Original Article

Lateral mass intra-pedicular screw fixation for subaxial cervical spines – An alternative surgical technique

ABSTRACT

Background: Lateral mass screw (LMS) and transpedicular screw (TPS) techniques are the two major options for performing posterior cervical fusion of the subaxial cervical spine. Although these two techniques can cover the vast majority of patients who require posterior fixation of the cervical spine, they are not without their limitations.

Objective: The objective of this study is to introduce a novel technique, lateral mass intrapedicular screw (LMIS) fixation, for posterior subaxial cervical spine (C3–C6) fixation.

Materials and Methods: The starting point of the screw is defined as the midpoint of the lateral mass. In the axial plane, the screw is angled at 20 –25 with respect to the midline of the spinous process. In the sagittal plane, the screw is directed toward the rostral quarter (zone 1) of the vertebral body and placed within the pedicle. A preliminary, proof-of-concept experiment was performed using a bone model created with synthetic bone and computed tomography images before performing the operation on a patient.

Results: During the preliminary experiment, insignificant breaching of the inner cortex of the pedicle was observed with one of the screws. However, no other screws breached the inner cortex in the same manner during the preliminary experiment or during the operation, and the intraoperative fixation was strong.

Conclusion: LMIS is a relatively simple and safe technique that can be performed for the fixation of subaxial cervical spines with screws that are longer than those used in LMS. We believe that this technique may join the two existing techniques to become a common alternative technique, particularly for patients with poor bone quality.

Keywords: Intrapedicular screw, lateral mass, posterior cervical fixation, subaxial spine

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INTRODUCTION

Currently, surgeons have two main options for performing the posterior cervical fusion of the subaxial cervical spine (C3-6). The lateral mass screw (LMS) technique is regarded to be the safer option of the two, as its trajectory minimizes the risk of vertebral artery injury due to screw perforation. However, given that its starting point is slightly medial to the center of the lateral mass and the screws are inserted at an oblique angle, it has a higher risk of the screws cutting out resulting in a loss of anchoring. The alternative method, transpedicular screw (TPS) technique, yields a higher pull out strength, but it is technically demanding and requires a good understanding of the anatomy.[1,2]

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With the patient placed in the prone position, the vertebral artery of the subaxial cervical spine runs directly underneath the lateral mass and is found on a plane anterior to the posterior wall of the vertebral body [Figure 1a]. In the sagittal plane, the pedicle is located on the most rostral quarter (zone 1) of the vertebral body [Figure 1b].[3,4]

Although many would agree that these two options are sufficient to cover the majority of cases that require posterior cervical fusion of the subaxial cervical spine, there are cases, perhaps in more elderly patients, where the surgeon might prefer to opt for a technique that has higher pull-out strength than the LMS but is safer than the TPS technique.

Here, we describe a novel approach of inserting a screw into the pedicle through the lateral mass for posterior cervical fixation.

MATERIALS AND METHODS

Lateral mass intrapedicular screw fixation for subaxial cervical spines

The concept of this new technique is to insert the screw from the lateral mass and direct it toward the pedicle to allow for longer screws to be used compared to LMS and to provide an increased pull-out strength. Compared to the TPS technique, less muscle stripping is required as the starting point is more medial.

Wet lab experiment using a bone model

As a proof of concept, we first tested our technique on three-dimensional cervical spine models that were created from computed tomography (CT) image data taken from patients with cervical spine myelopathy. The model uses synthetic bone that can be molded to resemble and reproduce the human bone structure. The screws were inserted using both a navigation system-guided method and fluoroscopy.

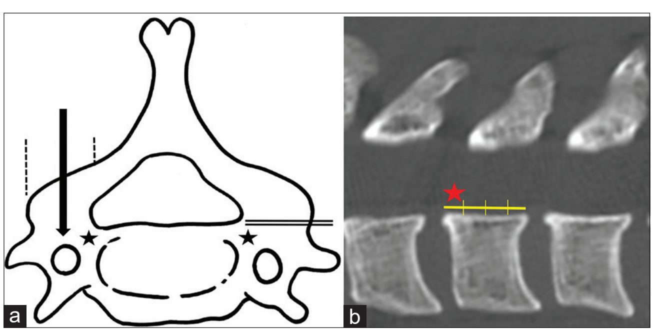

Figure 1: (a) Axial section of the subaxial cervical spine. The dotted line represents the width of the lateral mass. The arrow points to the paravertebral foramen that is located below the lateral mass. The double line corresponds to the level of the posterior wall of the vertebral body. The paravertebral foramen is located ventral to this double line. The star corresponds to the pedicle. (b) Sagittal computed tomography image of the subaxial cervical spine. The rostral quarter of the vertebral body (zone I) is indicated with a star. This is where the pedicle is located

The starting point of the screw is defined as the center of the lateral mass [Figure 2a]. The screw is tilted 20°–25° against the spinous process in the axial plane [Figure 2b]. It is important to note that if the screw is not tilted to a sufficient degree, there is a risk of vertebral artery perforation, and if the screw is tilted to an excessive degree, it will breach the spinal canal. The risk of vertebral artery perforation can be minimized by measuring the distance from the lateral mass to the vertebral artery prior to the surgery and selecting screws that are shorter than that measurement. In the sagittal plane, the screw is directed toward zone I of the vertebral body [Figure 1b].

We inserted screws (Vertex Select System; Medtronic Sofamor Danek, Co., Ltd., Japan) from C3 to C6 (that were all 4 mm in diameter and 12 mm (C3,4) and 14 mm (C5,6) in length) using the method described above. We then used an O-arm (O-arm Imaging System; Medtronic Sofamor Danek, Co., Ltd., Japan) to evaluate and assess the screw position.

We performed the following steps during the trial using a navigation system:

1. The cervical bone model was first mounted on a fluoroscopy table in the prone position. The navigation system (Stealth Station S8; Medtronic Sofamor Danek, Co., Ltd. Japan) was used to mark and register the appropriate landmarks on the model. The diamond-tipped burr, probe, ball-tipped probe (feeler), tap, and screws were all connected to the navigation system
2. The diamond-tipped burr was used to decorticate the center of the lateral mass, which acts as the starting point [Figure 3a]
3. During the probing procedure, using the navigation system, the probe was inserted at an angle of 20°–25° against the midline of the spinous process in the

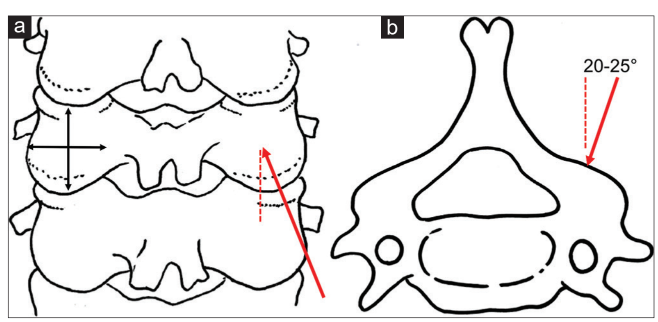

Figure 2: (a) Dorsal view schematic of the subaxial cervical spine. The midpoint of the 2 black arrows denotes the starting point. The red arrow represents the 20°–25° angulation that is required for safe screw insertion. (b) Axial view schematic of the subaxial cervical spine indicating the starting point and angulation required for the ideal trajectory

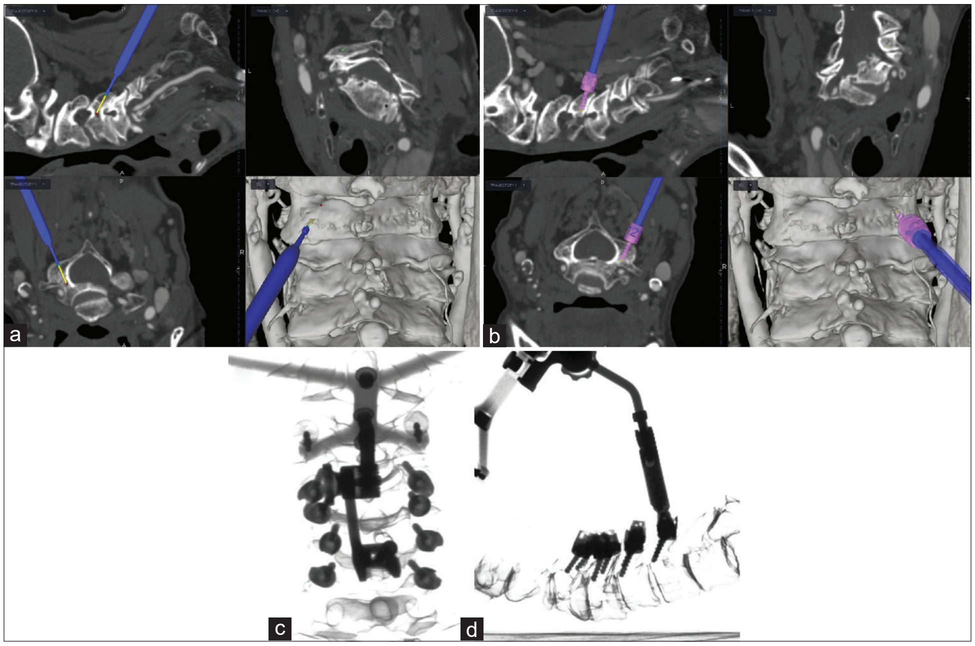

Figure 3: (a) Decortication of the left C3 starting point using a diamond burr and the navigation system. The yellow line acts as a guide for accurate screw insertion. (b) Screw insertion into the right C3 pedicle under navigation. (c and d) Dorsal (c) and sagittal (d) images taken using an O-Arm for screw evaluation

axial plane and directed toward zone I of the vertebral body, where the pedicle is located in the sagittal plane. The tactile feedback given by the bone model resembled that of human cancerous bone, and it was relatively easy to advance the probe in the correct direction

4. Using the ball-tipped probe, we checked for any potential breaches in the cortical bone and then measured and selected the appropriate screw length
5. The screw diameter was selected based on CT images. We used the same-sized tap for tapping the holes and inserted the screws in the same location [Figure 3b]
6. The positions of the screws were assessed using an O-arm [Figure 3c and d]
7. Similar steps were taken using sagittal images using a C-Arm to evaluate the reproducibility of this technique in a more clinical setting [Figure 4a-f].

RESULTS

One of the screws that was inserted using a C-arm had slightly breached the inner cortex of the pedicle [right C6, Figure 5a], but all other screws used in both methods had been inserted in the desired position [Figure 5b-e]. In hindsight, we could have selected longer screws for C3 and 4 [Figure 5f].

Case presentation

A 78-year-old male patient with Klippel–Feil syndrome was diagnosed with cervical myelopathy causing quadriplegia. There was narrowing of the spinal canal at C3-C4 and instability at C4/5. With consent, we performed a C4-C6 cervical laminoplasty and C4/5 posterior fixation using this novel technique, lateral mass intra-pedicular screw (LMIS). We performed the operation using a C-arm so that we could visualize the sagittal view of the cervical spine. We inserted screws (VERTEX SELECT SYSTEM; Medtronic Sofamor Danek, Co., Ltd. Japan) from C4 to C5 (that were all 4 mm in diameter and 10 mm [C4] and 14 mm [C5] in length) using the LMIS technique. The patient had no intra/postoperative complications and is currently undergoing rehabilitation. No breaches were detected on the postoperative CT images, and three of the four screws were successfully placed within the pedicle [Figure 6a-f]. The right C5 screw did not quite reach the pedicle.

DISCUSSION

For performing posterior cervical fusion in patients, several techniques and approaches are available.[5-7] To minimize the risk of vertebral artery perforation and for a relatively straightforward screw insertion, the LMS approach is often selected.[8] One disadvantage of this technique is that the screws can cut-out because its starting point is slightly medial to the midpoint of the lateral mass and the screws are inserted at an oblique angle.[7] The TP method is superior to the LMS in that the pull-out strength is higher, which decreases the risk of loosening, but it is technically more demanding with an added risk of vertebral artery perforation and requires more lateral muscle stripping for screw insertion.[9]

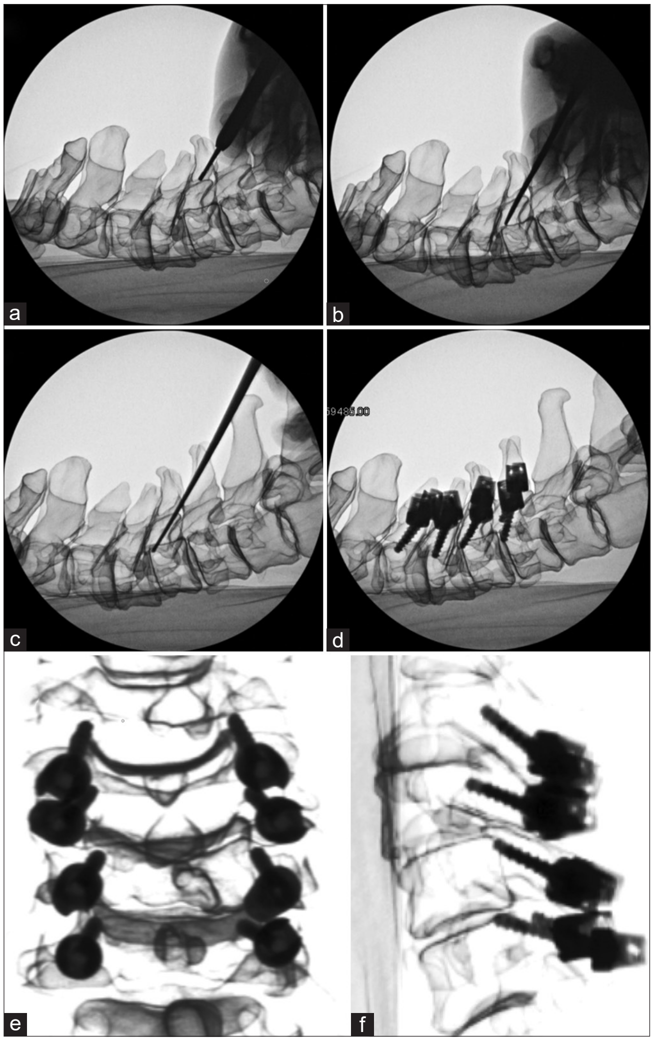

Figure 4: (a) Decortication of the left C5 starting point using a diamond burr under fluoroscopy. (b) Probing with the probe directed towards zone I. (c) Assessment of the foramen with a ball-tipped probe (feeler). Note that the posterior wall of the vertebral body was breached slightly. (d) Sagittal fluoroscopy image following screw insertion from C3 to C6. (e and f) Dorsal (e) and sagittal (f) images taken using an O-Arm for the screw evaluation

Recently, Maki *et al*. suggested paravertebral foramen screw fixation as a good salvaging method following a failed LMS insertion.[6,7] Although this method appears to be similar to our LMIS technique, there is an important difference in the starting point and the screw destination. With paravertebral foramen screw fixation, the screws are placed within the lateral mass, short of the pedicle, and the screws are inserted from the inferior margin of the inferior-articular process of the cranially adjacent vertebra, which means that the screws are inserted vertically to the posterior vertebral body wall in the sagittal plane. The screws, using paravertebral foramen screw fixation, are therefore comparatively shorter (<12 mm).[6,7] With LMIS fixation, the starting point is located at the center of the lateral mass, and the screws are inserted into the pedicle, allowing longer screws (14 mm) to

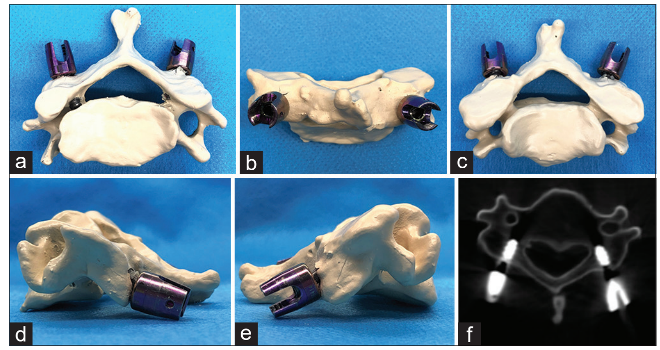

Figure 5: (a) Cranio-caudal view of the C6 bone model following screw insertion using sagittal images. The right screw slightly breached the inner wall of the pedicle. (b-e) Dorsal (b), cranio-caudal (c), left lateral (d), and right lateral (e) images of the C5 bone model with screws inserted using sagittal images. (f) -Arm image of the C4 bone model with screws inserted using sagittal images. Screws measuring 12 mm in length were inserted in both models, but they appear to tolerate screws that are 14 mm + long

be used, potentially resulting in superior fixation outcomes. However, it goes without saying that the length of the screws used should be selected with safety as the priority, and a careful pre/intraoperative measurement is vital.

CONCLUSION

We described a novel technique for the insertion of screws when performing a posterior cervical fusion operation, the LMIS technique. LMIS is technically less demanding than the transpedicular technique and requires less muscle stripping while allowing screws as long as 14 mm to be used, facilitating a significantly more rigid fixation than that generated by lateral mass screw techniques.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient has given his consent for his images and other clinical information to be reported in the journal. The patient understand that name and initials will not be published and due efforts will be made to conceal identity, but anonymity cannot be guaranteed.

Acknowledgment

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Nil.

Conflicts of interest

There are no conflicts of interest.

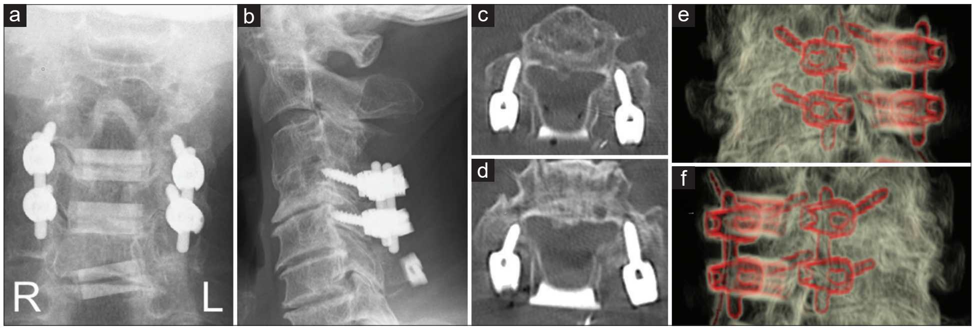

Figure 6: (a) Postoperative AP view of the cervical spine. Note that the right C5 screw did not reach the pedicle. (b) Postoperative lateral view of the cervical spine. Note that all screws were inserted towards zone I of the posterior vertebral wall. (c and d) Axial computed tomography images of C4 (c) and C5 (d). Note that the right C5 screw was directed towards a mass of cortical bone, which would explain why it was not possible to insert longer screws. (e and f) Postoperative three-dimensional computed tomography reconstruction. Note that the right C5 screw did not reach the pedicle

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