

## Original Article

# Accuracy of percutaneous pedicle screw insertion in spinal fixation of traumatic thoracic and lumbar spine fractures

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Received: 06 January 18 Accepted: 13 March 18 Published: 10 April 18

## Abstract

**Background:** Percutaneous insertion of pedicle screws was developed as a minimally invasive alternative to the different open spinal procedures. Here, we determined the accuracy of percutaneous pedicle screw insertion.

**Methods:** For 60 consecutive patients with thoracic/lumbar spine fractures, computed tomography (CT) studies were utilized to assess the accuracy of percutaneous pedicle screw positioning. A screw was identified as cortical encroachment if the pedicle cortex could not be visualized, while Frank penetration was defined if screw trajectory being located obviously outside the pedicle boundaries [e.g., subdivided as minor (<3 mm), moderate (3–6 mm), and severe (>6 mm)].

**Results:** Sixty patients received 410 pedicle screws placed percutaneously. Of these, 294 screws (71.7%) were ideally placed inside the pedicle. Alternatively, 56 screws (13.6%: 18 cases) showed pedicle encroachment and 60 screws (14.6%: 23 cases) showed pedicle penetration, e.g., 38 (9.2%) minor penetration and 22 (5.3%) were malpositioned (4.8% moderate and 0.5% severe). New postoperative neurological symptoms were identified in two cases (3.3%), where severe screw penetration was identified.

**Conclusion:** Percutaneous pedicle screw insertion in 60 patients receiving 410 percutaneously placed pedicle screws yielded 294 ideally placed, 56 showing pedicle encroachment, 60 (14.3%, 23 cases) exhibiting varying degrees of pedicle penetration, with 2 showing new postoperative neurological deficits (severe screw misplacement). Of interest, this technique proved to be more challenging in the thoracic spine. Larger series are needed to better establish the average rate of neurological injuries associated with percutaneous thoracic/lumbar screw misplacement.

**Key Words:** Fixation, fractures, percutaneous, screw

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**Website:**[www.surgicalneurologyint.com](http://www.surgicalneurologyint.com)**DOI:**

10.4103/sni.sni\_5\_18

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**How to cite this article:** Orief T, Alfawareh M, Halawani M, Attia W, Almusrea K. Accuracy of percutaneous pedicle screw insertion in spinal fixation of traumatic thoracic and lumbar spine fractures. *Surg Neurol Int* 2018;9:78.

<http://surgicalneurologyint.com/Accuracy-of-percutaneous-pedicle-screw-insertion-in-spinal-fixation-of-traumatic-thoracic-and-lumbar-spine-fractures/>

## INTRODUCTION

The percutaneous insertion of pedicle screws into the thoracic and/or lumbar spine (T/L) is a minimally invasive alternative to open surgical techniques. However, it is important to analyze the accuracy, safety, and reliability of the percutaneous T/L screw insertion as screw misplacement may contribute to neurological deficits and instability of the construct (e.g., resulting in screw loosening).

Here, we utilized computed tomography (CT) to document postoperative screw positioning in 60 consecutive patients with traumatic thoracic and lumbar spine fractures (e.g., axial assessment of medial and lateral pedicle penetration/breaches).

## MATERIALS AND METHODS

Within the first week following traumatic spinal injuries, 60 consecutive patients underwent the percutaneous placement of 410 transpedicular screws to address thoracic and/or lumbar (T/L) spine fractures addressing Table 1. Those exhibiting T/L fractures with retropulsed bony segments or the need for spinal decompression were excluded from the study.

Preoperative CT scans were utilized to plan the appropriate screw diameter and length to be utilized intraoperatively. A classical percutaneous technique was utilized to insert 4.5 and 6.5 mm pedicle screws (e.g., depending on the pedicle diameter in the preoperative CT scans).

Within the first postoperative week, screw locations were evaluated on thin-slice CT scans by three independent observers (an experienced spinal surgeon and two senior radiologists). On CT, the cortical walls of the pedicles were examined for bone defects, while the most superior and inferior slices of each pedicle were assessed to detect caudal/cranial screw penetration. Frank screw malpositioning, as defined by Leach and Wiesner, and new postoperative neurological symptoms deficits were assessed for all patients<sup>[3]</sup> [Table 2].

## RESULTS

The highest level of percutaneous instrumentation of this series was T7, and the lowest was L5. Of 410 screws, 175 (42.6%) were placed at the thoraco-lumbar junction (T11–L2) [Figure 1]. According to CT, 294 of 410 screws (71.7%) were ideally placed inside the pedicle (e.g., in the middle on both axial/sagittal CTs) [Figure 2a and b]. In 18 cases, 56 screws (13.6%) showed pedicle encroachment [Figure 3a and b]. In 23 cases, 60 screws (14.6%) showed pedicle penetration, 38 (9.2%) mild, 20 (4.8%) moderate, and 2 (0.5%) showing

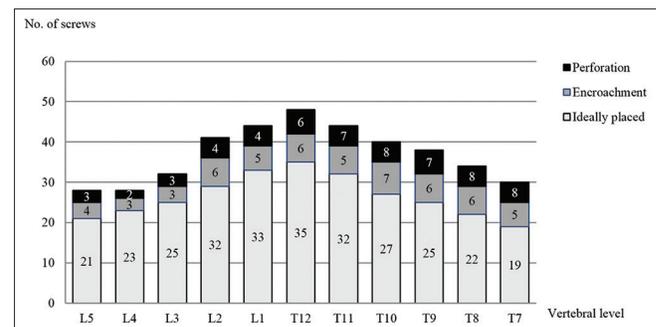
severe pedicle penetration (e.g., at right T11 and L4 pedicles) [Figures 4–6, Table 3].

Only 2 patients (3.33%) exhibited new postoperative neurological deficits. In the first patient, the right L4 root injury was attributed to severe medial screw penetration of the right L4 pedicle: this deficit partially resolved after screw adjustment (motor fully resolved/residual sensory deficit) [Figure 6b]. The second patient exhibited a right L5 pedicle perforation, but improved without additional surgery [Figure 5b].

Four patients had pin tract superficial infection not related to the position of the screws; all were treated with antibiotics, and none of required revision surgery.

## DISCUSSION

The reported misplacement rates for thoracic and lumbar percutaneously placed pedicle screws ranges



**Figure 1:** Chart showing the number of inserted screws (total = 410), and their position in the pedicle per spinal level as evaluated in the post-operative CT; ideally placed screws (white columns), pedicle encroachment (grey columns) and pedicle penetration (black columns)

**Table 1: Characteristics of the studied cases**

Characteristics of the studied cases			
Number		60	
Duration of the study		2014-2017	
Gender	Male	33	Female 27
Age	Range	19-67 years	Mean 43 years
Mechanism of the spine fracture	Motor Vehicle Accident	39 (65%)	Fall from height 21 (35%)

**Table 2: Classification of screw position in the spine**

Classification of screw malposition in the spine	
Encroachment penetration	If the Pedicle cortex could not be visualized
Minor	When screw trajectory was <3mm outside the pedicular boundaries
Moderate	When screw trajectory was 3-6 mm outside the pedicular boundaries
Severe	When screw trajectory was >6 mm outside the pedicular boundaries

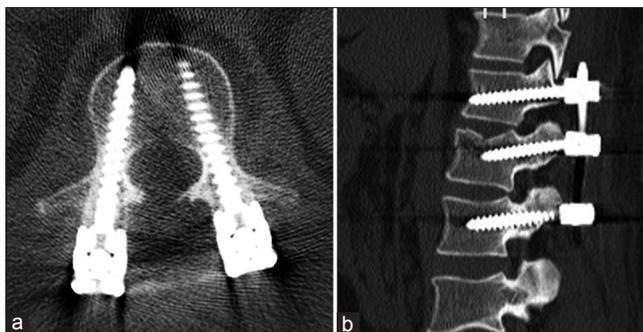


Figure 2: (a) Spine CT image showing ideal screw position inside the pedicle in axial view. (b) Spine CT image showing ideal screw position inside the pedicle in sagittal view

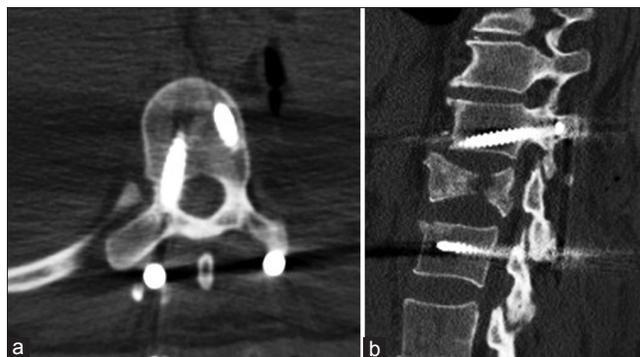


Figure 3: (a) Spine CT image showing screw encroachment of the pedicle in axial and view. (b) Spine CT image showing screw encroachment of the pedicle in sagittal view



Figure 4: (a) Spine CT image showing mild screw penetration of the pedicle (<3mm) in axial view. (b) Spine CT image showing mild screw penetration of the pedicle (<3mm) in sagittal view

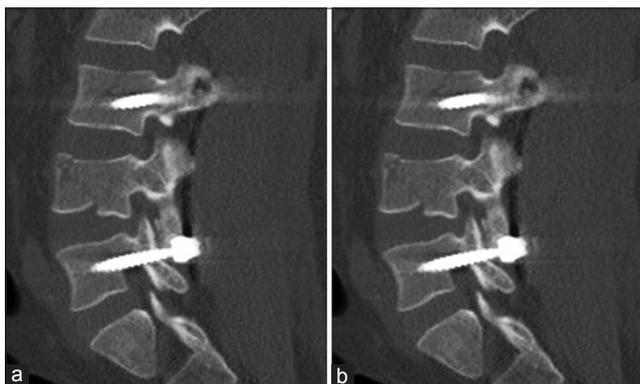


Figure 5: (a) CT image showing moderate screw penetration of the pedicle (3-6 mm) in axial view. (b) CT image showing moderate screw penetration of the pedicle (3-6 mm) in sagittal view

**Table 3: The number and percentage of pedicle encroachment and penetration of the inserted screws according to the post-operative CT images of the studied cases**

Screw position	CT images				Total
	Axial images		Sagittal images		
	Medial	Lateral	Cranial	Caudal	
Encroachment	23 (5.6%)	12 (2.9%)	12 (2.9%)	9 (2.2%)	56 (13.6%)
Penetration					
Minor (<3mm)	16 (3.9%)	8 (1.9%)	6 (1.4%)	8 (1.9%)	38 (9.2%)
Moderate (3-6 mm) <sup>†</sup>	8 (1.9%)	4 (0.9%)	4 (0.9%)	4 (0.9%)	20 (4.8%)
Severe (>6 mm) <sup>†</sup>	2 (0.5%)	0	0	0	2 (0.5%)
Total	26 (6.3%)	12 (2.9%)	10 (2.4%)	12 (2.9%)	60 (14.6%)
	38 (9.2%)		22 (5.3%)		

<sup>†</sup>Moderate and severe screw penetration is considered screw malposition in the presented study

from 8 to 40%.<sup>[2]</sup> In 1988, Weinstein *et al.* showed that simple roentgenograms were insufficient for the evaluation of adequate pedicle screw placement.<sup>[6]</sup> Later, Farber *et al.* documented that CT scans showed 10 times more pedicle violations vs. radiographs.<sup>[1]</sup> Different studies documented varying criteria for CT-documented pedicle screw misplacement.

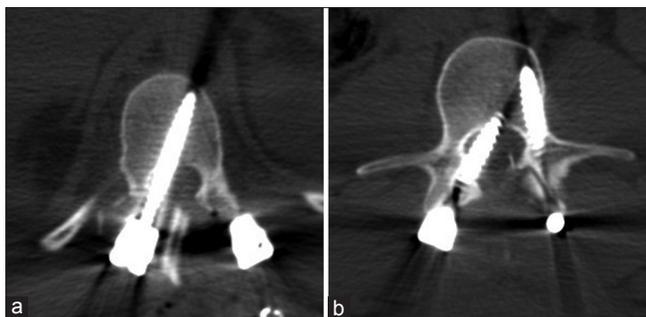
Heintel *et al.* evaluated 111 patients who underwent 502 percutaneous screw placement; 98% of screws were ideally

placed in the pedicle according to their postoperative CT evaluations.<sup>[2]</sup>

Schizas *et al.* reported a 23% incidence of screw penetration (15 patients, 60 percutaneous screws); severe pedicle penetration of 3.3% with an overall screw penetration rate of 30% on sagittal images.<sup>[4]</sup>

In the present study, the authors utilized CT to postoperatively analyze the placement of 410 screws in 60 patients; 294 screws (71.7%) were ideally placed, 13.6% showed encroachment. Another 14.6% demonstrated screw penetration; mild (9.2%), moderate (4.8%), and severe (0.5%) [Table 3]. Of interest, the incidence of screw penetration in the thoracic spine (44 screws, 10.7%) was higher than in the lumbar spine (16 screws, 3.9%) [Figure 1]. The incidence of new neurological deficits resulting from pedicle screw malpositioning was 3.3% (2 cases).

Previously, different studies documented varying criteria for screw misplacement. Heintel *et al.* evaluated 111 patients who underwent 502 percutaneous screw placements; 98% of screws were ideally placed in the pedicle according to the postoperative CT evaluation.<sup>[2]</sup>



**Figure 6: (a) Spine CT image showing severe screw penetration (>6mm) in axial view of the right T11 pedicle. (b) Spine CT image showing severe screw penetration (>6mm) in axial view of the right L4 pedicle**

Here the question is on the accuracy of CT analysis, given the nearly perfect incidence of screw placement. Schizas *et al.* reported a 23% incidence of screw penetration (15 patients, 60 percutaneous screws): severe pedicle penetration of 3.3% with an overall screw penetration rate of 30% was demonstrated on sagittal images.<sup>[4]</sup> In other studies, the frequencies of new neurological deficits ranged from 2 to 5%.<sup>[5]</sup>

## CONCLUSION

Percutaneous thoracic/lumbar pedicle screw insertion is demanding and should only be performed by experienced spine surgeons familiar with the technique of pedicle

screw placement. Notably, it is even more challenging in the thoracic spine. Although the risk of screw misplacement of 5.3% is low, larger series are needed to better establish the average rate of neurological injuries associated with screw misplacement.

## Financial support and sponsorship

Nil.

## Conflicts of interest

There are no conflicts of interest.

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