Accuracy of Pedicle Screw Placement in the Thoracic and Lumbosacral Spine Using a Conventional Intraoperative Fluoroscopy-Guided Technique: A National Neurosurgical Education and Training Center Analysis of 1236 Consecutive Screws

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Key words
- Accuracy
- Lumbar spine
- Pedicle screw
- Screw misplacement
- Spinal fusion
- Thoracic spine

Abbreviations and Acronyms
CT: Computed tomography

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OBJECTIVE: **Pedicle screw placement is a very common procedure used to stabilize all three columns of the thoracic and lumbar spine. The purpose of this study is to evaluate the incidence of screw misplacement and related complications in patients who underwent fluoroscopy-guided transpedicular screw fixation at a neurosurgical teaching institution.**

METHODS: **We retrospectively reviewed consecutive patients who underwent fluoroscopy-guided transpedicular screw fixation from January 2007 to May 2011 in the Department of Neurosurgery, Kantonsspital Aarau, a certified Swiss National Neurosurgical Education and Training Center. The accuracy of the pedicle screw trajectory was assessed using reconstructed postoperative axial, sagittal, and coronal computed tomography images. The displacement was classified as minor (≤2 mm), moderate (2.1–4 mm), and severe (>4 mm).**

RESULTS: **A total of 1236 pedicle screws were placed in 273 consecutive patients in the thoracic and lumbosacral spine. All surgeries were performed under the supervision of 7 board-certified neurosurgeons and faculty members. A total of 17 surgeons, including trainees, participated in all procedures. A total of 247 (20%) screws breaching the pedicle were identified, with 135 (10.9%) minor violations, 65 (5.3%) moderate violations, and 47 (3.8%) severe violations. Sixteen (5.9%) patients developed postoperative radiculopathy. All of these patients belonged to the subgroup of severe screw displacement.**

CONCLUSIONS: **The data presented confirm that for a training and education center, transpedicular fluoroscopy-guided screw fixation remains a technically demanding procedure. As defined in this study, neurological symptoms are likely associated only with severe screw misplacement.**

INTRODUCTION

The use of a transpedicular screw was first reported in 1959 by Boucher (6). In the 1970s, substantial further development of pedicle screw internal fixation proceeded in Switzerland and France, with further clinical benefits reported (9, 34). At present, transpedicular screw fixation is a widely and successfully used procedure for rigid stabilization of all three vertebral columns in various disorders of the thoracic and lumbar spine (14-16, 27, 28, 33, 38).

Despite continuing improvements in surgical and image-guided techniques, transpedicular screw insertion remains a demanding procedure due to the complex morphologic features of the pedicle. Correct positioning of the screws is of utmost importance, as violation of the pedicle wall or vertebral body may result in fixation failure or injury to neural, vascular, or visceral structures (1, 7, 16, 18, 26, 31, 33).

Studies investigating the accuracy of transpedicular screw instrumentation, using various imaging-guided techniques, show a wide range of misplaced screws (8, 13, 17, 20-23, 25, 29, 30, 35, 37, 40, 41). Most of these studies are series presented by experienced surgeons (2, 3, 7, 17, 18, 22, 23, 25, 27, 29-32, 35, 37, 40). Series of pedicle screw placement within the context of a training center are rare.

The aim of this study was to assess the incidence of pedicular screw misplacement and related complications in patients undergoing transpedicular fusion in the thoracic and lumbosacral spine within the context of a neurosurgical education and training center.

METHODS

We retrospectively reviewed 273 consecutive patients who underwent transpedicular screw fixation in the thoracic and lumbosacral spine from January 2007 to May 2011 at our institution. In all of the patients, an open surgical technique and intraoperative fluoroscopy were used. The surgeries were performed by 17 different neurosurgeons at all levels of training, including 10 residents and 7 attending neurosurgeons. Although the operative reports did not specify the individual surgeon inserting the screw, residents placed at least half of all assessed pedicle screws under the supervision of a board-certified neurosurgeon.

The open surgical technique included the posterior dissection of the paravertebral muscles from the spinous process down to the transverse process. The entry point was defined according to the anatomic landmarks (11, 19). The selection of screw diameter and length was based on preoperative computed tomography (CT) images and intraoperative evaluation. The surgeon aimed to choose the largest screw diameter that pedicle anatomy would allow unless the screw diameter exceeded 8 mm, which was rarely the case. Under anterior–posterior fluoroscopic visualization the screw was inserted. The craniocaudal and mediolateral trajectories for inserting the instrumentation were selected using preoperative CT images, intraoperative anterior–posterior and lateral fluoroscopic guidance, and the surgeons' estimation of the trajectory angle. The ideal screw position aimed for was parallel to the superior endplate of the instrumented vertebrae in the sagittal plane films and convergent angulation from lateral to medial in the axial plane films (5).

All patients underwent a CT scan within 48 hours after surgery for evaluation of the screw position. Data were obtained using a 64-detector-row helical CT scanner (Aquilion, Toshiba Medical, Nasu, Japan). The spine protocol generates 1-mm source slices, acquired with a 32 × 1 mm collimation and a pitch factor of 0.656 at a rotation time of 1 second. Dosage parameters were 135 kV and software-based modulated mAs of maximum 300 Sure Exposure. Sagittal and coronal sections were reconstructed in 3-mm thickness from the raw data. Evaluation of the screw positioning accuracy on the CT scans was carried out by the investigators and an independent neuroradiologist on reconstructed images in axial, sagittal, and coronal planes.

Correct screw position was defined as previously reported with slight modifications (2, 24), namely when the screw was completely surrounded by pedicular cortex in all three reconstructed planes, without any violations of its borders. Screw misplacement was classified as minor, moderate, or severe. A violation was considered "minor" when the distance between the edges of the screw and the cortical margin of the pedicle (violation distance) measured a maximum of 2 mm. "Moderate" violation was defined as a violation distance ranging from 2.1 to 4 mm, and/or measuring less than a screw diameter. "Severe" violation was defined as a violation distance more than 4 mm and/or more than a screw diameter. The direction of the violating screw was noted with reference to the cortical margins of the pedicle as medial, lateral, superior, or inferior (Figure 1).

The incidence of revision surgeries, radicular pain, and postoperative neurological deficits, in terms of sensory deficits and motor weakness, attributable to screw misplacement was recorded. Associated risk factors potentially leading to screw misplacement were not considered in the study. The rate of misplaced screws in the lumbosacral spine was compared with the rate of misplaced screws in the thoracic spine. In addition, laterally misplaced screws in the lumbosacral spine were compared with the rate of laterally misplaced screws in the thoracic spine. Statistical analyses were performed using Fisher's exact test. The significance level was set at a P value < 0.05. Data were analyzed and visualized with GraphPad Software 6.0 (San Diego, California, USA, statistical software version for Windows). Values were expressed as mean ± standard deviation.

RESULTS

In our institution a total of 1236 screws were inserted in 273 patients (137 men and 136 women) using a conventional open technique and intraoperative fluoroscopy over a period of more than 4 years. The patients' overall age was 54.9 (± 14.3) years. The indications for surgery were spondylolisthesis (42.5%), degenerative disease (37.4%), revision surgery (9.9%), trauma (8.1%), tumour (1.5%), and infection (0.3%) (Figure 2). There were 1146 screws (92.7%) inserted in the lumbosacral spine and 90 screws (7.3%) in the thoracic spine. An overview of screw placement according to segmental level is given in Figure 3.

A total of 247 (20%) screws were identified on postoperative CT scans as breaching the pedicle. Most of the misplaced screws were in lateral locations (120; 9.7%), followed by medial violating screws (82; 6.6%), superior misplaced screws (27; 2.2%), and inferior misplaced screws (18; 1.5%). Minor violation was found for 135 (10.9%), moderate violation for 65 (5.3%), and severe violation for 47 (3.8%) of all 1236 inserted screws. The rate of misplaced screws in the thoracic spine (33.3%; $n = 30$) was higher than in the lumbosacral spine (18.9%; $n = 217$). Using Fisher's exact test, the difference of misplaced screws in these 2 spinal regions was statistically significant ($P = 0.0023$). Topographic analysis of misplaced screws showed a higher incidence of laterally positioned screws in the thoracic spine (28.8%; $n = 26$) compared with the lumbosacral spine (8.2%; $n = 94$). The difference in these 2 groups was statistically significant ($P < 0.0001$). Despite the overall higher incidence of lateral breeching screws, especially in the thoracic spine, no conflicts with the adjacent anterior vasculature were recorded. A detailed overview and description of the screws with violations are given in Table 1.

Twenty-three patients (8.4%) underwent revision surgery for a total of 28 screws (2.3%). All of the symptomatic screws were located in the lumbosacral spine. Of the 18 (1.5%) misplaced screws causing clinical symptoms, we observed medial location in 66.7% ($n = 12$), inferior location in 22.2% ($n = 4$), and superior location in 11.1% ($n = 2$). Radiculopathy directly attributable to the screw misplacement was seen in 16 patients (5.9%), all belonging to the subgroup of severe screw violation. Eight patients (2.9%) developed radicular pain only, whereas 6 (2.2%) and 2 patients (0.7%) developed additional motor and sensory deficits, respectively. All but 1 of these symptomatic patients underwent early revision surgery. An overview of the patients with misplaced pedicular screws who had operative revision of the misplaced hardware is given in Table 2. A case-by-case analysis is given in Supplemental Table 1.

Of the 1236 inserted screws, 28 (2.3%) were replaced—4 (0.3%) belonging to the moderate violation group and 24 (1.9%) belonging to the severe violation group. The incidence of revision of severe misplaced screws was 51.1%. No neurological symptoms were seen in the 4 patients with misplaced screws belonging to the moderate violation group.

DISCUSSION

We present a single-center analysis of 1236 pedicle screws placed with fluoroscopy-guided technique in which 17 different surgeons participated in all procedures. All surgeries were performed under the supervision of 7 board-certified