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Original Article

Comparison of the accuracies of transpedicular screw insertion during computed tomography-free, -based, and intraoperative computed tomography spinal surgeries

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ABSTRACT

Purpose: This study aims to compare the accuracies of transpedicular screw (TPS) insertion using with computed tomography (CT)-free, CT-based, and intraoperative CT (iCT) with integrated navigation during lumbar spinal surgery.
Materials and Methods: This study is a retrospective cohort study comparing perioperative data from three patient groups—CT-free navigation (CTF) group, CT-based navigation (CTB) group, andiCT group—who were treated at the Orthopedic Department of Chang Gung Memorial Hospital, Chiayi, Taiwan. Patients who received posterior lumbar TPS insertion with the assistance of computer navigation from January 2002 to June 2011 were included in the study. All demographic and perioperative data were collected from reviews of the medical charts. Postoperative CT images were reviewed to determine screw position.
Results: This study enrolled 56 patients: 22 patients were enrolled in the CTF group (106 screws), 15 patients in the CTB group (70 screws), and 19 patients in the iCT group (114 screws). The rate of screw insertion without pedicle wall penetration was 89.62% in the CTF group, 98% in the CTB group, and 98% in the iCT group. ($p = 0.01$) The rate of pedicle wall penetration >2 mm was 5.66%, 0%, and 0% in the CTF, CTB, and iCT groups, respectively. One patient in the CTF group developed a residual neurologic deficit. There were noscrew-related complications in the CTB or iCT groups.
Conclusion: The use of CT navigation (CT-based and iCT navigations) results in a significantly higher accuracy of screw insertion compared with two-dimensional fluoroscopic navigation for TPS insertion ($p = 0.01$). Intraoperative CT-integrated navigation provides additional advantages, including simpler registration and the ability to double-check positioning during the operation, andtends to produce less blood loss.

1. Introduction

The misplacement of transpedicular screws (TPS) often creates unwanted complications.[1] Several methods had been used to enhance the accuracy of pedicle screw insertion, including the bone landmark method, open laminar method, fluoroscopic navigation, CT-based navigation, and intraoperative CT (iCT) navigation.[2–5] Pedicle screw accuracy during spinal surgery has been reported to be between 79–100%.[6,7] Theoretically, by using a navigation system the incidence of TPS misplacement should decrease.[8] However, the accuracies of different navigation systems are rarely reported in the literature. This aim of this study is to compare the accuracy of TPS insertion usingCT-free (CTF), CT-based (CTB), and iCT with integrated navigation (BrainLab AG, Feldkirchen, Germany; Siemens, Munich, Germany) during lumbar spinal surgery.

2. Materials and methods

2.1. Subjects

This is a retrospective cohort study comparing perioperative datafrom three patient groups—CTF group,CTB group, the iCT group—who were treated at the Orthopedic Department of Chang

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Gung Memorial Hospital, Chiayi, Taiwan. Patients who received posterior lumbar TPS insertion with the assistance of computer navigation from January 2002 to June 2011 were included in the study. Patients were grouped into the three groups according to the navigation method used. The CTF navigation system was used from 2002–2004, the CTB navigation system was used from 2007–2009, and the iCT navigation system was used from 2010–2011. Screws that were placed in the thoracic region were excluded from analysis. All demographic and perioperative data were collected by reviewing the medical charts. This study was approved by the institutional review board (IRB No. 100-0901B) of our hospital.

2.2. TPS-insertion methods

2.2.1. CTF navigation

TPS insertion was assisted with the use of a two-dimensional (2D) fluoroscopic navigation station (VectorVision[2] fluoro; Brainlab AG, Feldkirchen, Germany). The reference frame was attached to the spinous process of the vertebra, and the optical sensor camera was also properly positioned. The surgical tools, including the pedicle awl, probe, and screwdriver, were tracked. A calibration image was obtained using an image intensifier (Siremobil 2000, Siemens, Munich, Germany). Anteroposterior and lateral fluoroscopic images of the two vertebrae adjacent to the reference arm were obtained. After the data were captured and transferred to the workstation, a computer-simulated image of the patient's anatomy and the registered tools were displayed in each view. We located the entry point and trajectory of each TPS using the registered pointer and guidance from the navigation system. The pilot hole was prepared using a registered pedicle probe. A TPS of sufficient length and diameter was inserted according to the specifications of the navigation system. The pilot hole was not entirely checked by the ball-tipped probe.

2.2.2. CTB navigation

For this method, TPS insertion was assisted by the use of a three-dimensional (3D) CT navigation station (VectorVision spine; Brainlab AG, Feldkirchen, Germany). Image data from the initial preoperative CT scans were obtained and transferred from the CT scanner to the navigation workstation to produce a 3D image of the targeted spinal segment. With the patient in a prone position, a reference clamp was securely attached to the spinous process of the vertebra. After pair-point matching using at least four local bone landmarks on the targeted vertebra, the CT image was used to guide TPS insertion. The surgical instruments, includingthe pedicle awl, probe, and screwdriver, were tracked. The surgeon located the entry point for the TPS using the registered pointer. After the entry point was located, the navigation system displayed the screw trajectory through sagittal and axial views. The pilot hole was then prepared, and the screw was placed using guidance from the navigation system. The pilot hole was not entirely checked by the ball-tipped probe. A TPS of sufficient length and diameter was also selected according to specifications of the navigation system.

2.2.3. iCT navigation

For this method, TPS insertion was assisted with the use of an iCT navigation system (Spine & Trauma iCT; Brainlab AG, Feldkirchen, Germany; Figs. 1, 2). The navigation system was composed of a sliding gantry 40-slice CT scanner (SOMATOM Sensation open, Siemens, Munich, Germany) with the following specifications: 241.2 mm at 120 kVp, 200 mAs, rotation time of 1 second, multiplanar reconstructions with slice thickness/increment of 3 mm, and a frameless infrared-based navigation station (BrainLab, VectorVision sky; BrainLab AG, Feldkirchen, Germany). With the patient in a prone position, a reference clamp was securely attached to the spinous process of the vertebra. A control CT scan was performed for registration. Images from the initial control CT scans were obtained and transferred from the CT scanner to the navigation workstation to produce a 3D image of the relevant spinal segment and to provide automatic registration. After verifying the registration of the target vertebrae, the CT image was used to guide TPS insertion. The surgical instruments, including the drill guide and probe, were tracked. The surgeon located the entry point of the TPS using the registered pointer. After the entry point was located, the navigation system displayed the trajectory through sagittal and axial views. The pilot hole was prepared with the drill guide, and the screw was entirely placed with guidance from the navigation system. The pilot hole was not entirely checked by the ball-tipped probe. A TPS of sufficient length and diameter was also selected according to the specifications of the navigation system. After TPS insertion, a confirmation CT scan was immediately performed.

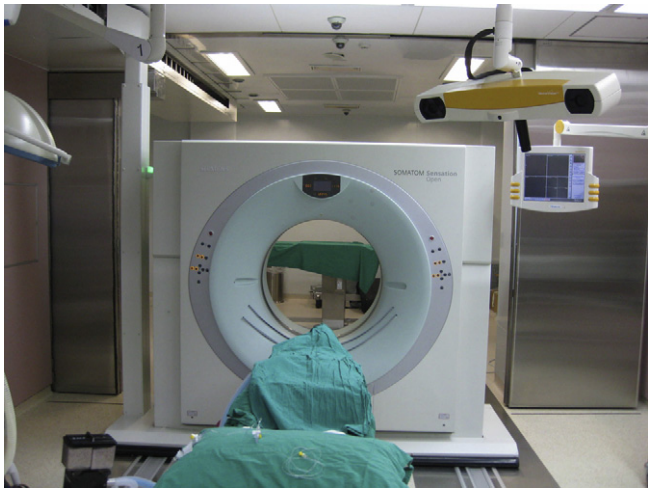

Fig. 1. Intraoperative CT scan obtained using an integrated computer navigation system in the operating suite.

2.3. Assessment of screw position

Screw position was assessed in the CTF and CTB groups using CT scans 1–4 days after surgery. The postoperative CT images were reviewed for screw position by measuring the digitalized images (PACS, Centricity Enterprise Web, version 3.0; GE Medical systems, Fairfield, Connecticut, United States). The axial reconstructions were analyzed by an investigator blind to the method of insertion. The assessment utilized a measurement scale in the digital image system. The distance breeched by the screw was graded as follows, as previously described by Belmont et al[9]: screw entirely in the bone, <2 mm from the bone, 2–4 mm from the bone, and >4 mm from the bone.

2.4. Statistical analysis

All demographic and perioperative data were assessed using the Chi-square test or Mann-Whitney rank sum test using SPSS software (version 12.0; SPSS Inc. Chicago, Illinois, United States). Results were considered statistically significant if the p value was <0.05.

3. Results

Fifty-six patients were included in this study, and they were divided into three groups according to the method of TPS insertion.