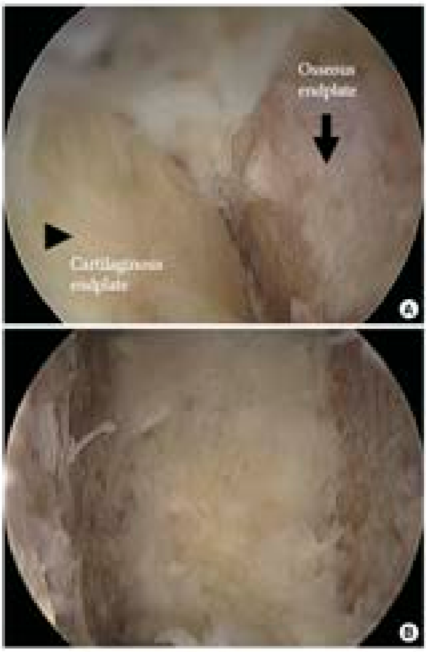

Fig. 4. Endoscopic images during endplate preparation. (A) The cartilaginous endplate (arrowhead) was separated from the osseous endplate (arrow). (B) Final view of the endoscopic endplate preparation. The cartilaginous endplate was completely removed without injury to the osseous endplate.

pituitary. For good visualization of the contralateral endplate, a 30° endoscopy is used. Sometimes we change the endoscopy from 0° to 30°. After confirmation of complete endplate preparation under endoscopic view, allogenous or autogenous bone chips are inserted using a specialized funnel under C-arm fluoroscopic guidance (Fig. 5A, B). Continuous saline irrigation is stopped during the insertion of fusion materials.

Finally, a long TLIF cage is inserted through the working portal after dura retraction. C-arm fluoroscopy was used during cage insertion. The cage is repositioned obliquely or transversely using a cage pusher device. If we use short PLIF cages, we usually put in 2 cages for interbody fusion. The first cage is obliquely and deeply inserted into the midline or contralateral side. After insertion of the first cage, the second short cage is inserted. The specialized dura retractor is deeply inserted for protection, covering the dura as well as the first inserted cage. Since the remnant of the superior articular process can protect the exiting nerve root during cage insertion, the ipsilateral exiting nerve root is decompressed after cage insertion. Finally, the exiting nerve root is additionally decompressed in cases with foraminal lesions with exiting root indentations. A drainage catheter is inserted to prevent postoperative epidural hematoma.

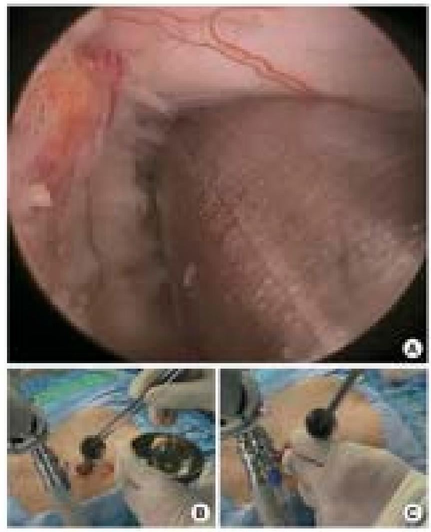

Fig. 5. The fusion materials were inserted into the intervertebral space using a funnel before cage insertion (A, endoscopic view). (B, C) Overview of fusion material insertion using a funnel and an impactor.

CASE PRESENTATIONS

1. Case I (1 cage insertion technique)

A 56-year-old female patient presented with back pain, claudication, and radicular pain in both the legs. The more painful side was the right leg. The preoperative magnetic resonance imaging (MRI) and x-ray images demonstrated degenerative spondylolisthesis with stenosis at L4–5 (Fig. 6). We performed biportal endoscopic TLIF of the L4–5 level. Biportal endoscopic TLIF was performed with the right approach. The postoperative MRI showed a reduction in spondylolisthesis and good de-

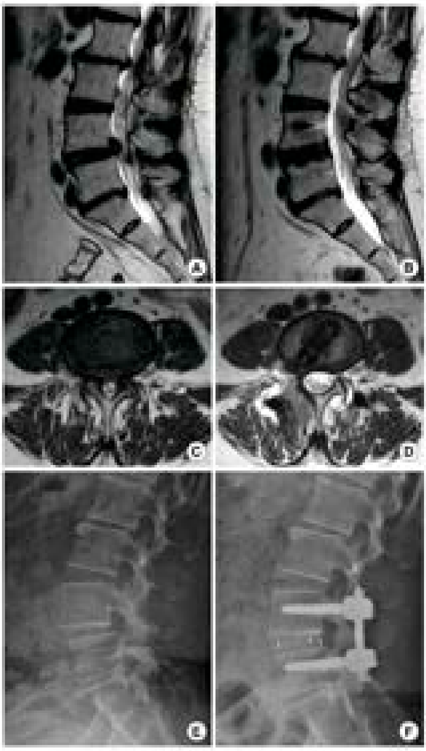

Fig. 6. Radiologic images of a 56-year-old female patient. (A) The preoperative magnetic resonance images show degenerative spondylolisthesis of L4–5. (B) After biportal endoscopic transforaminal lumbar interbody fusion (TLIF), the spondylolisthesis was well-resolved. Central stenosis of L4–5 (C) was decompressed after surgery (D). (E) The preoperative x-ray also revealed spondylolisthesis of L4–5. (F) The postoperative x-ray showed the large TLIF cage and percutaneous pedicle screw inserted.

compression status of the central stenosis (Fig. 6). Postoperatively, the patient's symptoms were significantly improved. (Supplementary video clip 1).

2. Case 2 (2 cages insertion technique)

A 55-year-old female patient presented with radicular pain in both legs and neurological intermittent claudication. The preoperative MRI and x-ray images revealed degenerative spondylolisthesis with central and foraminal stenosis at L4–5 (Fig. 7). The patient underwent biportal endoscopic TLIF with a 2-cage insertion technique. The postoperative MRI and x-ray images

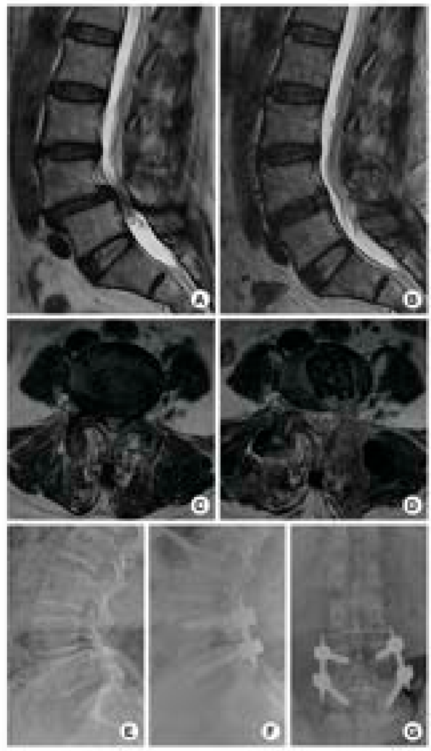

Fig. 7. A 55-year-old female patient presented with pain with claudication in both legs. (A) The preoperative magnetic resonance imaging showed degenerative spondylolisthesis with central stenosis at L4–5. (B) This patient received biportal endoscopic transforaminal lumbar interbody fusion using the 2-cage insertion technique. Preoperative spondylolisthesis (A) and central stenosis (C) were significantly resolved postoperatively (B, D). (E) The preoperative x-ray image demonstrates degenerative spondylolisthesis of L4–5. (F, G) The postoperative x-ray images reveal a reduction in spondylolisthesis and the presence of 2 inserted cages. The pain was significantly improved after surgery.

demonstrated a significant reduction in spondylolisthesis and good decompression of the neural structures (Fig. 7). The pain was resolved after the biportal endoscopic TLIF (Supplementary video clip 2).

DISCUSSION

Conceptually, this biportal endoscopic TLIF approach might have the advantages of both MIS fusion and endoscopic surgery. Theoretically, biportal endoscopic fusion surgeries may be suitable for endoscopic assistant fusion surgery. However, the term seems to be confused with air-based microendoscope-assisted fusion surgeries. Microendoscope-assisted TLIF was performed using tubular retractor systems. Therefore, we suggested that the term of endoscopic TLIF may be better than endoscope-assisted TLIF in the water-based endoscopic lumbar interbody fusion surgeries. This technique is based on conventional microscopic TLIF procedures.[1] Therefore, it is possible to achieve the direct decompression of neural tissue by biportal endoscopic TLIF,[14,21] and insert large, long TLIF cages, like in MIS TLIF.[4,5] The contralateral nerve root could be fully decompressed through the contralateral sublaminar approach.[4,14] The contralateral sublaminar approach for contralateral nerve root decompression is one of the advantages of the biportal endoscopic approach.[1,13] Also, indirect decompression was achieved by the reduction of spondylolisthesis and the restoration of the collapsed disc space. Since we could insert a large, long cage for conventional TLIF, the narrowed disc space was distracted by the insertion of a large-sized cage.[1]

The direct decompression of central canal and nerve roots was performed by removing the ligamentum flavum, and by laminectomy and facetectomy.[1,14] Since there was a possibility of exiting nerve root injury during insertion of a cage, we usually decompressed the ipsilateral exiting nerve root after a cage insertion. The lateral remnant of the superior articular process imparted protection to the exiting nerve root during cage insertion. If patients had severe foraminal stenosis or foraminal disc herniation, we performed direct foraminal decompression through a total facetectomy.

The distraction of narrowed disc space was important to cage insertion and for performing indirect decompression. The placement of serial dilators or cages trials into the disc space led to disc space distraction without endplate injury. It was further hypothesized that contralateral medial facet release may be important for the reduction of spondylolisthesis and the restoration of disc height. We performed contralateral facet release

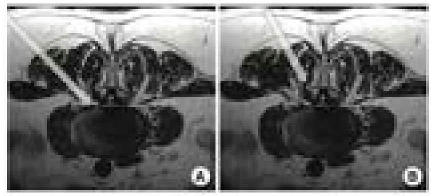

Fig. 8. Two types of endoscopic transforaminal lumbar interbody fusion (TLIF). The trans-Kambin approach (A) and the posterolateral approach (B). The trans-Kambin approach was similar to transforaminal lumbar discectomy and the posterolateral approach was similar to minimally invasive TLIF with tubular retractor systems.

through complete removal of the contralateral ligamentum flavum around the facet joint and partial removal of the contralateral superior articular process. Some clinicians prefer to insert 2 cages rather than 1 cage. By using the biportal endoscopic approach, it is possible to insert 2 PLIF cages via a unilateral biportal endoscopic approach.

Two types of endoscopic lumbar interbody fusion surgeries can be used, depending on the surgical approaches (Fig. 8, Table 1). The first is the trans-Kambin approach (Fig. 8A),[6,7,13,19] and the other is a posterolateral approach (Fig. 8B).[1,4,21] The trans-Kambin endoscopic TLIF procedure was performed via Kambin's triangle, like fully endoscopic transforaminal lumbar discectomy. Endplate preparation and cage insertion were performed via Kambin's triangle.[6] The posterolateral approach is similar to MIS TLIF surgery. The posterolateral endoscopic TLIF approach is based on MIS TLIF (Fig. 8B).[1,21,28] Direct decompressive procedures, including ipsilateral laminotomy and total facetectomy, were performed in the posterolateral endoscopic TLIF approach. Although endoscopic TLIF through the trans-Kambin approach is less invasive than the posterolateral approach, the disadvantage of the trans-Kambin approach is exiting nerve root injury. Previous studies reported the frequency of exiting nerve irritation or injury from 0% to 22% in the trans-Kambin approach in uniportal endoscopic TLIF.[1,19] Since a cage is inserted through Kambin's triangle, there might be a high possibility of exiting nerve root injury during insertion. Direct decompression and endplate preparation may also be limited in the trans-Kambin approach.

In contrast, the posterolateral approach might have a lower possibility of exiting nerve root injury during cage insertion. Before cage insertion, full neural decompression procedures were performed. Enough space for cage insertion was made

Table 1. Comparison of 2 types of endoscopic TLIF

Variable	Trans-Kambin approach	Posterolateral approach
Bone work	Ipsilateral superior articular process (Foraminoplasty)	Ipsilateral superior articular process and inferior articular process Ipsilateral lamina
Direct decompression		
Ipsilateral	Possible	Possible
Contralateral	Impossible	Possible
Indirect decompression	Possible	Possible
Endplate preparation	Direct sighted under endoscopic view	Direct sighted under endoscopic view
Cage insertion	One cage	One or 2 cages
Exiting nerve root injury	Slightly higher than the posterolateral approach	A little
Similar surgical approach	Transforaminal endoscopic discectomy	Minimally invasive TLIF

TLIF, transforaminal lumbar interbody fusion (trans-Kambin approach versus posterolateral approach).

Table 2. Summary of publications of biportal endoscopic lumbar interbody fusion

Study	Publication year	Study design	Cases	Follow-up (mo), mean ± SD	Clinical outcomes	Perioperative complications
Heo et al.[5]	2017	Cases series	69 Cases	13.5 ± 7.1	Improvement of VAS and ODI	Dura tear (2), hematoma (3)
Kim and Choi[10]	2018	Cases series	14 Cases		Improvement of VAS	L5 root palsy (1), dura tear (1)
Heo et al.[6]	2019	Cases control study	23 Cases (biportal), 45 cases (microscopic)	13.4 ± 2.5	Improvement of VAS and ODI	Hematoma (1)
Park et al.[11]	2019	Cases control study	71 Cases (biportal), 70 cases (conventional)	17.1 ± 4.9	Improvement of VAS and ODI	Dura tear (3), infection (1) Hematoma (1)
Ahn et al.[7]	2019	Systemic review	-	-	-	-

SD, standard deviation; VAS, visual analog scale; ODI, Oswestry Disability Index.

through facetectomy and laminectomy. We could also achieve complete direct decompression of the central canal and nerve roots, like in MIS TLIF. We could place the cages safely during biportal endoscopic TLIF.[5] This posterolateral approach was available in biportal or uniportal endoscopic systems.[9]

Five articles on biportal endoscopic fusion surgeries have been published (Table 2).[illegible] Two articles reported the technique and preliminary clinical results. These 2 articles focused on the technical aspect of biportal endoscopic TLIF.[5,10] Additionally, early favorable clinical outcomes were presented. Another 2 articles presented comparative studies of biportal endoscopic TLIF with conventional PLIF or TLIF surgeries.[6,11] Compared to conventional fusion surgeries or MIS fusion surgeries, the benefits of biportal endoscopic fusion were less blood loss and postoperative pain. These advantages of biportal endoscopic TLIF may lead to early recovery and early return to work after surgery. Moreover, the combination of biportal endoscopic fusion surgery with enhanced recovery after surgery programs might reduce complications and shorten hospital stays after surgery.[8] However, biportal endoscopic fusion surgeries were more difficult than conventional open surgery or microscopic surgery with a tubular retractor. A comparison of operation time may offer clues to the technical difficulty. The operation time for biportal endoscopic fusion surgeries was longer than that for conventional PLIF and TLIF surgeries.[6,11] Moreover, there were complications related to biportal endoscopic TLIF. Durotomy, postoperative epidural hematoma, infections, and nerve root palsy have been reported in previously published articles (Table 2).[illegible] Although the reported complications related to biportal endoscopic TLIF were mainly minor, endoscopic fusion procedures are very difficult and have the possibility of major complications. Incomplete surgery may be another problem of endoscopic fusion surgeries. Therefore, we strongly recommend that endoscopic fusion surgeries should be tried after extensive experience with endoscopic surgeries, such as endoscopic decompression and endoscopic discectomy using uniportal or biportal endoscopy.

The last article was a review article about endoscopic TLIF, including biportal as well as uniportal endoscopic systems.[2] There were only short-term clinical outcomes of endoscopic TLIF and no randomized case-control studies of endoscopic lumbar fusions. Consequently, this review article was not able to conclude the advantages and superiority of endoscopic TLIF.[2]

Compared with MIS TLIF, biportal endoscopic approaches may afford better endplate preparation. We could insert an endoscope into the intervertebral disc space during endplate preparation. It was possible to precisely demonstrate the condition of the endplate via endoscopy. The cartilaginous endplate was separated and removed from the osseous endplate under a magnified endoscopic view.[3] General instruments used for endplate preparation, such as an angled curette, box designed curette, and angled pituitary forceps, were available to perform complete endplate preparation under endoscopic guidance. Thirty-degree endoscopy and angled instruments may be useful for contralateral disc removal and endplate preparation. Endoscopy-guided endplate preparation may prevent osseous endplate injury during endplate preparation and subsidence of a cage. One of the important purposes of lumbar fusion surgery is the restoration of segmental lordosis. Since the biportal endoscopic TLIF technique achieved complete facetectomy and could accommodate the insertion of a large TLIF cage, this biportal endoscopic approach might be as good as MIS TLIF in restoring segmental lordosis.

Biportal endoscopic TLIF exhibited similarity with MIS TLIF with a tubular retractor and has several advantages of endoscopic approaches. However, a long-term follow-up study and randomized case-control studies should be performed.

CONCLUSION

Herein, we present the technique and literature review of biportal endoscopic TLIF. Biportal endoscopic TLIF might have the advantages of MIS fusion surgeries as well as those of the endoscopic approach. Direct decompression, endoscopically guided endplate preparation, and the insertion of large cages may be the merits of biportal endoscopic lumbar fusion procedures. To reveal the efficacy and clinical usefulness of the biportal technique, long-term blinded, randomized case-control studies are needed.

POINTS OF THE SURGICAL TECHNIQUE

1. In the biportal endoscopic TLIF technique, direct decompression was first performed via unilateral laminotomy with bilateral decompression.
2. The inferior articular process, as well as the superior articular process, was removed for safe insertion of a large cage.
3. The cartilaginous endplate should be completely removed from the osseous endplate for interbody fusion under a magnified, clear endoscopic view. It was possible to demonstrate endplate conditions during the endplate preparation procedure via endoscopy.
4. A large volume of fusion materials, including auto-bone, allo-bone, and demineralization bone matrix, should be inserted via a funnel before insertion of the cage.
5. The release of the medial part of the contralateral facet joint may be helpful for disc space distraction and the reduction of spondylolisthesis.
6. Percutaneous pedicle screw insertion was subsequently performed after the interbody fusion procedures.

CONFLICT OF INTEREST

The authors have nothing to disclose.

SUPPLEMENTARY MATERIALS

Supplementary video clip 1-3 can be found via https://doi.org/10.14245/ns.2040178.089.v.1, https://doi.org/10.14245/ns.2040178.089.v.2, and https://doi.org/10.14245/ns.2040178.089.v.3.

Supplementary video clip 1. Left-sided biportal endoscopic TLIF with the insertion of one TLIF cage. Video clip 2. Left-sided biportal endoscopic TLIF with the insertion of 2 PLIF cages. Video clip 3, the author's interview and overall surgical procedures.

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CORR Insights®: Poor Bone Quality, Multilevel Surgery, and Narrow and Tall Cages Are Associated with Intraoperative Endplate Injuries and Late-onset Cage Subsidence in Lateral Lumbar Interbody Fusion: A Systematic Review

Sergio A. Mendoza-Lattes MD[1]

Where Are We Now?

Lateral lumbar interbody fusion (LLIF), a surgical procedure to treat disc problems in the lower back, provides a solid load-bearing fusion construct that improves sagittal alignment and can provide indirect decompression of the neural canal and foraminal spaces. The disc space opening is also critical to restoring sagittal alignment by lengthening the anterior column. Cage subsidence, a major complication of LLIF can result in nonunion, loss of alignment, and perhaps even recurrent compression of the neural elements.

In the current study, Wu et al. [7] systematically reviewed 183 abstracts, exploring patient, implant, and surgical techniques and the factors that can lead to cage subsidence following LLIF. The authors found late subsidence in 32% of standalone LLIFs and 18% of LLIFs with circumferential constructs.

The authors examined multiple risk factors for LLIF cage subsidence, including those related to patient characteristics (obesity, osteoporosis, number of levels) as well as factors related to the surgical technique. They find that aggressive disc height restoration and small-footprint cages more often resulted in intraoperative endplate failures and subsidence. They also found that patient-related factors such as obesity or osteoporosis as well as multilevel procedures contributed to increased rates of cage subsidence.

Where Do We Need To Go?

The study results suggest that careful patient selection can potentially reduce the risk of LLIF cage subsidence, particularly emphasizing body weight and bone health. Their results also suggest that meticulous surgical technique and prevention of intraoperative endplate fractures should be highlighted when choosing LLIF to provide indirect decompression and restoration of sagittal alignment. The surgical technique should include careful and progressive disc space expansion and precise implant placement that aligns with the vertebral endplates in the coronal, sagittal, and rotational orientation. Axially rotated cages can lead to point loading and endplate subsidence. Finally, the results also suggest that the endplate subsidence may decrease when the LLIF spacer is backed up with posterior instrumentation.

CT scans commonly used for diagnostics and preoperative planning can be used to estimate bone mineral density of the motion segments of interest [1, 5]. Early attempts at using low-dose radiation imaging devices to provide

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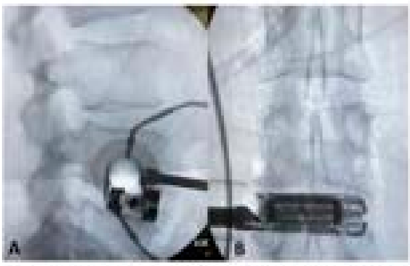

Fig. 1 A-B (A) The endplates are visualized on the lateral view, allowing for optimal orientation of the implant during insertion. (**B**) Dual-X® expandable LLIF with final 22-mm endplates placed through an 18-mm tubular retractor.

level-specific bone density have also been documented [4].

How Do We Get There?

The development of custom three-dimensionally printed implants adapted to individual endplate characteristics, disc space geometry, and bone quality would help us better serve our patients on an individual basis rather than in a one-size-fits-all capacity [3, 6]. As we think about designing those implants of the future, we should consider how geometry and materials interact in ways that support fusion, but also adapt (or at least vary) according to differences among our patients and the shapes and dimensions of their spines. As of now, we don't know whether these devices are superior to off-the-shelf devices, and given the costs and uncertainties of the new implants, future studies need to compare them in well-controlled trials. The role of expandable cage designs is also not clear, and although they may provide a limited degree of adaptability, there are no clear studies suggesting benefits in reducing endplate subsidence [2].

Finally, expandable implants (Fig. 1A-B) can provide the benefit of smaller insertion portals, facilitating the use of smaller retractors. This may be particularly relevant considering the need for better precision in the orientation of the interbody implants to avoid point-loading or intraoperative endplate fractures.

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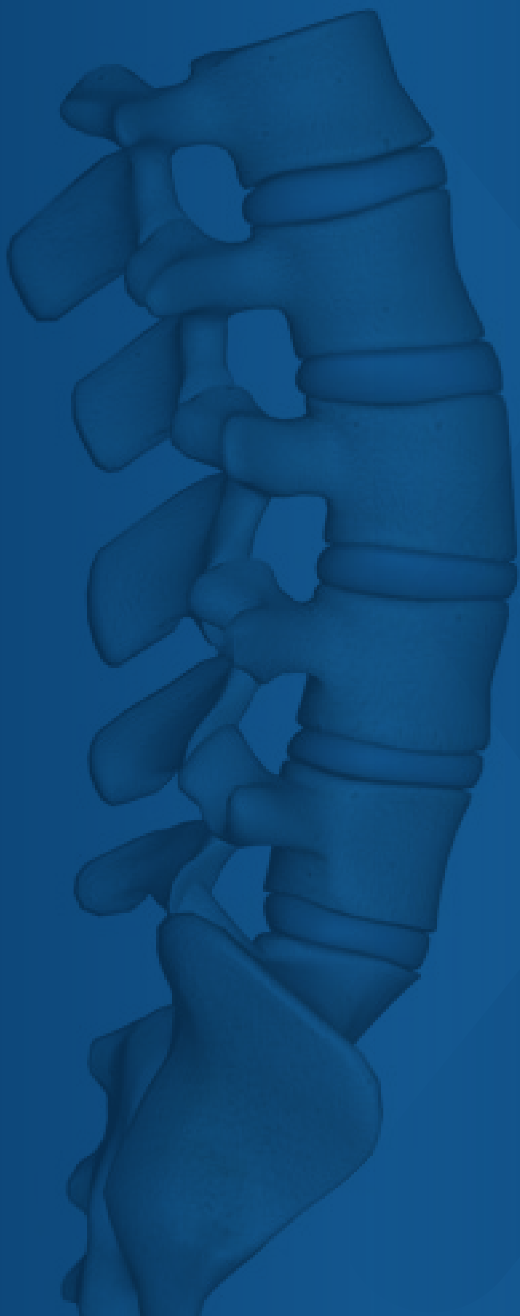
thank you



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