

## Case Series

# Can Postoperative Radiographs Accurately Identify Screw Misplacements?

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## Abstract

**Study Design:** Retrospective case series.

**Objective:** The objective of this study was to determine the safety of postoperative radiographs to assess screw placement.

**Summary of Background Data:** Previously defined criteria are frequently employed to determine pedicle screw placement on intra-operative supine radiographs. Postoperatively, radiographs are typically used as a precursor to identify screws of concern, and a computed tomographic (CT) is typically ordered to confirm screw safety.

**Methods:** First, available postoperative PA and lateral radiographs were reviewed by 6 independently blinded observers. Screw misplacement was assessed using previously defined criteria. A musculoskeletal radiologist assessed all CT scans for screw placement. Pedicle screw position was classified either as acceptable or misplaced. Misplacements were subclassified as medial, lateral, or anterior.

**Results:** One hundred four patients with scoliosis or kyphosis underwent posterior spinal fusion and had postoperative CT scan available were included. In total, 2,034 thoracic and lumbar screws were evaluated. On CT scan, 1,772 screws were found to be acceptable, 142 were laterally misplaced, 30 medially, and 90 anteriorly. Of the 30 medially placed screws, 80% to 87% screws were believed to be in positions other than medial, with a median of 73% (63% to 92%) of these screws presumed to be in normal position. Similarly, of the 142 screws placed laterally, 49% to 81% screws were identified in positions other than lateral, with a median of 77% (59% to 96%) of these screws felt to be in normal position. Of the 90 anteriorly misplaced screws, 16% to 87% screws were identified in positions other than anterior, with 72% (20% to 98%) identified as normal. The criteria produced a median 52% sensitivity, 70% specificity, and 68% accuracy across the 6 observers.

**Conclusion:** Radiograph is a poor diagnostic modality for observing screw position.

**Level of Evidence:** Level IV.

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**Keywords:** Spinal deformity; Pedicle screw accuracy; Radiograph; CT scan; Pedicle screw misplacements; Posterior spinal fusion

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## Introduction

Pedicle screw misplacement rates have ranged from 20% to 30%, even among more experienced spine surgeons [1-5]. Plain radiographs, fluoroscopy, and CT scans are used to determine screw accuracy. Although CT is considered the gold standard, radiographs and fluoroscopy are readily available and carry a lower radiation burden. However, radiographs and fluoroscopy have been shown to be inferior to CT scan because of their biplanar nature of image acquisition. To overcome this limitation, a variety of radiograph-based criteria have been delineated. These

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criteria can help identify misplacements in the axial (medial or lateral) and sagittal planes (anterior). In 2005, Kim et al. [6] described three criteria to determine screw position on radiographs: (1) violation of the harmonious segmental change of the tips of the inserted screws with reference to vertebral rotation using the posterior upper spinolaminar junction; (2) no crossing of the medial pedicle wall by the tip of the pedicle screw inserted; and (3) violation of the imaginary midline of the vertebral body by the tip of the screw. They reported a sensitivity of 0.87, specificity of 0.97, and accuracy of 0.98 in determining medial misplacements and sensitivity of 0.94, specificity of 0.90, and accuracy of 0.96 for lateral misplacements. These criteria were developed retrospectively from post-op CT scans and have been frequently used by surgeons for intra- and post-operative assessment of pedicle screw placements. Anterior screw misplacements are usually assessed on lateral radiographs by the 80:20 rule (if the screw length in the vertebral body is  $\geq 80\%$  of the width of the vertebral body, the screw is likely anteriorly misplaced) [7,8].

Vallespir et al. [9] used Kim et al. [6] criteria in 11 patients and found poor sensitivity in detecting medial and lateral violations but moderately accurate for both. Validity of these criteria, aside from their study, has not been carried out and its interobserver and intraobserver reliabilities have not been determined. Previous studies have shown poor reliability of radiographs in assessing pedicle screw misplacement [5,10–14]. This is due to the rotational component of the deformity and limitation of radiographs due to its two-dimensional nature. Because screw misplacements occur in the axial plane, value of radiographs even with defined criteria need to be evaluated further. The objective of this study was to evaluate the ability of post-operative radiographs to safely identify misplacements using these criteria in a large number of patients with spinal deformity.

## Materials and Methods

This was an IRB approved study. Inclusion criteria were patients who had (1) scoliosis or kyphosis; (2) primary posterior spinal fusion using all pedicle screw constructs; (3) posteroanterior (PA) and lateral radiographs; and (4) postoperative CT scan on file. The exclusion criteria were patients who underwent anterior or combined anterior and posterior fusions. One hundred four spinal deformity patients operated between January 2004 and December 2010 met the inclusion criteria. All pedicle screws were placed using the free hand technique, as described by Kim et al. [7].

### *Radiograph and computed tomography examination*

The first available postoperative standard PA and lateral radiographs were used to visualize all instrumented levels. Our use of postoperative CT scan has changed over the time

period of data collected for this study. In the early years, the fusion levels were routinely scanned to confirm proper screw placement. In later years, postoperative CT of the entire instrumented spine was obtained only on suspicion of misplacement on radiograph. Multidetector computed tomography (MDCT) was performed on a 16-slice (Mx8000, Philips Medical Imaging, Netherlands) or 64-slice (Light-speed, General Electric Medical Systems, Milwaukee, WI) scanner. Scans were obtained in the axial plane followed by sagittal and coronal reformatting. Parameters used for both scanners included an amperage of 70–275 mA, peak kilovoltage of 120–140 kVp,  $512 \times 512$  matrix, field of view to fit, helical mode with pitch of 0.5, standard algorithm and windowing appropriate for visualization of hardware. Slice thickness on the 64-slice scanner was 3.75 mm with reformatting in three planes to 0.625 mm thickness; slice thickness on the 16-slice scanner was 2 mm with 1–2 mm spacing.

A fellowship-trained musculoskeletal radiologist assessed all CT scans for screw placement. Pedicle screw position was classified as acceptable or misplaced. Misplaced screw was a screw whose central axis was perforating the outer or inner cortical bone, as described by Kim et al. [6]. These misplacements were further sub-classified as medial (OM), lateral (OL), or anterior (OA), depending on the cortical wall violated by the screw.

Postoperative PA and lateral full-length radiographs obtained at the end of surgery or immediately postoperation were reviewed blindly by six independent observers and evaluated for accuracy of screw placement. These consisted of two trained medical students who were part of the spine deformity research team (Observers 1 and 2), two fellowship-trained musculoskeletal radiologists (Observers 3 and 4), two orthopaedic surgeons; one pediatric orthopaedic fellowship-trained (Observer 5), and one spine fellowship-trained (Observer 6). The radiographs were reviewed on PACS (Picture Archiving and Communication System, GE Healthcare, UK), which allows for adjusting magnification, contrast, brightness, and digital measurements. Screw misplacements on postoperative PA radiographs were assessed using Kim et al.'s [6] criteria. Though described for intraoperative supine radiographs, these criteria are commonly used to identify misplacements on postoperative radiographs. A CT scan is usually done if misplacement is suspected. We adapted Kim et al.'s criteria to postoperative radiographs, as these criteria should be independent of patient position and screw placement does not change with position [6]. Although screw relationship with the vertebra can change during manipulation, these criteria should still be applicable and help identify misplacements after manipulation. On lateral radiographs, screw misplacement was assessed using the following criteria: (1) Extension of the pedicle screw tip past the anterior border of the vertebral body (unacceptable—anterior) [6] and (2) ventral screw penetration  $\geq 80\%$  of the width of the vertebral body (unacceptable—anterior)

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