Available online at www.sciencedirect.com
ScienceDirect
International Journal of Spine Surgery 7 (2013) e88–e94
www.sasjournal.com

Pedicle violation and Navigational errors in pedicle screw insertion using the intraoperative O-arm: A preliminary report

Jacob E. Mathew, MBBS MCh[a,*], Kelvin Mok, MEng[b], Benoit Goulet, MD[c]

[a] Department of Orthopedics, Montreal General Hospital, Montreal, Quebec, Canada
[b] Neuronavigation, Montreal Neurological Institute, Montreal, Quebec, Canada
[c] Neurosurgery, Montreal Neurological Institute, Montreal, Quebec, Canada

Abstract

Background: Use of computer-assisted insertion of pedicle screws has some advantages owing to the reportedly decreased incidence of pedicle breach and clinical events. Registration-based methods based on preoperative computed tomography imaging, 2D fluoroscopy, and 3D fluoroscopy are the most popular, however each has its limitations. O-arm–based navigation, which uses intraoperative acquisition and registration of navigated images, may overcome many of these disadvantages. We set out to study the clinical accuracy and navigational accuracy for pedicle screw insertion using our recently acquired O-arm and present our preliminary findings.
Methods: The first 26 patients operated consecutively for L4-5 fusion were included in the study. O-arm–based navigation was used to insert the pedicle screws. Postoperative computed tomography images were acquired and assessed for pedicle breach and anterior cortical perforation. Planned trajectories of each screw were compared with the actual trajectories in the postoperative images to assess navigational accuracy in both axial and sagittal planes.
Results: A total of 104 screws were inserted. One screw (1%) breached the pedicle laterally. Nonsignificant anterolateral cortical perforations were noted in 7 screws (6.7%), all of which occurred at L5 level. The mean axial and sagittal navigational error was 2.3° (± 1.7) and 3.1° (± 2.3), respectively. There were no significant differences in the errors between L4 or L5 level. The occurrence of anterior perforation correlated with the degree of axial ($P = .02$) but not sagittal ($P = .12$) navigational error. There were no clinical events related to the screw insertion.
Conclusion: Use of O-arm–guided pedicle screw insertion was associated with low incidence of pedicle breach (1%) and a low range of navigational error in both sagittal and axial planes. Anterolateral vertebral body perforation was higher at L5 without any negative clinical events. Despite the high need for technical support, we found that O-arm was a very efficient tool for accurate pedicle screw insertion.

Keywords: O-arm; Computer-assisted navigation; Clinical accuracy; Navigational accuracy; Pedicle screw

Introduction

Pedicle screw fixation to augment bony fusion is commonly performed in spine surgery. Although most pedicle violation errors are clinically irrelevant, nerve root injuries are not uncommon. cerebro spinal fluid leak, vascular injury, and visceral injury have also been reported.[1–4] Over the last decade, the use of image-guided navigation for pedicle screw insertion is preferred by some surgeons owing to the reportedly decreased incidence of pedicle breach and clinical events. The 3 most popular navigation systems used are computed tomography (CT) navigation, 2D fluoroscopy, and 3D fluoroscopy.

CT-based navigation using paired point and surface registration is widely practiced. It requires the acquisition of preoperative CT images of the spine. Intraoperatively, selected anatomical points on the vertebra were matched to the computer-generated model on the work station. However, the process is time consuming and has a considerable learning curve, and the results are variable.[5–8]

Fluoronavigation relies on anteroposterior and lateral 2D images obtained intraoperatively. Although relatively inexpensive, the quality of 2D fluoroscopic images obtained at certain levels can be disappointing.

3D fluoroscopy-based navigation provides real-time intraoperative 3D imaging. Intraoperative images can be

* Corresponding author: Jacob E. Mathew, MBBS, MCh, Department of Orthopedics, Montreal General Hospital, B5.158 Avenue Cedar, 1650 Montreal, Canada H3G1A4. Tel.: +1-514-991-5905.
E-mail address: jacob.mathew@mail.mcgill.ca

2211-4599 © 2013 ISASS – The International Society for the Advancement of Spine Surgery. Published by Elsevier Inc. All rights reserved.
http://dx.doi.org/10.1016/j.ijsp.2013.06.002

obtained while the digital reference array (DRA) is attached to the patient thereby automating the registration process. The O-arm (Medtronic Surgical Technologies, Louisville, Colorado) is a recent 3D fluoroscopy system that provides image quality similar to that of CT. The preliminary results are promising regarding accuracy of pedicle screw insertion with the O-arm.[9–12] However, the reports on navigational errors using the O-arm are limited to axial errors.[12,13]

The goal of our series was to describe axial and sagittal navigational errors, in addition to the clinical accuracy for O-arm–assisted pedicle screw insertion in L4-5 degenerative spondylolisthesis.

Methods

Twenty-six consecutive patients with degenerative spondylolisthesis underwent L4-5 instrumented fusion by the senior author (BG) from September 2011 to December 2012. All pedicle screws were inserted with help of the O-arm. All patients received high-resolution preoperative CT imaging for navigation planning (2-mm isotropic resolution, 1-mm overlap with anatomical coverage of L2-S2 vertebrae. The digital imaging and communications in medicine images were imported to the StealthStation (Medtronic Surgical Technologies, Louisville, Colorado), and 2D and 3D models were reconstructed to simulate L3-S1 fusion. Printouts of this simulation with screw sizes were displayed in the operating room.

We exposed the spinous processes from the inferior aspect of L3 spinous process to the superior aspect of L5, the L4 and L5 laminae, and the transverse processes till the tips. The integrity of L3-4 interspinous ligaments and facet joints was preserved. The passive DRA was fixed on the L3 spinous process. The O-arm was draped with sterile plastic and positioned around the patient on the Jackson table (Orthopedic Systems Incorporated). A 3D low-resolution image was acquired in 13 seconds while the breathing was stopped. A total of 392 single images were recorded in a full 360° rotation of the radiation source and detector unit. The images were taken without the retractor (Crank, Codman) in place. The data set from the O-arm was automatically transferred to the StealthStation where 2D and 3D images were created. Planning of the screws was done by the senior author on the StealthStation (version 2.0). The navigation wand was registered on the divot of the passive DRA. The navigation wand with the ball tip was applied to the spinous process laminae and transverse process to check the accuracy of the system.

The screw image was reproduced on the patient to match the entry point, exit point, and angulation. In a few instances, the planning was changed to accommodate the limitation of the retractors. An air drill was used to traverse the outer cortex of the base of the mammillary process in line with the planned screw. A nonnavigated straight pedicle probe was inserted along the direction provided by the navigation probe. The trajectory and depth were confirmed by the navigation wand. The integrity of the pedicle walls and anterior cortex was tested with a ball point. A proper-sized tap was inserted along the pedicle. A pedicle screw (Stryker Xia 3 system, Hamilton, Ontario, Canada) was inserted after checking with the navigation probe. All screws were polyaxial. We attempted to use 6.5-mm diameter screws but a few of them were 5.0 mm, 5.5 mm, or 6.0 mm screws owing to anatomical constraints. The screw length varied from 30–55 mm. The senior author placed all screws on the right side and 25% of the screws on the left side, while the fellow or resident placed the rest under supervision of the senior author.

A thin-cut postoperative CT scan (Toshiba Aquilon One, Tochigi-Ken, Japan) from L3 to S1 was done. Errors were evaluated on axial (media and lateral) and sagittal images (cranial and caudal) for pedicle breach and anterolateral perforations of the vertebral body. The pedicle errors were graded using accepted definitions: grade I (0–2.0 mm), grade 2 (2.1–4.0 mm) grade 3 (4.1–6.0 mm), and grade 4 (6.1–8.0 mm).[14,15] Anterolateral perforations were quantified in millimeter as the distance traversed by the tip of the screw beyond the perpendicular of the cortical margin (Fig. 3).

Navigational errors

To study the navigational error, a snap shot of the planned screw images (virtual images) acquired by the O-arm on the StealthStation and the postoperative CT images on the picture archiving and communication system (Intelliviewer software version 4-2-1-P301, Intelerad Systems Inc., Montreal, Canada) were compared. The axial screw angle was defined as the angle made by the pedicle screw axis with the midsagittal vertebral axis (Fig. 1). The midsagittal vertebral axis is a line bisecting the vertebral body, midpoint at the base of the lamina, and tip of the spinous process, and it has been described earlier.[16] The sagittal screw angle was defined as the angle made by the pedicle screw axis with the superior end plate of the respective vertebral body (Fig. 2).

The difference between the planned axial screw angle and the postoperative axial screw angle was defined as the axial navigational error (Fig. 1A and B). Similarly, the difference between the planned sagittal screw angle and the postoperative sagittal screw angle was defined as the sagittal navigational error (Fig. 2A and B). Statistical analysis was done using the JMP software (version 8.0).

Results

A total of 104 screws were inserted in 26 patients. None of the patients had complications from hardware misplacement. There were no new postoperative radiculopathy or vascular injuries.