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Case Report

Computer-assisted Minimally Invasive Posterior Lumbar Interbody Fusion without C-arm Fluoroscopy

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Computer-assisted spinal surgery is becoming more common; however, this is the first technical report to describe the technique of minimally invasive spinal posterior lumbar interbody fusion (MIS-PLIF) without using C-arm fluoroscopy. The authors report 2 years of follow-up of a 49-year-old female patient with L4 degenerative spondylolisthesis. The patient suffered from low back pain and intermittent claudication for more than 6 years. The authors performed computer-assisted MIS-PLIF without C-arm fluoroscopy. Instead, O-arm® navigation, the use of which reduces radiation exposure to patients as well as others in the operating room, was employed. Surgery was successful, and correct lumbar alignment was maintained. She had neither neurological deficits nor low back pain at her 12-month final follow-up. In conclusion, computer-assisted MIS-PLIF without C-arm fluoroscopy is a useful technique that reduces radiation exposure to the surgeon and operating room staff.

Key words: computer-assisted surgery, posterior lumbar interbody fusion, O-arm

Minimally invasive spine surgery (MISS) has become the preferred choice for spinal fusion compared with the conventional open technique because MISS tends to cause less postoperative pain and has better wound cosmetics [1, 2]. Computer-assisted spinal surgery is also the trend for placing pedicle screws, and 3-dimensional (3D) image guidance technology is available for MISS [3-7]. The O-arm system with Stealth navigation (Medtronic Sofamor Danek, Inc., Memphis, TN, USA) is one of the better navigation systems because of its excellent accuracy and automated registration. However, there are few reports that have reported the safety aspects of its spinal applications [3-7]. Currently, extended exposure to intraoperative radiation is the main concern for MISS surgeons using guidance technology. We report on a new technique of minimally invasive spinal posterior lumbar interbody fusion (MIS-PLIF) without C-arm fluoroscopy.

Case Report

Patient history. A 49-year-old woman was referred to our orthopedic department in January 2014 for ongoing low back pain and intermittent claudication over more than 6 years. She also had numbness and muscle weakness in both legs.

Physical examination. On examination, she could walk only 300 m due to sciatica on her left side. There was no hyperreflexia of her legs and no abnormal abdominal reflex, but there was moderate pain in her left leg, and her range of spinal motion was limited.

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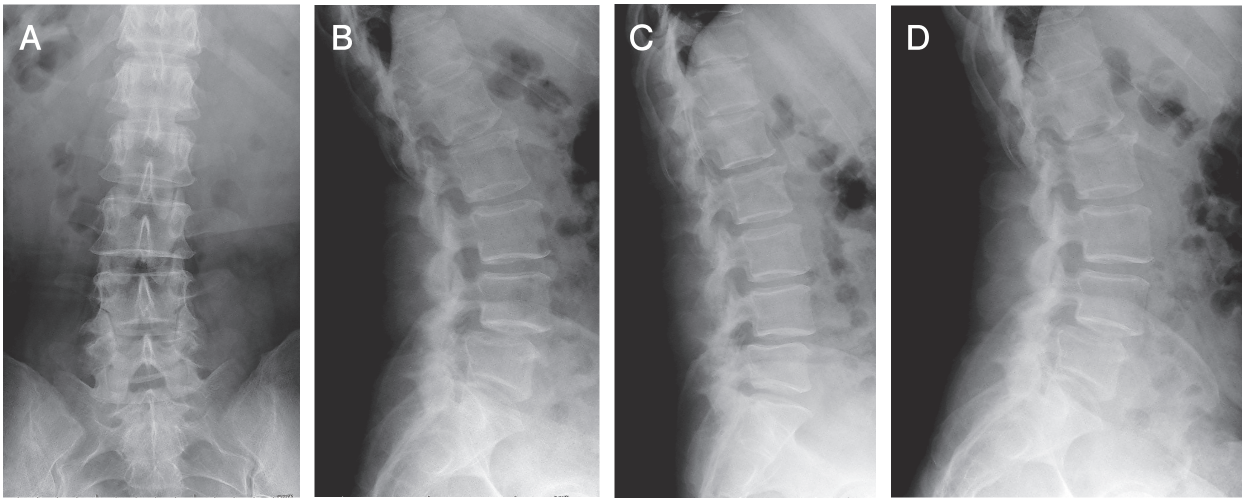

Fig. 1 Preoperative lumbar radiograms. There is mild spondylolisthesis at the L4 level and instability at the L4/5 level. A, Anteroposterior view; B, Lateral neutral position; C, Lateral flexion view; D, Lateral extension view.

Preoperative imaging. Radiographic examination at the initial visit showed grade 1 degenerative spondylolisthesis and moderate instability at the L4/5 level (Fig. 1). Preoperative MRI revealed mild L4/5 disc degeneration and L4 slip (Fig. 2). There was also dural sac stenosis at that level.

Surgical technique. The patient was positioned prone on a Jackson frame, and the percutaneous reference frame pin was anchored into the ilium. After positioning the O-arm, we obtained the 3D reconstructed images and transmitted them to the Stealth station navigation system Spine 7® (Medtronic Sofamor Danek, Inc., Memphis, TN, USA) (Fig. 3A). Navigation was accurate to less than 0.1 mm. The pedicle screw system was Solera Sextant 4.75 mm (Medtronic Sofamor Danek, Inc., Memphis, TN, USA), and PLIF cages were Caliber (Robert Reid Inc., Tokyo, Japan). After verifying the instruments, we inserted percutaneous pedicle screws into the L4 and L5 vertebrae using Stealth screen 3D images without Jamshidi needles or guide wires (Fig. 3B). After making a midline skin incision for decompression of the L4/5 level, we placed the MIS retractors, registered the PLIF cages and inserted them under navigational guidance (Figs. 3C, D). Finally, the appropriate rod was inserted percutaneously. Note that if there is a concern about inaccurate screw placement, the surgeon can obtain a second "spin" using the O-arm. The operative time was 2 h and 38 min and the estimated blood loss was 365 ml. There were no postoperative complications and no neurological compromise.

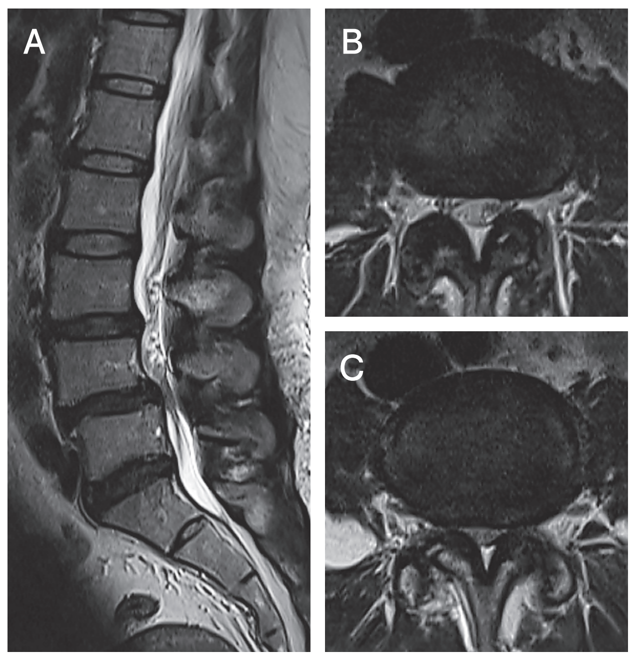

Fig. 2 Preoperative MRI. The preoperative T2-weighted mid-sagittal image shows L4/5 stenosis. A, T2-weighted mid-sagittal image; B, T2-weighted axial view at L3/4 level; C, T2-weighted axial view at L4/5 level.

Follow-up imaging. Two months after the

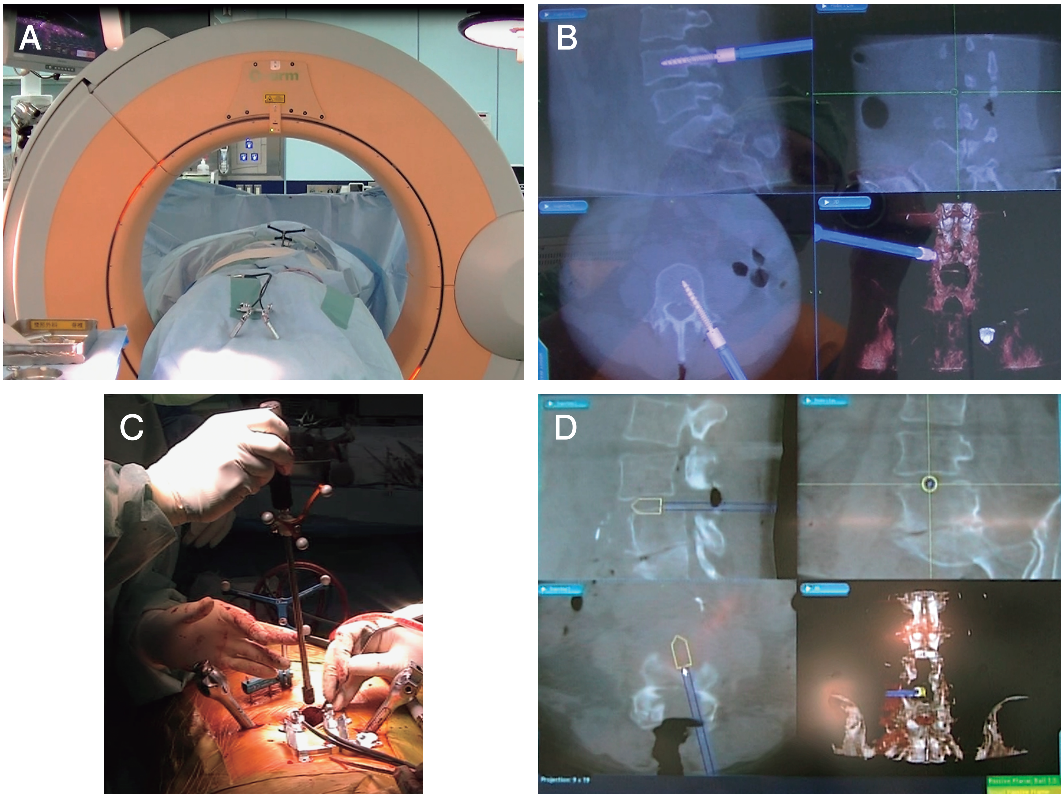

Fig. 3 Intraoperative image. The reference arc is attached to the iliac crest. The percutaneous pedicle screw and a cage were inserted by the O-arm and Stealth S7 navigation. A, O-arm; B, Percutaneous pedicle screw; C, Insertion of cage; D, Navigation image ed axial view at L4/5 level.

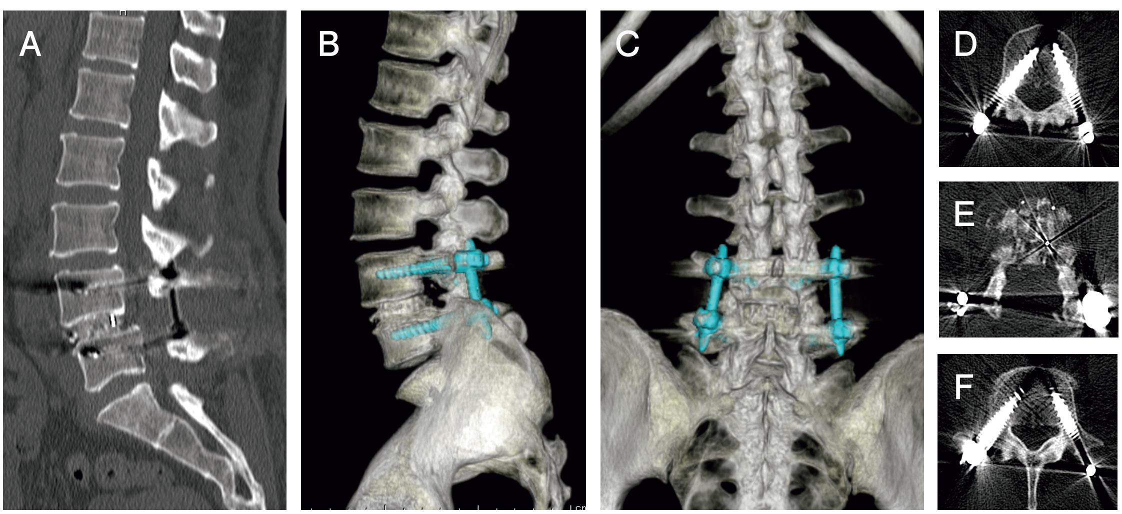

Fig. 4 Postoperative CT. The sagittal reconstruction image shows a solid bony fusion. A, Sagittal reconstruction image; B, 3-D lateral image; C, 3-D posterior image; D, L4 level; E, L4/5 level; F, L5 level.

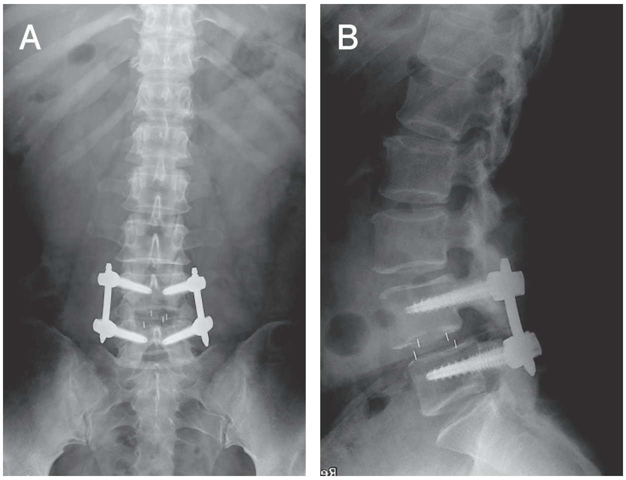

Fig. 5 Final (2-year follow-up) radiograms. Pedicle screws are inserted correctly. The solid bony fusion is obtained. **A**, Anteroposterior image; **B**, Lateral image.

surgery, the patient recovered to nearly full activity. The postoperative CTs demonstrated good correction of curve and appropriate sagittal alignment (Fig. 4). She has maintained good spinal balance with no neurological deficits for more than 24 months (Fig. 5).

Discussion

The O-arm system offers several important advantages over previous methods for percutaneous pedicle screw insertion [3, 4]. The first advantage is the accuracy rate for percutaneous pedicle screw insertion with this method. Many reports [3-7] have shown that O-arm-based navigation has a higher accuracy rate than the preoperative CT-based navigation or fluoroscopic techniques [4, 6]. The pedicle screw perforation rate with the O-arm ranges from 1% to 3% [3-5]. On the other hand, the perforation rate of preoperative CT-based navigation and fluoroscopy techniques range from 3% to 10% [8-10] and 13% to 30% [7, 11, 12], respectively. With the MISS percutaneous method, the accuracy rate is extremely important because the sounding technique used to check for perforation with other methods is not available with MISS. Sembrano reported that the surgical procedure was changed based on intraoperative O-arm imaging findings in 13% of all spine surgeries due to screw malposition. There are a few reports with respect to the accuracy of percutaneous pedicle screw placement [3, 7, 13, 14]. The placement of the reference arc is also important for percutaneous pedicle screw insertion. From L3 to the pelvis, the reference arc should be placed at the iliac crest [4]. However, if the pedicle screws are placed on the cranial side at the L2 level, the reference arc should be placed in the spinous process near the targeted vertebra to improve accuracy. The surgeon also should pay attention not to rotate the vertebra during screw insertion, because the reference frame is not always attached to the corresponding vertebra.

The second advantage is the reduced radiation exposure for the surgeon and operating room staff. Many reports have documented the harmful effects of radiation exposure to the surgeons and the operative team [15-17]. The most valuable aspect of advanced imaging with O-arm navigation may be the reduction of radiation exposure during pedicle screw insertion. Unfortunately, most O-arm reports have recommended using additional C-arm fluoroscopy for cages or rod insertion or did not mention the possibility of using the O-arm for this purpose [3-7]. Our new technique does not require any C-arm fluoroscopy for cage or rod insertion because the cage insertion is also navigated (Fig. 2). Furthermore, the Solera Sextant system does not require image guidance during rod insertion. It is also important to consider radiation exposure to the patient. Each O-arm 3D scan is equal to 60% of an ordinary CT scan, according to the manufacturer's radiation measurement (Medtronic, Minneapolis, MN, USA) [5], which estimates that 1 intraoperative CT scan delivers approximately 9 mGy, or the equivalent of 35 sec of fluoroscopy. Previous reports indicate that, for degenerative and scoliosis cases, the fluoroscopic times were 84 sec [16] and 168 sec [19], respectively. O-arm navigation makes it possible to reduce radiation exposure for patients as well as others in the operating room. An additional advantage is that this technique allows the OR staff and spine surgeons to perform screw placement without heavy lead aprons.

The third advantage of the O-arm system is that there is no risk of a guide wire problem. If the anterior cortex is perforated by a guide wire, the conventional percutaneous surgical method becomes very dangerous, with the possibility of advancing the wire into the abdominal cavity. Chung *et al.* reported a case with MIS-TLIF in which the patient postoperatively developed paraplegia due to subdural hematoma as a rare complication of a guide wire [20]. One of the risks of using a guide wire with the O-arm technique is the inability to track the real-time location of the guide wire [3]; however, our technique does not require a guide wire. The pedicle shadows in overweight or osteoporotic patients can be difficult to discern with C-arm fluoroscopy [21] but O-arm navigation does not have this problem.

On the other hand, there are a few disadvantages of MIS-PLIF using O-arm navigation without the C-arm fluoroscopy technique. Eck *et al.* reported that 10% of medial screws breach into the thoracic spine using cadaveric models [22]. The accuracy of the O-arm technique depends on how firmly the reference frame is attached. The surgeons should always pay attention to confirm the accuracy of the navigation. A deep understanding of spinal anatomy and meticulous preoperative planning are also very important for this procedure. Compared with the C-arm technique, one of the disadvantages of the O-arm technique is the difficulty of tracking the location of the rods. However, several systems have useful mechanisms to solve this kind of problem.

In conclusion, MIS-PLIF with O-arm® navigation and without C-arm fluoroscopy might be a safe and effective surgical technique.

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