

Case Report

C-arm Free Unilateral Biportal Endoscopic Discectomy: A Technical Note

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This report presents a new unilateral biportal endoscopic (UBE) technique for lumbar disc herniation without C-arm guidance. Lumbar disc herniation requires surgical intervention when conservative methods fail. Shifts towards minimally invasive percutaneous endoscopic lumbar discectomy, including uniportal and biportal approaches, have been hindered by challenges such as steep learning curves and reliance on radiation-intensive C-arm guidance. We here describe the use of standard intraoperative navigation in UBE to reduce radiation exposure and increase surgical accuracy. A 24-year-old man with low back and bilateral leg pain with gait disturbance was referred to our hospital. He had had conservative treatment for 12 months in another hospital before admission, but this proved unsuccessful. On admission he had low back pain (VAS 4/10) and bilateral leg pain (VAS 8/10), muscle weakness of the bilateral legs (manual muscle testing (MMT) grade of the extensor hallucis longus: 4/4), and numbness of the bilateral lower legs. Preoperative lumbar MRI showed L4/5 large central disc herniation. He underwent C-arm free UBE discectomy under the guidance of O-arm navigation. The surgery was successful, with postoperative lumbar MRI showing good decompression of the dural sac and bilateral L5 nerve roots. The MMT grade and sensory function of both legs had recovered fully on final follow-up at one year. The new UBE technique under navigation guidance was shown to be useful for lumbar disc herniation. This innovative technique was safe and accurate for the treatment of lumbar intervertebral disc herniation, and minimized radiation exposure to surgeons.

Key words: lumbar disc herniation, unilateral biportal endoscopic technique, navigation, O-arm, minimally invasive spine surgery (MISS)

Lumbar disc herniation (LDH) is a prevalent lumbar disease, often manifesting as sciatica, low back pain, and neurological dysfunction [1]. In cases where conservative treatment fails, surgical intervention becomes imperative [2]. Historically, classical open discectomy was the standard treatment. However, in recent years, minimally invasive surgery using microdiscectomy [3] has largely supplanted open discectomy as the preferred surgical option for this condi-

tion, owing to its numerous advantages including reduced muscle injury, lower blood loss, minimized scarring, and shorter hospital stays [4-6].

Fully endoscopic techniques have been proven effective for treating LDH and have become increasingly popular for treating this condition worldwide. This technique has evolved into two primary approaches: the uniportal and the biportal approaches [7,8]. Recent studies comparing these two methods have established that both are safe and effective in treating LDH [8-10].

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Advances in medical technology and surgical tools over the past few years have positioned endoscopy as a viable alternative to traditional surgical methods, with some considering it the new gold standard in the treatment of lumbar degenerative diseases. Notably, uniportal endoscopy, while effective, has a steep learning curve, making its adoption challenging for experienced spine surgeons [11]. This is one reason for the resurgence of interest in biportal techniques, which align more closely with the practices of traditional spine surgeons and offer additional advantages, such as the use of standard surgical instruments, thereby impacting the cost of the procedures as well.

Despite these advancements, endoscopic spine surgery, like other minimally invasive techniques, conventionally requires the use of a C-arm for guidance, and therefore presents a significant risk of radiation exposure, particularly for the surgeon and operating staff [12]. To mitigate this issue, innovative techniques of intraoperative navigation have been developed, though these have predominantly focused on the uniportal approach [13, 14]. Moreover, the current solutions offered by endoscopic equipment manufacturers largely revolve around investing in additional, integrated navigation systems for the uniportal sets, further escalating the costs of procedures. To address these issues, our article proposes the use of intraoperative computerized tomography (CT) and intraoperative navigation to optimize the endoscope trajectory, instrument insertion, and decompression in biportal endoscopy. By eliminating the need for C-arm guidance, this approach reduces radiation exposure and enhances the safety of the unilateral biportal endoscopy (UBE) technique for treatment of LDH.

The study outlined in this article was conducted with the approval of our institute's ethics committee (No. 459), and all necessary patient consents were obtained. Our findings offer a pragmatic and economically viable solution, potentially transforming the landscape of minimally invasive spine surgery by making advanced techniques more accessible and safer.

Case Presentation

Case 24 years old male, L4/5 lumbar disc herniation. **1. Patient history.** A 24-year-old man with low back and bilateral leg pain with gait disturbance was referred to our hospital. He had had conservative treat-

ment for 12 months in another hospital before admission. However, the conservative treatment did not work for him.

2. Physical examination. The patient had low back pain (visual analogue scale 4/10) and bilateral leg pain (visual analogue scale 8/10). He had muscle weakness of the bilateral legs (extensor hallucis longus 4/4) and numbness of the bilateral lower legs but was able walk without any support. On examination, he had no hyperreflexia of the bilateral legs. He had no urinary or bowel incontinence.

3. Preoperative imaging. Preoperative anteroposterior lumbar radiography indicated slight instability at the L4/5 level (Fig. 1). Preoperative lumbar 3D CT showed lumbar scoliosis due to disc herniation. Preoperative MRI indicated L4/5 central disc herniation and compressing bilateral L5 nerve roots (Fig. 2).

4. Surgery.

(1) Patient positioning, neuromonitoring, and navigation.

The UBE technique under navigation guidance is performed with the patient in a prone position on a full carbon operating table under general anesthesia. We routinely perform neuromonitoring using a multimodality intraoperative monitoring system. In muscles whose innervating nerves are adequately decompressed, the amplitude of the motor evoked potential usually increases. A navigation reference frame is inserted from the iliac bone to the sacral bone through the SI joint of the contralateral side without fluoroscopy (Fig. 3). Then intraoperative CT scan images are obtained using a mobile CT scanner (O-arm). Each instrument—the navigated pointer, dilater, high-speed burr, *etc.*—is then registered.

(2) Skin incision and bony resection.

With the help of a navigated pointer, two longitudinal 6–7 mm skin incisions are marked. The first line is the medial pedicle line at L4–L5. One skin incision is for surgical instruments (just parallel to the upper endplate of L5; Fig. 4) and the other is for the endoscope (3 cm cranial to the first one). The interlaminar working space is made by the navigated first dilater. Then the endoscope is inserted on the left side and the monopolar coagulator probe on the right side. The soft tissue around the interlaminar space is coagulated with the monopolar probe and the lateral edge of the L5 lamina is resected with the navigated high speed burr, the ultrasonic bone cutter, and Kerrison rongeurs. Before

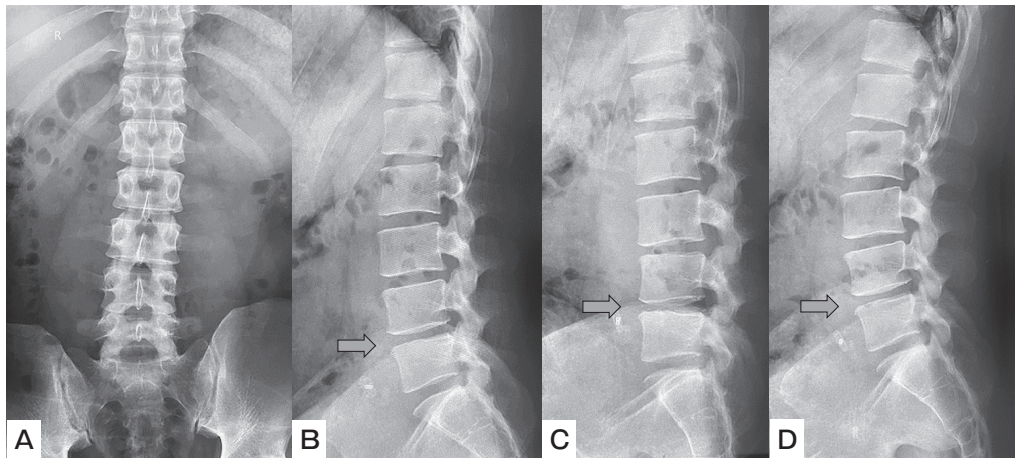


Fig. 1 Preoperative radiographs. **A**, Antero-posterior lumbar radiogram; **B**, Lateral lumbar neutral radiogram; **C**, Lateral lumbar flexion radiogram; **D**, Lateral lumbar extension radiogram. L4/5 disc space narrowing and slight instability was observed (red arrows).

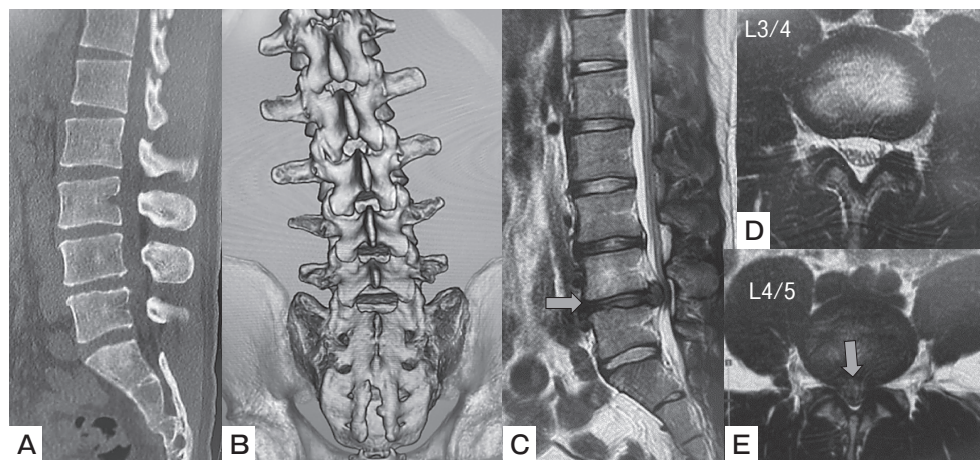


Fig. 2 Preoperative CT and MR imaging. **A**, Mid sagittal 3D reconstruction CT; **B**, 3D CT; **C**, T2-weighted mid-sagittal MR imaging; **D**, T2-weighted axial MR imaging at L3/4; **E**, T2 weighted axial MR imaging at L4/5. A large lumbar disc herniation was observed in (E) (red arrows).

using the navigated instruments, the surgeon should check the accuracy of navigation because sometimes the reference frame shifts. During bony resection, the navigated high speed burr is used to confirm the location (Fig. 5).

(3) Ligamentum flavum resection and discectomy.

After adequate bone resection, the ligamentum flavum is removed with Kerrison rongeurs and the nerve root is identified. To maintain a clear image, bleeding is coagulated at every step. The nerve is retracted medially with the angled nerve retractor. The outer annulus is cut with a special small knife and the herniated disc is removed with pituitary forceps and a bole probe (Fig. 6).

After irrigation with saline water to remove the debris, a wound suction tube is placed (Fig. 7).

(4) Skin closure.

Finally, the skin is closed with an absorbable suture. The drain is removed 24 hours after surgery.

5. Postoperative images. The postoperative radiogram and CT showed minimum bony resection. Postoperative MRI showed a good decompression of the dural sac and nerve roots. The bony resection area was adequate (Fig. 8).

6. One year follow-up. The patient was fully recovered at the two-month follow-up. At the final, one-year follow-up, the patient had no ADL distur-

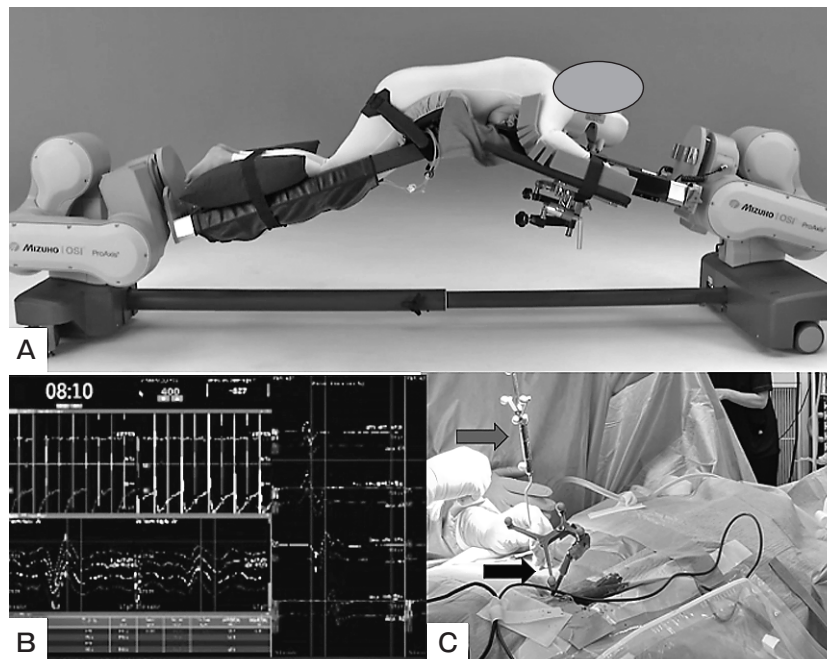


Fig. 3 Patient positioning, neuromonitoring, and navigation. A, Prone position; B, Neuromonitoring; C, A navigation reference frame (black arrow) and a navigated pointer (red arrow).

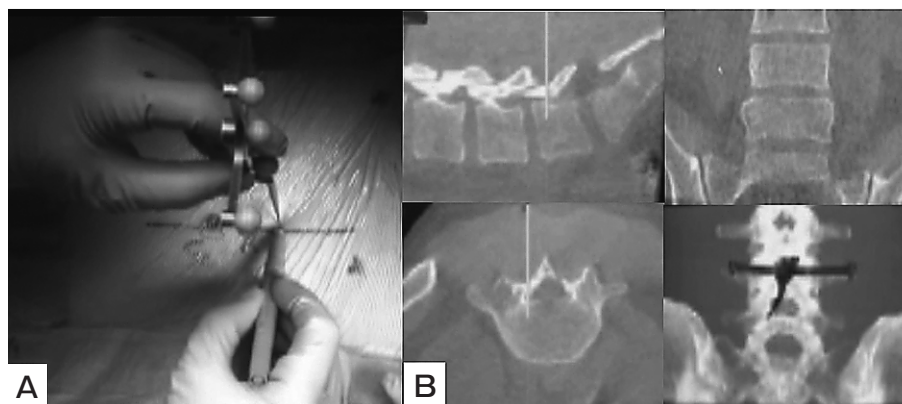


Fig. 4 Skin incision. A, Intraoperative image; B, Navigation monitor.

bance and no herniated disc recurrence.

Discussion

History of endoscopic discectomy. In the mid-1970s, Kambin *et al.* were the first to introduce the idea of percutaneous disc decompression through nucleotomy; they used Craig's cannula in a posterolateral approach in 136 patients and achieved a clinical success rate of 72% [15]. In 1975, Hijikata *et al.* independently

published a similar technique for posterolateral percutaneous discectomy [16]. Later, the percutaneous endoscopic lumbar discectomy (PELD) technique was first introduced for contained LDH via the triangular operative region known as Kambin's triangle, in which there are no neurovascular structures [17]. However, in the PELD technique the primary surgical focus was limited to the intradiscal region surrounding the annular tear [18].

Since the mid-1990s, there has been a shift toward a

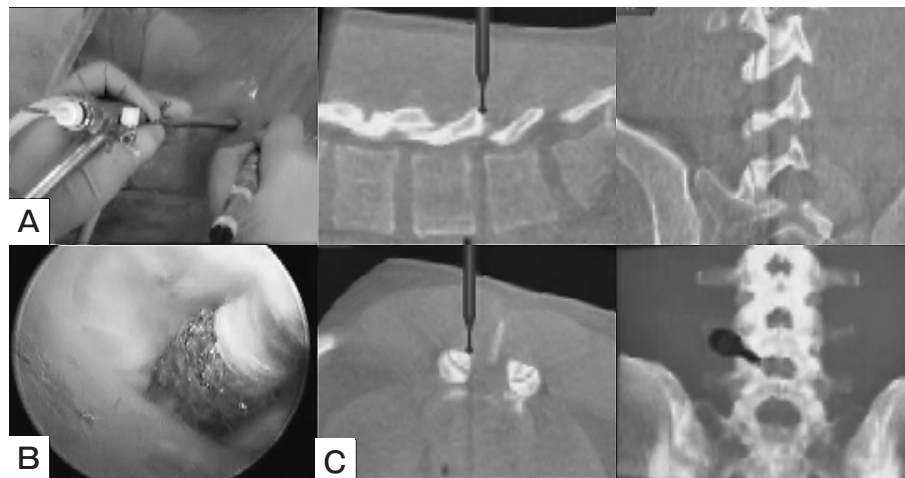


Fig. 5 Bony resection. A, Intraoperative image; B, Endoscopy image; C, Navigation monitor.

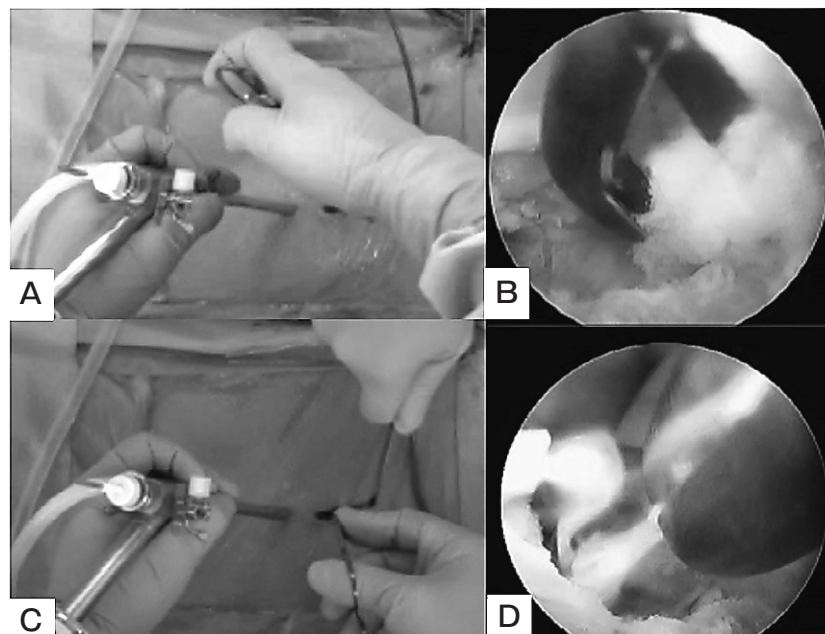


Fig. 6 Ligamentum flavum resection and discectomy. A, B, Ligamentum flavum resection with Kerrison rongeurs; C, D, Discectomy with pituitary forceps.

genuine transforaminal approach, incorporating the use of a working channel endoscope, which is allowed to pass completely through the intervertebral foramen into the epidural space instead of just going through the safe working zone and into the disc [19]. This advancement enabled surgeons to directly decompress extruded disc fragments with the benefit of direct endoscopic visualization. From year 2000, Kambin and Yeung inde-

pendently pioneered the concept of targeted endoscopic discectomy through the transforaminal approach with advanced wide-angled endoscopy for various kinds of herniation [20,21]. From year 2006, a specific discectomy technique was developed using percutaneous endoscopic interlaminar discectomy (PEID) in patients with L5-S1 level LDH with high iliac crests [22]. Recently, PELD and PEID have emerged as the two

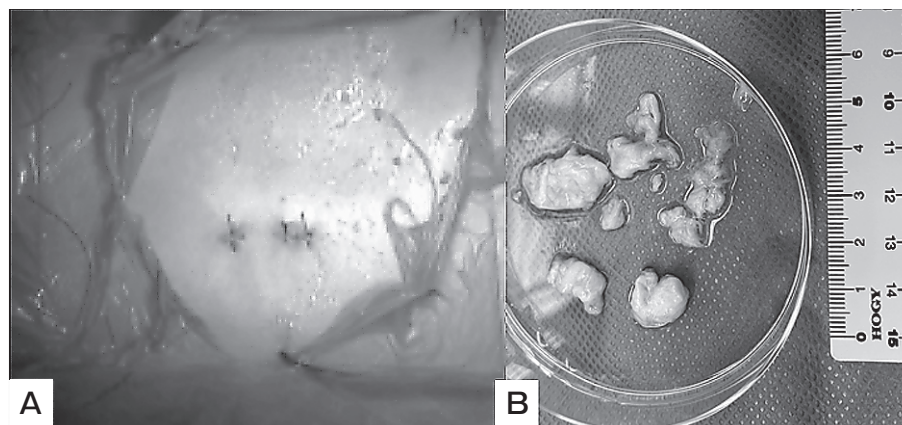


Fig. 7 Skin closure. A, Postoperative radiogram; B, Removed disc material.

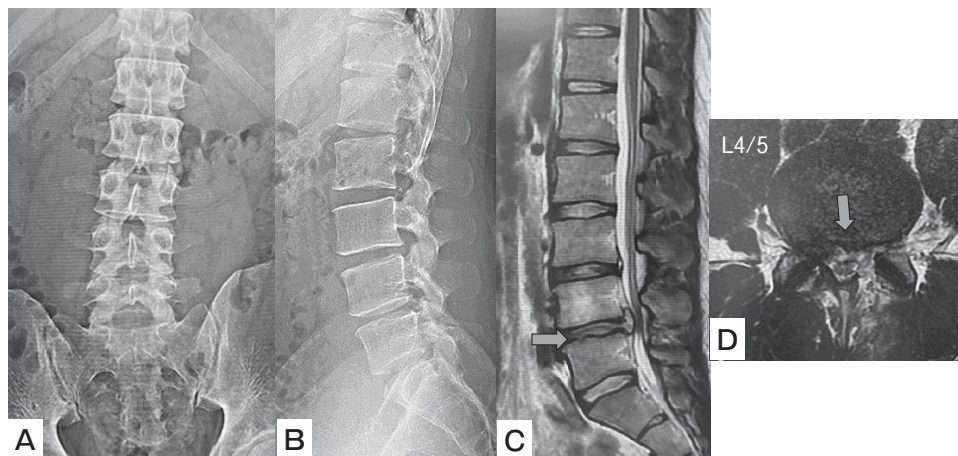


Fig. 8 Postoperative images. A, Postoperative lumbar anteroposterior radiogram; B, postoperative lumbar lateral radiogram; C, Mid sagittal T2-weighted MR imaging; D, Axial T2-weighted MR imaging at L4/5. The herniated disc is adequately resected (red arrow).

most extensively used procedures in endoscopic spinal surgery [23].

Advantages and disadvantages of UBE compared with the uniportal technique. The use of biportal endoscopy for spinal surgery was first reported in 1996 [24]. This technique utilized two portals on one side and used a simple endoscopic system like that used in knee arthroscopy. A significant advantage of UBE over PELD/PEID lay in its utilization of two channels instead of pipes, which provided enhanced operational flexibility with freely adjustable angles. In addition, there was substantial evidence that the learning curve for UBE was relatively short, ensuring the safe performance of the procedure [25,26].

Among minimally invasive procedures, UBE and PELD were initially reported to be as effective as conventional open surgery in terms of alleviating symptoms and enhancing functional abilities in LDH patients with less trauma and fast recovery [27,28]. But more recent evidence indicated that patients undergoing PELD may face higher recurrence and revision rates compared to patients treated with traditional open surgery and microdiscectomy [29]. Notably, the advancement of minimally invasive spine surgery in recent years has brought about the introduction of UBE with a lower LDH recurrence during follow-up compared to PELD [30].

Despite these advantages, UBE also has several

disadvantages compared with PELD. UBE was associated with a longer surgery time and hospital stay than PELD [30]. Muscle damage and radiation exposures of UBE are higher than those of PELD [31, 32].

Endoscopy techniques without a C-arm. As the invasiveness decreases in spine surgery, the need for a C-arm increases. While radiation does not pose a significant risk for the treated patient, it does present a cumulative risk for the surgeon and the operating team, because they are repeatedly exposed to this radiation throughout their careers [33].

Several attempts have been made to perform UBE without a C-arm, such as by employing an ultrasonic technique, a robot, augmented reality, or an electromagnetic system. Liu *et al.* evaluated the precision of the US V Nav technique for guiding transforaminal puncture through the fusion of real-time ultrasound and CT images [34]. Three-dimensional CT was employed to visualize bone tissue, while real-time and non-radiation ultrasound were utilized to showcase and precisely locate the foramen. In 2021, Mengran Jin *et al.* illustrated that the TiRobot system, when coupled with intraoperative CT scanning, significantly enhanced puncture accuracy and reduced radiation exposure for both surgical staff and patients during PELD surgeries [35]. Huang *et al.* developed an augmented reality surgical navigation system which markedly reduced the number of punctures and excessive use of the C-arm in endoscopic surgery [36]. Other surgeons presented a novel, real-time, 3D electromagnetic navigation system for percutaneous full-endoscopic foraminoplasty and discectomy [37, 38].

Advantages of our new technique. Previous study has described successful navigation-assisted surgery in PELD without the use of a C-arm [39]. However, there is no report which describes the feasibility, safety, and accuracy of O-arm-based navigation in UBE. This technique could eliminate the need for C-arm guidance, reduce the radiation exposure and enhance the safety of bone resection with navigation. Furthermore, it could decrease the complications caused by inaccurate or improper punctures or decompression, such as leakage of cerebrospinal fluid and irreversible dura or nerve root damage [40].

The percutaneous approaches are challenging for spine surgeons, and their difficulty is often daunting to potential users [41]. Balain *et al.* reported that the learning curve affected the clinical results (Oswestry

disability index) of full endoscopic lumbar spine surgery [42]. According to a report by Hsu *et al.*, a full endoscopic lumbar transforaminal procedure had a steeper learning curve than an interlaminar one [43]. Our new navigated technique has the potential to solve this learning curve problem because the disorientation during UBE can be reduced by the navigated instruments.

There is a concern of radiation exposure to the patient when using navigation. To mitigate this, we use a small field of view and low dose mode for the scan. It has been noted that the radiation dose per second is four times greater by the O-arm scan compared to fluoroscopy. But the O-arm scan can be performed in as little as 23 sec, which is equivalent to 90 sec of fluoroscopy. Moreover, additional time may be required for fluoroscopy in difficult cases. Ahan reported an average fluoroscopy time of 150 sec and average surgical time of 49.8 min in 30 patients undergoing percutaneous endoscopic lumbar discectomy [44].

Limitations. Several limitations should be noted in this technical report. First, because navigation accuracy is crucial to perform surgeries safely, the reference frame should be attached to a stable bony structure. In our technique, the percutaneous navigation reference is inserted into the sacroiliac joint on the contralateral side without fluoroscopy. The percutaneous pin should not be inserted more than 1 cm beyond the sacroiliac joint in order to avoid injury to the pelvic organs. Second, a multicenter study with a larger sample size and longer follow-up is needed for further validation. Finally, a study comparing O-arm navigation with other computer navigation systems would be helpful in fine-tuning the C-arm free endoscopic approach.

Conclusion

Our new unilateral biportal endoscopic (UBE) technique under navigation guidance is useful for the treatment of lumbar disc herniation. This innovative technique was here shown to be safe, accurate, and efficient in a patient with lumbar intervertebral disc herniation. This new approach is expected to reshape the learning curve of UBE, to mitigate the surgical complexity, and to minimize radiation exposure for surgeons.

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