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Clinical Study

Accuracy of upper thoracic pedicle screw placement using three-dimensional image guidance

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Abstract

BACKGROUND CONTEXT: Pedicle screw malposition rates using conventional techniques have been reported to occur with a frequency of 6% to 41%. The upper thoracic spine (T1–T3) is a challenging area for pedicle screw placement secondary to the small size of the pedicles, the inability to visualize this area with lateral fluoroscopy, and significant consequences for malpositioned screws. We describe our experience placing 150 pedicle screws in the T1–T3 levels using three-dimensional (3D) image guidance.

PURPOSE: The aim of this study was to assess the accuracy of 3D image guidance for placing pedicle screws in the first three thoracic vertebrae.

STUDY DESIGN: The accuracy of pedicle screw placement in the first three thoracic vertebrae was evaluated using postoperative thin-section computed tomography (CT) scans of the cervicothoracic region.

PATIENT SAMPLE: Thirty-four patients who underwent cervicothoracic fusion were included.

OUTCOME MEASURES: Radiological investigation with CT scans was performed during the postoperative period.

METHODS: Thirty-four consecutive patients underwent cervicothoracic instrumentation and fusion for a total of 150 pedicle screws placed in the first three thoracic vertebrae. All screws were placed using 3D image guidance. Medical records and postoperative imaging of the cervicothoracic junction for each patient were retrospectively reviewed. An independent radiologist reviewed the placement of the pedicle screws and assessed for pedicle breach. All cortical violations were reported as Grade 1, 0 to 2 mm; Grade 2, 2 to 4 mm; and Grade 3, greater than 4 mm.

RESULTS: Overall, 140 (93.3%) out of 150 screws were contained solely in the desired pedicle. All 10 pedicle violations were Grade 1. The direction of pedicle violation included three medial, four inferior, two superior, and one minor anterolateral vertebral body. No complication occurred as a result of screw placement or the use of image guidance.

CONCLUSIONS: Upper thoracic pedicle screw placement is technically demanding as a result of variable pedicle anatomy and difficulty with two-dimensional visualization. This study demonstrates the accuracy and reliability of 3D image guidance when placing pedicle screws in this region. Advantages of this technology in our practice include safe and accurate placement of spinal instrumentation with little to no radiation exposure to the surgeon and operating room staff.

Keywords: Upper thoracic; Cervicothoracic fusion; Pedicle screws; Three-dimensional; Image guided; Accuracy

Introduction

When compared with the lumbar spine, the thoracic pedicle is smaller, with increasing variability in its anatomy [1–6]. Given this inconsistency, techniques using anatomic landmarks have resulted in elevated rates of aberrant screw

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EVIDENCE & METHODS

Context
The placement of pedicle screws in the upper cervical spine is difficult. In this article, the authors report their experience using a three-dimensional image guidance system.

Contribution
The system is reported to work well in the authors' hands, with 93% of screws accurately placed, as seen on follow-up thin-cut CT scans. The authors report no clinically important complications of screw misplacement.

Implications
The ability to generalize is an important consideration in this report. Where are the authors and the institution on the learning curve relative to a surgeon contemplating new use of this technology? Is the accuracy reported due to a specific surgical skill, specific technician support, etc.? Or are the results due to the technology itself? That said, most reports using such technologies have been quite positive, and most who use them regularly consider them a step up in accuracy and, hence, safety. This study suggests this method should be directly studied against conventional imaging to compare clinical utility.

—*The Editors*

placement, 6% to 41% [4,7]. Furthermore, the close proximity of vital structures such as the thoracic pleura, nerve roots, and spinal cord cause even small deviations in screw placement to result in significant morbidity [1–6,8–10].

The addition of conventional fluoroscopy has improved the placement of cervical and lumbar instrumentation. The use of anterior-posterior fluoroscopy to effectively place thoracic pedicle screws has been described [11]. However, difficult visualization of the thoracic pedicle and anterior vertebral body with lateral views renders this imaging modality challenging and dependent on the surgeon's experience, especially when instrumenting the upper thoracic levels.

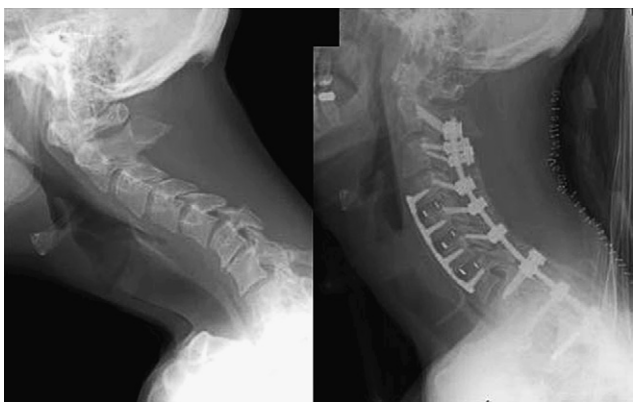

Fig. 1. (Left) Preoperative and (Right) postoperative radiographs of a patient treated for cervical deformity with instrumentation down to the T3 level.

Image-guided spinal surgery made its advent in 1996 and has been shown to increase the safety and accuracy of spinal instrumentation placement [12–17]. The authors describe their experience in placing 150 upper thoracic (T1–T3) pedicle screws using three-dimensional (3D) image guidance.

Methods

Approval for this review was obtained from the Mayo Clinic Institutional Review Board. The medical records and radiological studies of 34 consecutive patients who had undergone posterior cervicothoracic fusion between October 2002 and October 2008 were retrospectively reviewed. The senior author (EWN) placed or supervised the placement of all 150 screws. Three-dimensional image guidance was accomplished using either the BrainLAB Vector Vision (BrainLAB Inc., Westchester, IL) image-guided system or the Medtronic Stealth Station Treon (Medtronic Inc., Littleton, MA) image-guidance system. The patients included 18 men and 16 women between 41 and 84 years of age. The most common indication for surgery in this series was cervical deformity (Fig. 1). Other indications included trauma, tumor, myelopathy, and infection. Cervicothoracic constructs were extended to one of the first three thoracic vertebrae, with a total of 150 screws placed (T1=68, T2=54, T3=28). The ''in-out-in'' technique was used for the placement of pedicle screws into extremely narrow pedicles. This technique allows for lateral cortical purchase of a pedicle with a more medial trajectory, so the tip of the pedicle screw ends up in the vertebral body. Exploitation of this maneuver permits the use of wider screws in a more medial trajectory and can be an advantage to an extremely narrow screw having to be used in a straight trajectory or when the pedicle does not have the anatomy to accommodate the smallest diameter screw available. The pedicle entry point is just lateral to the normal pedicle entry point, and thus the screw engages the lateral aspect of the pedicle. In the midpoint of the pedicle, the screw trajectory is extrapedicular while engaging the lateral cortex of the pedicle before entry into the vertebral body. These intentional breaches were necessary to perform the procedure and thus not counted in the breach analysis. Postoperative follow-up of these patients ranged from 1 to 24 months with an average of 10 months.

Surgical procedure

All patients underwent preoperative computed tomography (CT) scanning using an image-guided protocol, and