

O-arm navigation-guided unilateral biportal endoscopic lumbar interbody fusion using a lateral lumbar interbody fusion cage

Min Gyu Kang¹, Yun Seong Cho¹, Ji Young Jang¹, Jung Hoon Kang¹, Nhat Duy Nguyen², Dong Ah Shin¹, Seong Yi¹, Yoon Ha¹, Keung Nyun Kim¹, Chang Kyu Lee¹

¹Department of Neurosurgery, Spine and Spinal Cord Institute, Severance Hospital, Yonsei University College of Medicine, Seoul, Korea

²Department of Neurosurgery, University of Medicine and Pharmacy at Ho Chi Minh City, Ho Chi Minh City, Vietnam

Received Jan 17, 2025; **Revised** Feb 18, 2025; **Accepted** Mar 16, 2025

Corresponding author: Chang Kyu Lee

Department of Neurosurgery, Spine and Spinal Cord Institute, Yonsei University College of Medicine, Severance Hospital, 50-1 Yonsei-ro, Seodaemun-gu, Seoul 03722, Korea

Tel: +82-2-2228-2153, **Fax:** +82-2-393-9979, **E-mail:** nscklee@yuhs.ac

Unilateral biportal endoscopic surgery has received attention in the field of minimally invasive spinal surgery because of its various advantages, including minimized musculoligamentous injury, low postoperative pain, and faster recovery, compared with conventional open spinal surgery. Navigation system advancements have improved the precision of instrument placement and cage positioning, thereby facilitating the insertion of larger cages in the unilateral biportal endoscopic transforaminal lumbar interbody fusion (UBE-TLIF). In this study, we demonstrated the safety and efficacy of lateral lumbar interbody fusion cage insertion in UBE-TLIF with the assistance of O-arm navigation.

Keywords: Image-guided surgery; Endoscopy; Spinal fusion; Unilateral biportal endoscopic approach; Spinal implants

Introduction

Minimally invasive spinal surgeries have changed the treatment of degenerative spinal disorders by reducing tissue damage, minimizing postoperative pain, and expediting recovery. Among these, unilateral biportal endoscopic transforaminal lumbar interbody fusion (UBE-TLIF) has received significant attention due to its ability to facilitate direct decompression and meticulous endplate preparation [1]. However, achieving optimal fusion and spinal alignment with conventional

interbody cages remains challenging, especially in cases needing substantial lordotic correction or those complicated with endplate irregularities and osteoporosis.

The lateral lumbar interbody fusion (LLIF) cage, with its larger footprint and lordotic design, provides superior load distribution and stability compared to traditional TLIF or posterior lumbar interbody fusion (PLIF) cages [2]. LLIF cage insertion through the lateral approach poses technical challenges, particularly at the lumbosacral junction, due to limited access and risk of neurovascular injury despite its advantages [3]. Recent

advancements in navigation technology, such as the O-arm system, have improved the precision of instrument placement and cage positioning [4].

Technical Notes

This technical note describes a novel approach that integrates O-arm navigation with UBE-TLIF to facilitate safe and effective large LLIF cage insertion. This method addresses the limitations associated with conventional techniques, such as insufficient decompression in severe foraminal stenosis or restricted access at L5–S1 related to the iliac crest by combining the benefits of endoscopic visualization and real-time navigation.

We demonstrate the feasibility and clinical outcomes of this hybrid technique through a detailed case illustration. This approach not only emphasizes its potential to achieve optimal spinal alignment and solid fusion but also underscores its safety, precision, and reduced learning curve. The results indicate the value of integrating advanced navigation systems into minimally invasive spine surgery, paving the way for the broader adoption of this innovative method.

Case illustration

A 60-year-old woman presented with worsening back pain and left-side dominant leg pain for 2 years. She was not able to walk a long distance due to her progressive stooping posture. Conservative treatment, including medication, physical therapy, and spinal injections, for >1 year was ineffective. Radiographic imaging demonstrated lumbar degenerative kyphosis, degenerative spondylolisthesis at L3–L4, retrolisthesis at L4–L5, degenerative disc disease at L4–L5, and foraminal stenosis at L5–S1.

A staged operation was planned for effective correction of the spinal alignment and neural decompression. Initially, oblique lumbar interbody fusion was performed at L3–L4 and L4–L5. O-arm navigation-assisted UBE-TLIF using an LLIF cage at L5–S1 was performed after a few days of recovery, followed by percutaneous pedicle screw fixation from L3 to S1. Severe foraminal stenosis at L5–S1 was resolved directly.

The patient recovered well after the staged operation. She reported back and leg pain improvement. Stooping posture and walking distance limitation were resolved. These results were maintained at the postoperative 6-month follow-up. The patient provided written informed consent for the publication of the clinical details and intraoperative images included in this report.

Surgical steps

During navigation-assisted approaches, preventing interference between the endoscope and the reference frame is essential. To address this, the position of the reference frame should be adjusted according to the involvement of a left- or right-sided UBE fusion approach in the procedure, thereby improving the surgical workflow and efficiency. To overcome line-of-sight challenges, the navigation tracker is strategically positioned based on the surgical approach [4]. The tracker is affixed to the right posterior superior iliac spine (PSIS) for the left-sided procedures, whereas it is secured to the spinous process of the upper lumbar levels for the right-sided approaches (Figs. 1, 2).

We demonstrate the left-sided UBE-TLIF in the following:

- (1) The navigation reference frame was secured to the patient's PSIS.
- (2) The disc space and pedicle levels were determined using the navigation probe (Fig. 3A). We used both two- and three-dimensional images of the O-arm to guide the planning of skin incisions. The endoscopic portal was established at the lateral margin of the upper vertebral pedicle (Fig. 3B). The working portal was created extending from the disc space to the lateral margin of the lower vertebral pedicle



Fig. 1. Positional relationship between the scope and reference frame in the left-sided approach.

(Fig. 3C). An overview of the skin incisions for the biportal endoscopic devices is illustrated (Fig. 3D).

- (3) The lower margin of the upper lamina was localized using a navigation probe following biportal endoscopic device placement.
- (4) The ipsilateral lamina and facet were removed with a high-speed drill and chisel, and contralateral laminotomy and foraminotomy followed.
- (5) Bilateral nerve root decompression was performed, followed by discectomy. The degree of discectomy, disc space depth, and endplate margins were validated under navigation guidance (Figs. 4, 5).
- (6) A navigation-connected cage trial was employed to

identify the appropriate cage size. A polyetheretherketone cage measuring 45 mm×18 mm×10 mm with a large footprint was selected.

- (7) The cage was inserted into the disc space under simultaneous navigation and endoscopic monitoring to ensure optimal trajectory and depth. The final position of the cage was confirmed with the navigation probe.
- (8) The alignment and location of each vertebra were changed after the interbody cage insertion. Therefore, an additional O-arm navigation scan was performed. Percutaneous pedicle screws were inserted with the help of navigation to complete the procedure.



Fig. 2. Positional relationship between the scope and reference frame in the right-sided approach.

Discussion

LLIF is a minimally invasive spine surgery with the advantage of making a lordotic curve and a high fusion rate caused by the large footprint of the cage [2,5]. However, indirect decompression is insufficient in patients with severe spinal stenosis, especially foraminal stenosis. Moreover, LLIF is sometimes limited to the lumbosacral area due to the iliac crest [3].

Moreover, UBE-TLIF is a minimally invasive spine surgery that decompresses the thecal sac and nerve root directly. The enhanced visualization illustrated by endoscopy facilitates meticulous endplate preparation, which is crucial for reducing the risk of cage subsidence and increasing fusion rates [1,6].

Double PLIF or TLIF cages are typically utilized in UBE-TLIF, and we opted for the larger LLIF cage to improve lordotic correction and maximize the cage footprint [7]. Large footprint cages, which are typically rectangular or kidney-shaped designs, maximize load distribution and reduce the risk of subsidence. Con-

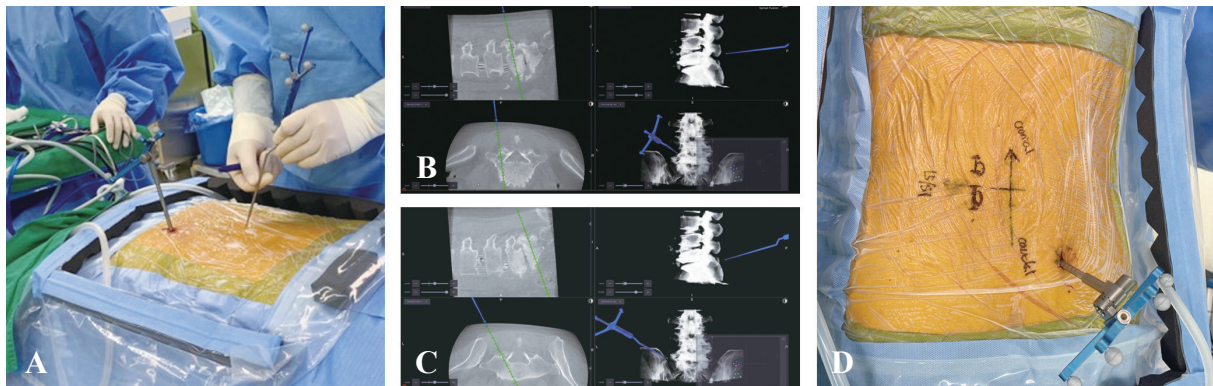


Fig. 3. Planning to determine the insertion points of the endoscopic portal and working portal using the navigation probe (A). Navigation screen showing the position of endoscopic portal (B) and working portal (C). An overview of the skin incisions (D).

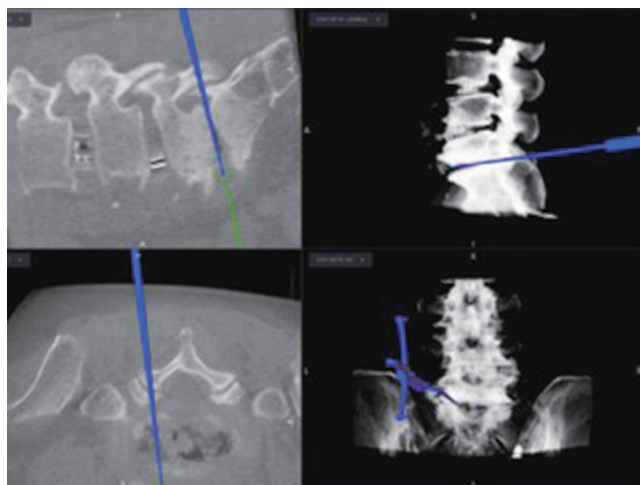


Fig. 4. Verification of ipsilateral disc space and endplate preparation was performed using the navigation probe.

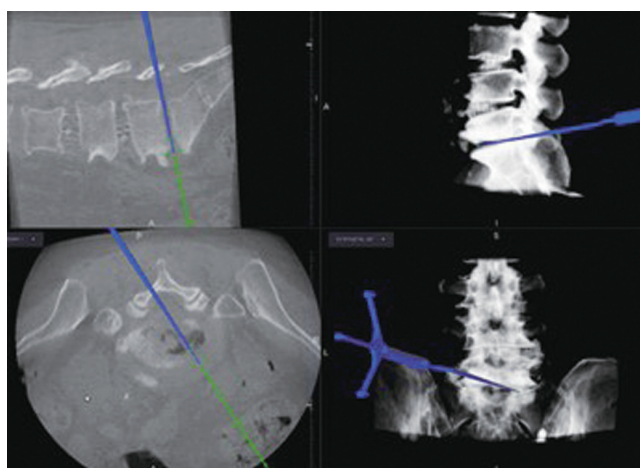


Fig. 5. Verification of contralateral disc space and endplate preparation was performed using the navigation probe.

versely, bullet-shaped, long straight, or curved-type cages, which are used in the posterior or transforaminal approach, have a smaller bone-cage contact area, increasing the risk of subsidence. The broader bone-cage contact area provides a stable platform for fusion, particularly in patients with endplate irregularities or osteoporosis [8].

LLIF cage insertion through the posterolateral corridor is technically demanding, but with the help of navigation, the process is more precise and safer, thereby preventing damage to the thecal sac and nerve roots. Unlike previous reports using navigation and UBE, we inserted the largest possible cage with the lordotic angle without utilizing a C-arm fluoroscope [9,10]. To ensure precise and safe LLIF cage placement under navigational guidance, an additional incision was strategically established at a more lateral position to optimize the insertion trajectory (Fig. 6). Furthermore, the use of a

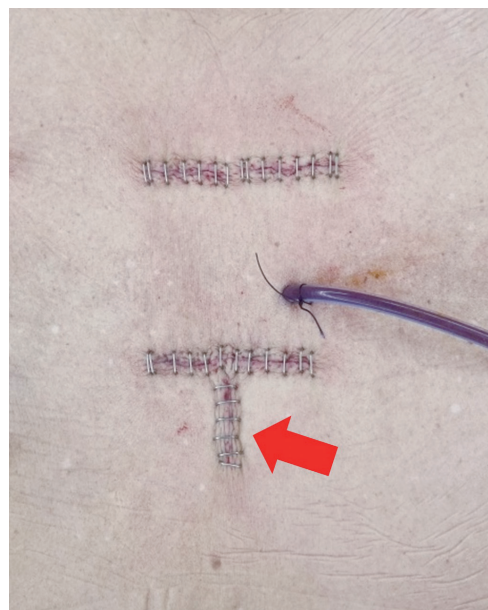


Fig. 6. Additional skin incision for lateral lumbar interbody fusion cage insertion (red arrow).

smaller cage is advised to minimize the risk of complications and ensure procedural safety in cases where the anteroposterior diameter of the disc space is notably narrow.

O-arm navigation is used for percutaneous pedicle screw insertion, providing improved accuracy. O-arm navigation systems are reliable, but certain factors could affect their accuracy during surgery. For instance, errors in initial registration, slight patient movement during the procedure, or limited imaging resolution may result in minor discrepancies. Additional C-arm fluoroscopic guidance may be required in such cases to confirm anatomical landmarks and improve the precision of the procedure. The combined use of these imaging modalities addresses these limitations, thereby improving navigation accuracy and surgical confidence.

Compared with traditional methods, the navigation system significantly reduces radiation exposure for both the patient and the surgical team, making it safer for frequent use in complex cases. Navigation-guided UBE-TLIF provides improved precision and reduces the risk of complications, which helps shorten the learning curve.

In conclusion, the integration of O-arm navigation in UBE-TLIF facilitates safe and effective large interbody cage insertion, which may contribute to achieving solid fusion and optimal lordotic alignment.

Key Points

- O-arm navigation enhances the safety and precision of unilateral biportal endoscopic transforaminal lumbar interbody fusion, enabling accurate placement of large interbody cages even at challenging levels like L5–S1.
- Use of a lateral lumbar interbody fusion (LLIF) cage in a posterior biportal endoscopic approach allows for improved lordotic correction and load distribution, especially in patients with endplate irregularities or osteoporosis.
- This hybrid technique combines real-time navigation and endoscopic visualization, reducing the learning curve and minimizing intraoperative risks without relying on C-arm fluoroscopy.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

ORCID

Min Gyu Kang: <https://orcid.org/0009-0002-2997-6990>;
Yun Seong Cho: <https://orcid.org/0009-0002-0665-1982>;
Ji Young Jang: <https://orcid.org/0000-0003-2636-7794>;
Jung Hoon Kang: <https://orcid.org/0000-0001-9139-8111>;
Nhat Duy Nguyen: <https://orcid.org/0009-0003-4549-5705>;
Dong Ah Shin: <https://orcid.org/0000-0002-5225-4083>;
Seong Yi: <https://orcid.org/0000-0003-0700-4744>;
Yoon Ha: <https://orcid.org/0000-0002-3775-2324>;
Keung Nyun Kim: <https://orcid.org/0000-0003-2248-9188>;
Chang Kyu Lee: <https://orcid.org/0000-0002-1366-3677>

Author Contributions

Conceptualization: CKL. Methodology: MGK, YSC, JYJ, JHK, NDN. Resources: MGK, YSC, JYJ, JHK, NDN. Investigation: MGK, CKL. Visualization: MGK, CKL. Validation: DAS, SY, YH, KNK, CKL. Project administration: CKL. Supervision: DAS, SY, YH, KNK. Writing—original draft: MGK, CKL. Writing—review & editing: CKL. Final approval of the manuscript: all authors.

References

1. Kim JE, Choi DJ, Park EJ, et al. Biportal endoscopic spinal surgery for lumbar spinal stenosis. *Asian Spine J* 2019;13:334-42.
2. Mobbs RJ, Phan K, Malham G, Seex K, Rao PJ. Lumbar interbody fusion: techniques, indications and comparison of interbody fusion options including PLIF, TLIF, MI-TLIF, OLIF/ATP, LLIF and ALIF. *J Spine Surg* 2015;1:2-18.
3. Shirzadi A, Birch K, Drazin D, Liu JC, Acosta F Jr. Direct lateral interbody fusion (DLIF) at the lumbosacral junction L5-S1. *J Clin Neurosci* 2012;19:1022-5.
4. Hagan MJ, Remacle T, Leary OP, et al. Navigation techniques in endoscopic spine surgery. *Biomed Res Int* 2022;2022:8419739.
5. Zhu HF, Fang XQ, Zhao FD, et al. Comparison of oblique lateral interbody fusion (OLIF) and minimally invasive transforaminal lumbar interbody fusion (MI-TLIF) for treatment of lumbar degeneration disease: a prospective cohort study. *Spine (Phila Pa 1976)* 2022;47:E233-42.
6. Heo DH, Hong YH, Lee DC, Chung HJ, Park CK. Technique of biportal endoscopic transforaminal lumbar interbody fusion. *Neurospine* 2020;17(Suppl 1):S129-37.
7. Pao JL. Biportal endoscopic transforaminal lumbar interbody fusion using double cages: surgical techniques and treatment outcomes. *Neurospine* 2023;20:80-91.
8. Faizan A, Kiapour A, Kiapour AM, Goel VK. Biomechanical analysis of various footprints of transforaminal lumbar interbody fusion devices. *J Spinal Disord Tech* 2014;27:E118-27.
9. Quillo-Olvera J, Quillo-Resendiz J, Quillo-Olvera D, Barrera-Arreola M, Kim JS. Ten-step biportal endoscopic transforaminal lumbar interbody fusion under computed tomography-based intraoperative navigation: technical report and preliminary outcomes in Mexico. *Oper Neurosurg (Hagerstown)* 2020;19:608-18.
10. Suvithayasiri S, Kim YJ, Liu Y, Lee C, Vasant Khandge A, Kim JS. Placement of 2 cages using navigation-guided biportal endoscopic transforaminal lumbar interbody fusion: illustrative case. *J Neurosurg Case Lessons* 2024;8:CASE23512.