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Case Report

C-Arm-Free Minimally Invasive Cervical Pedicle Screw Fixation (MICEPS): A Technical Note

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A minimally invasive posterolateral approach designed to avoid the lateral misplacement of midcervical pedicle screws was reported, but there is no technical report that describes this technique without C-arm fluoroscopy. We report the results of a 2.5 years follow-up of a 62-year-old female patient with C4 metastatic breast cancer. The patient suffered from severe neck pain and impending quadriplegia for 2 months after radiation therapy. We performed C-arm-free minimally invasive cervical pedicle screw fixation (MICEPS). The patient was successfully treated with surgery, and her neck pain was well controlled. She had neither neurological deficits nor neck pain at the final (2.5-year) follow-up. C-arm-free MICEPS is a useful technique; in addition, the surgeons and staff have no risk of radiation exposure, there is a reduced need for postoperative imaging, and a decreased revision rate can be expected with C-arm-free MICEPS.

Key words: cervical spine, navigation surgery, minimally invasive surgery, cervical pedicle screw, C-arm free

Minimally invasive spine surgery (MISS) has been performed many times for spinal fusion compared to the conventional open technique because MISS ensures better results for early postoperative recovery and wound cosmetics [1,2]. Cervical pedicle screw fixation is also becoming more widely used for various cervical unstable conditions including cervical deformity, trauma, infection, and degenerative disease [3,4]. A new minimally invasive cervical pedicle screw fixation technique (MICEPS) via the posterolateral approach has been described [5,6]. This procedure reduces not only soft tissue damage but also vertebral artery injury, which poses a potential fatal complication risk. The original MICEPS technique under C-arm guidance requires radiation exposure and a long duration of the surgery, which in turn increase patients' perioperative stress. Radiation exposure is also a significant concern for surgeons performing MISS, because the conventional MISS technique requires a long period of intraoperative radiation exposure [7]. We addressed this problem and hereby report a new technique: C-arm-free MICEPS performed with an O-arm system with navigation (C-arm free MICEPS).

Surgical Indications and Contraindications

The indications for MICEPS fixation through the posterolateral approach are the same as those for conventional posterior cervical fusion from C2 to C7. The contraindications for MICEPS fixation are congenital anomaly (*i.e.*, defects of the cervical pedicles), traumatic VA aneurysm, bilateral vertebral artery injuries (VAI), and difficulty concerning the prone position for surgery [6].

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Operative Procedure

Preoperative planning. Preoperative planning is very important when performing C-arm-free MICEPS, as it is performed to identify any anomaly or occlusion of the vertebral artery by conventional MRI or MR angiography. Computed tomography is useful to check the narrow pedicle, pedicle fracture, and congenital pedicle defects.

Patient positioning for C-arm-free MICEPS. The patient is positioned in the prone position with carbon Mayfield on a Jackson frame to enable to CT scanning by the O-arm (Fig. 1). The feasibility of cervical pedicle screw insertion (arrow, Fig. 1) should be confirmed before surgery because the skin incisions used with this new technique are >6 cm lateral from the cervical midline.

Incision and muscle exposure. First, the reference frame is attached to the C7 spinous process for C2-7 pedicle screw insertion (Fig. 2A). If it is necessary, T1-3 pedicle screws are also inserted with C7 reference. For better accuracy when C2-3 screw insertion is needed, the use of the C2 spinous process is more precise. The O-arm® (Medtronic, Memphis, TN, USA) is then positioned, and 3D reconstructed images are obtained (Fig. 2B) and transmitted to the Stealth station navigation system Spine 7® (Medtronic). The patient's intraoperative exposure dose is slightly less than that provided by a normal spinal CT scan, which is approx. 5 mSV. After the CT scan is obtained and all of the navigated instruments are calibrated, bilateral skin incisions (approx. 4 cm long) are made under navigation guidance (Fig. 3). The underlying subcutaneous tissue and nuchal fascia are cut with electrocautery. The targeted lateral masses are exposed with blunt finger dissection between the levator scapulae and splenius muscles. A small self-retaining retractor should be applied to maintain a clear surgical field.

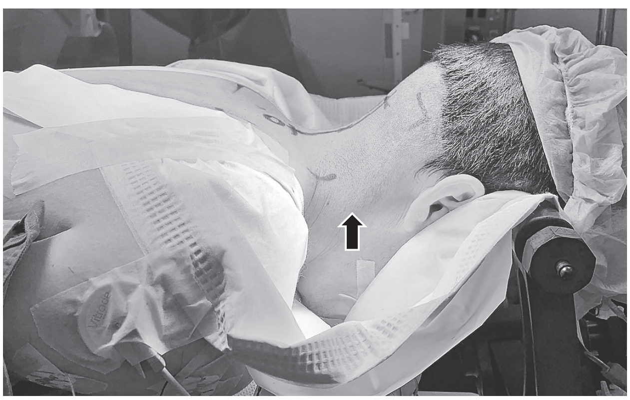


Fig. 1 Patient positioning. The patient is positioned in the prone position with a carbon Mayfield on a Jackson frame.

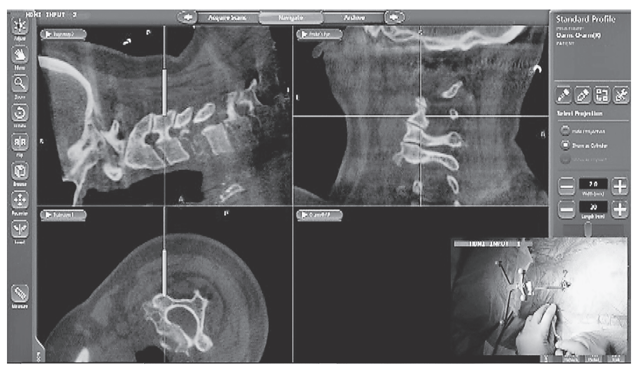
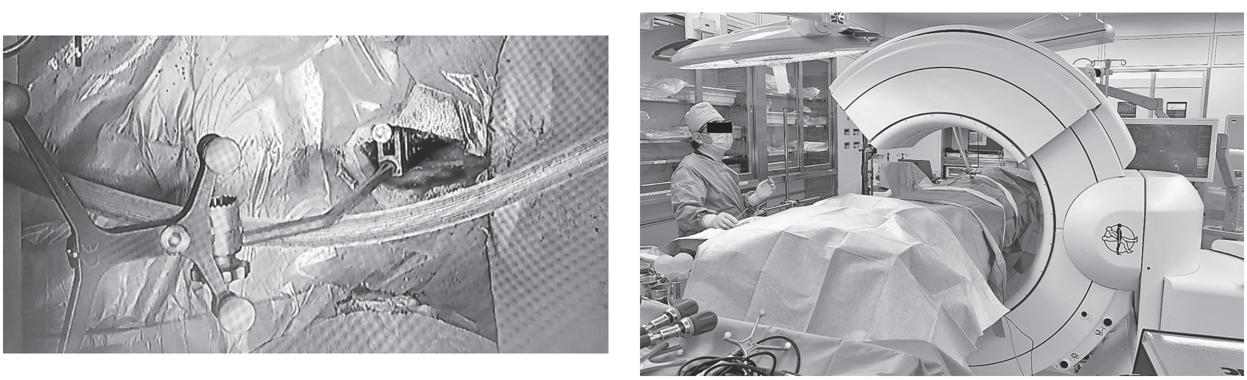


Fig. 3 Skin incision. Bilateral 4-cm skin incisions are made under navigation guidance.



A B

Fig. 2 Intraoperative CT scan. A, The reference frame is attached to the C7 spinous process; B, The O-arm is positioned, and 3D reconstructed images are obtained.

Pedicle screw insertion. Neuromonitoring is useful to prevent neurological complications during this procedure. The entry point of the pedicle screw is determined using the navigation system. Intraoperative navigation accuracy checks are very important to the safety of the new C-arm-free MICEPS technique. At least three points on the bone surface (the tip of the exposed spinous process, and both sides of exposed facet joints) should be checked before using the navigation-guided high-speed burr. This accuracy check should be performed for every vertebra.

A pilot hole is made on the lateral mass with the navigation-guided high-speed burr (Fig. 4A). If the targeted pedicle is relatively narrow, it is much safer to shave the medial wall of the pedicle because the vertebral artery is located laterally (Fig. 4B). The cervical pedicle is then probed using a navigation-guided pedicle probe (Fig. 5A). Careful attention must be paid not to breach the transverse foramen. If there is no resistance of cancerous bone with the probe or if there is any doubt of navigation accuracy, another CT scan should be taken with a reference arc attached to the corresponding spinous process, because the navigation accuracy will worsen due to the distance from the reference or loosening of the reference arc.

The diameter and length of each pedicle screw are determined on the navigation monitor screen. With navigation-guided tapping (Fig. 5B), adequate pedicle screws are inserted under navigation (Fig. 6AB). After the insertion of all pedicle screws, another O-arm-based scan should be obtained to check the inserted screws' locations.

Rod insertion and deformity correction. The rods are measured, contoured, and placed on the pedicle screws and secured. The rod contouring is performed with a preoperative radiogram, and if it is nec-

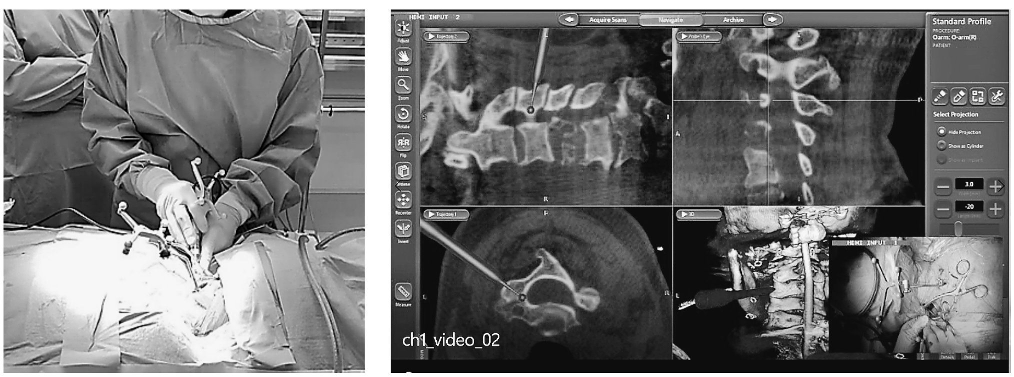


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Fig. 4 Navigation-guided high-speed burr **A**, A navigation-guided high-speed burr is used to make a starting point for a pedicle screw; **B**, For safety, the medial wall of the pedicle is shaved with a diamond burr.

A B

Fig. 5 Screw hole preparation. **A**, The pilot hole is made by the special cervical navigation-guided pedicle probe; **B**, The tapping is also navigated.

essary to correct deformity, cervical malalignment is reduced by using the rod contouring technique.

Case Presentation

Patient history. A 62-year-old woman was referred to our orthopedic department for severe neck pain. She had experienced neck pain and hand numbness for >3 months.

Physical examination. On examination, she could not move her neck smoothly because of severe neck pain. There was no hyper-reflexia of her legs and no abnormal abdominal reflex, but there was severe pain radiating to her left hand, and the range of her neck motion was limited.

Preoperative imaging. Cervical radiograms at the patient's initial visit demonstrated the radiolucency of the C4 vertebra and a reduction of cervical lordosis (Fig. 7A). Preoperative MRI and CT revealed C4 vertebral destruction and mild spinal cord compression at the C4 level (Fig. 7B, C).

Surgery. The reference frame was attached to the C7 spinous process. From the posterolateral skin incision, C2, C3, C5, and C6 pedicle screws were inserted via the C-arm-free MICEPS technique (Fig. 8). The operative time was 1 h 35 min, and the estimated blood loss was 210 ml. There have been no postoperative complications and no neurological compromise.

Follow-up imaging. By 2 months after the surgery, the patient was back to nearly full activity. The postoperative radiograms demonstrated good correction of the curve and the maintenance of appropriate sagittal alignment. All of the inserted pedicle screws were in the correct position as shown by CT (Fig. 9). The patients has had good spinal balance and no neurological deficit for > 2 years (Fig. 10).

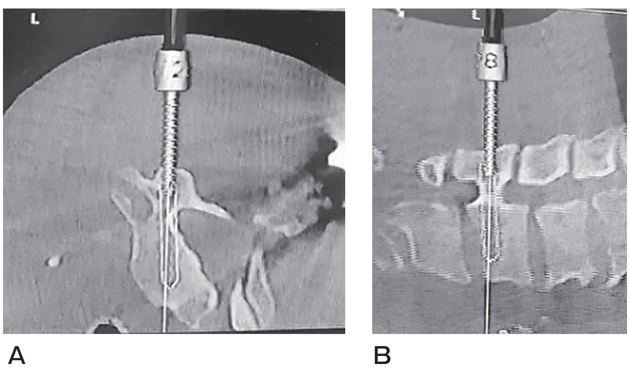

Fig. 6 Pedicle screw insertion. Pedicle screws are accurately inserted under navigation.

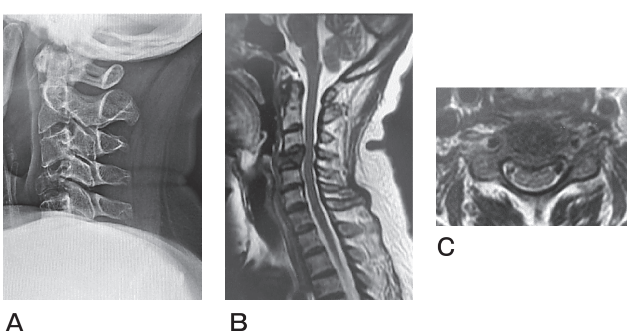

Fig. 7 Preoperative cervical radiogram and MRI. A, The lateral cervical spine radiogram shows radiolucency of the C4 vertebra and a reduction of cervical lordosis; B, Preoperative MRI showing C4 vertebral destruction and mild spinal cord compression at the C4 level.

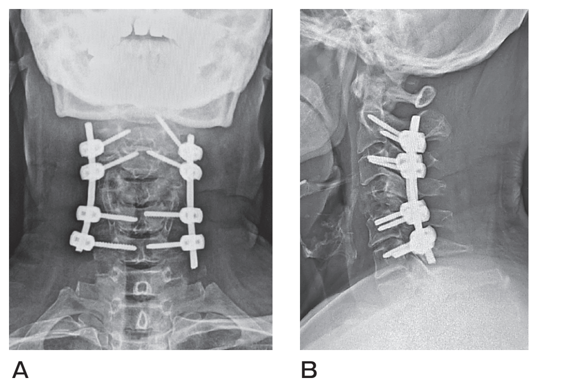

Fig. 8 Postoperative radiograms. The postoperative radiograms demonstrated good correction of the curve and the maintenance of appropriate sagittal alignment. A, Anteroposterior view; B, Lateral view.

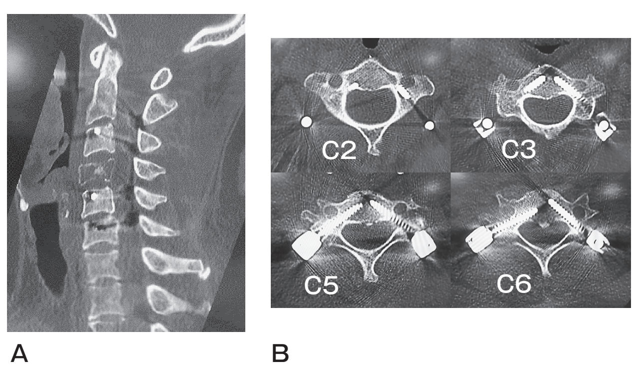

Fig. 9 Postoperative CT. All pedicle screws were inserted at the correct position as shown by CT.

Discussion

Biomechanically, posterior cervical fixation with pedicle screws provides strong stability for an unstable spine [8]. In some situations such as the presence of a metastatic spinal tumor, cervical trauma, or cervical deformity, pedicle screw fixation is more suitable than lateral mass screw fixation [8, 9]. However, the risk of a vertebral artery injury due to cervical pedicle screw fixation has been reported in conventional midline techniques [10, 11]. With the new posterolateral MICEPS fixation described herein, the relatively horizontal pedicle screw insertion at the midcervical spine helps to avoid VA injury [12]. Approximately 75% of misplacements of conventional pedicle screws are lateral deviations [9] due to the medial hard cortex of the pedicle [13] and vertebral rotation [14]. This risk is reduced with the navigation-guided high-speed burr because it not necessary to push the vertebra. With a diamond burr it is possible to penetrate the hard medial cortex.

Other advantages of the MICEPS technique are as follows: cervical lordosis enables a small incision which accommodates more levels of fixation (Fig. 11), and there is less intraoperative bleeding and less postoperative neck pain because the technique is minimally invasive. The MICEPS technique allows the use of a direct lateral approach to the insertion point of each pedicle screw, and thus massive muscle detachment is not necessary.

The original MICPS technique requires fluoroscopy [5]. To avoid the intraoperative radiation problem, new techniques without a C-arm for anterior scoliosis surgery [15] and posterior lumbar interbody fusion (PLIF) [16] were reported. With our new technique, there is no radiation exposure for the surgeons and the operating room staff at centers performing large numbers of MISS procedures. Several studies have documented the harmful effects of radiation exposure to surgeons and the operative team during MISS [17-19]. Advanced imaging along with an O-arm system with navigation may be most effective at reducing the radiation-exposure period for pedicle screw insertion [20]. O-arm based navigation techniques have shown a higher accuracy rate compared to preoperative CT-based navigation and fluoroscopic techniques [21-23]. The patient organ radiation dose that accompanied the use of an O-arm ranged from 20 to 30 mGy for a three-dimensional thoracic spine [24]. For the cervical spine, 20 mGy (mSy) is enough to obtain high-quality CT images, and this dose is less than that of a normal diagnostic CT scan. According to the International Commission on Radiological Protection, the annual occupational dose limit for medical staff is 50 mSv [25].

There are several limitations of this new technique. It is difficult to check the entire set of anatomical landmarks of the posterior aspect of the cervical spine directly with this technique. It is also difficult to perform direct posterior decompression of the spinal cord with this technique. However, posterolateral fusion is possible via a posterolateral approach. The C-arm-free MICEPS with an O-arm + navigation technique is indicated for patients with a metastatic spinal tumor, those at risk for vertebral collapse, those with vertebral col-

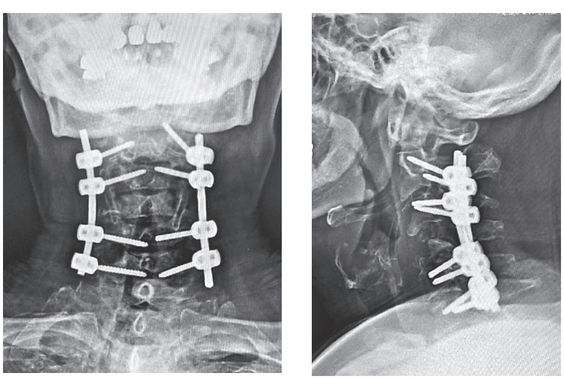

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Fig. 10 Final follow-up radiograms. Final follow-up radiograms (at 2 years and 6 months postsurgery) show good spinal balance and no neurological deficit.

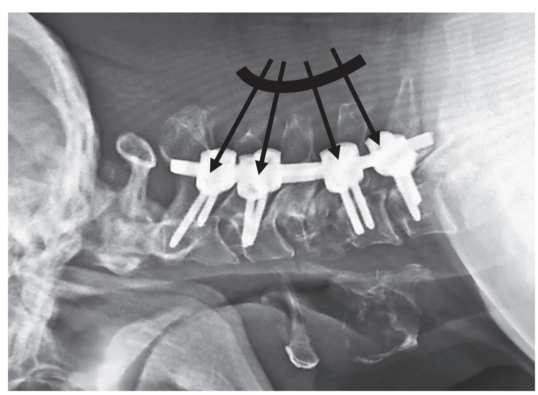

Fig. 11 The relationship between pedicle screw directions and cervical lordosis. For the MICEPS procedure, a small skin incision is enough to perform multiple pedicle screw insertions because of cervical lordosis.

lapse but not static spinal cord compression, and those needing augmentation after the anterior approach is used [12].

Another study limitation regards the navigation accuracy. We did not evaluate the accuracy of the screw placement without the C-arm. The reported pedicle violation rate is as high as 2.8% even with intraoperative 3D image-based navigation [26]. When surgeons have any doubt about the navigation accuracy, a new CT scan should be obtained, or the support of other intraoperative image modalities such as a C-arm should be considered.

Conclusion

C-arm-free MICEPS with an O-arm and navigation is a safe and effective technique in terms of anatomical, clinical, and biomechanical properties. Compared to conventional fluoroscopic techniques, the new technique described herein provides no radiation exposure for the surgeon and staff, reduces the need for postoperative imaging, and decreases the revision rates.

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