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Romanian Neurosurgery (2020) XXXIV (1): pp. 20-25
DOI: 10.33962/roneuro-2020-003
www.journals.lapub.co.uk/index.php/roneurosurgery

Accuracy of 2D fluoroscopy with preoperative CT fused neuronavigation in thoracic and lumbar pedicle screw insertion

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Keywords
2D fluoroscopy,
CT-fluoro matching,
image guided surgery,
screw accuracy,
transpedicular screw fixation

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ISSN online 2344-4959
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First published March 2020 by London Academic Publishing www.lapub.co.uk

ABSTRACT

Aim: Pedicle screw fixation is an established technique in the lumbar and thoracic area. Fluoroscopy-guided screw placement and subsequently navigation have decreased the rate of misplaced screws, but no technique has wholly eliminated this risk. This paper aims to study the difference between the accuracy of the fluoroscopic guided screw placement to that of the 2D fluoroscopy- preop CT fused neuronavigation guided technique, a lesser-used navigation technique.

Material and Methods: This retrospective study reflects our results using both techniques between March 2018 and March 2019 in both degenerative or traumatic spinal pathology for thoracic and lumbar regions. The accuracy of the screw placement was measured using Mirza grading system on postoperative CT images.

Results: A total number of 56 patients underwent spinal instrumentation surgery. A total of 274 screws were placed with a mean number of 4.89 screws per patient; 199 screws were implanted using neuronavigation and 75 using the freehand-2D fluoroscopy-guided technique. The accuracy rate of pedicle screw placement in the freehand technique guided by 2D fluoroscopy was 88,00%. With the use of neuronavigation, the accuracy increased to 89,96%.

Conclusion: Pedicle screw placement accuracy is higher when guided by CT-fluoro matching neuronavigation compared to freehand fluoroscopy-guided technique and can be used in departments where there is no intraoperative O-arm or 3D fluoroscopy available.

INTRODUCTION

In the past 30 years, spinal surgery has seen a significant increase in the development of surgical techniques and instrumentation.

Pedicle screw fixation is an established technique in the lumbar and thoracic area (3). There are many techniques of pedicle screw placement starting from the "free hand technique" described by Kim and Lenke (5,17) to modern techniques that use intraoperative image guidance: 2D fluoroscopy, 2D/3D fluoroscopy navigation, cone beam intraoperative CT navigation or intraoperative MRI navigation (11).

Fluoroscopy-guided screw placement has decreased the rate of misplaced screws from 55% to 21% in the thoracic region and from 40% to 12% in the lumbar region (14). Neuronavigation in spinal surgery further decreased the rate of misplaced screws, but no intraoperative navigation technique has wholly eliminated this risk (4,7,13).

Neuronavigation using 2D fluoroscopy- CT fusion is a technique used for pedicle screw placement that was described by Sakai (12). This technique uses a preoperative CT thin cut slice scan that is linked via neuronavigation to a set of intraoperative fluoroscopic images and allows for navigation even in the absence of 3D fluoroscopic C-arms or intraoperative CT machines (12). Despite being introduced more than ten years ago, this technique has not seen wide adoption, and no relevant studies are available to assess its efficacy.

This paper aims to study the difference between the accuracy of the fluoroscopic guided screw placement to that of the 2D fluoroscopy-CT fused neuronavigation guided technique.

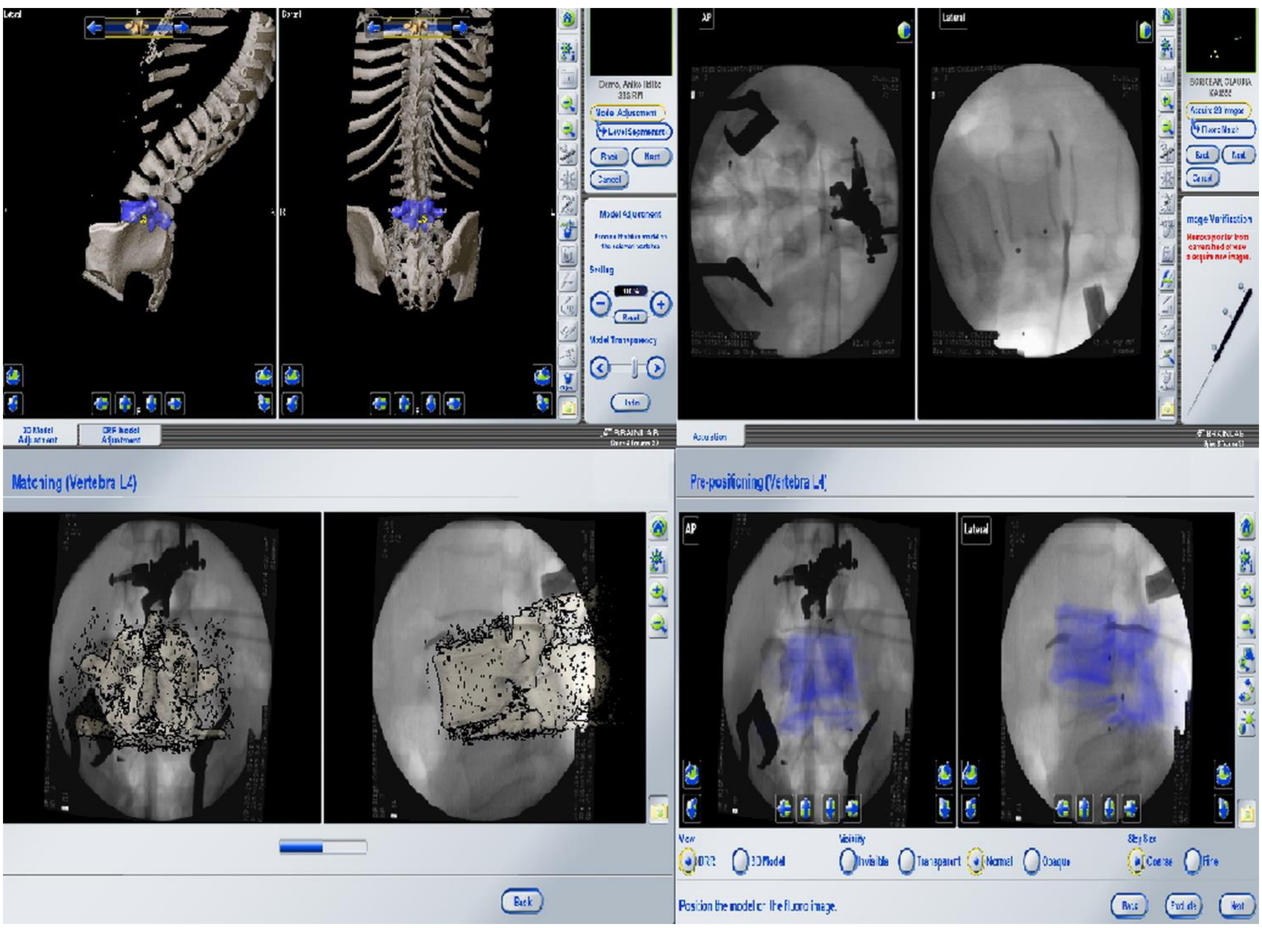

Figure 1: Fusion between the intraoperative fluoroscopy and a 3D model of a vertebra (based on the CT scan) and subsequently registration of the defined vertebra.

Materials and Methods

This retrospective study was performed between March 2018 and March 2019 at the Department of Neurosurgery of the Tîrgu Mureș Clinical Emergency

Hospital, Romania. Patients were operated by a team of multiple neurosurgeons, all with proper levels of spinal instrumentation expertise. The study has included traumatic and degenerative cases in the thoracic and lumbar spine; redo surgeries or repositioning of misplaced screws were not included.

All patients were operated in a prone position using a Bertchtold translucent table (Stryker, Michigan, USA). Intraoperative fluoroscopy was performed in all cases with a Siemens Siremobil Compact L 200 machine (Siemens, Munich, Germany). For cases in which the neuronavigation guided technique was used, a preoperative CT thin cut slice (under 3 mm slices) scan of the operated area was obtained before surgery. A Curve BrainLab (BrainLab, Munich, Germany) neuronavigation system was used in conjunction with a Spine and Trauma software (BrainLab, Munich, Germany) (Figure 1). A fusion between the intraoperative fluoroscopy and a 3D model of a vertebra (based on the CT scan) and subsequently registration of the defined vertebra was performed using Sakai's (12) previously described technique (Figure 1).

Medtronic polyaxially titanium screws (Medtronic, Minnesota, USA) or Stryker (Stryker, Michigan, USA) monoaxial and polyaxially titanium screws with diameters ranging from 4 to 6 mm, and lengths between 40 and 60 mm were used, depending on the spinal level and pedicle width.

There are two commonly used grading systems used for measuring screw placement accuracy: Zdichavsky (18), (9) and Mirza (10) which use postoperative CT images to analyze the pedicle screw placement accuracy. We have chosen to use in our study the Mirza scoring system (Table 2).

Table 1. Demographic distribution.

No. Patients	56	
Sex		
Male	36 (64, 28%)	
Female	20 (35, 72%)	
Age (years)		
Mean	52,76	
Range	20-75 years	
Pathology/Level	**Traumatic**	**Degenerative conditions**
Thoracic	15 patients (26,78%)	0 patients (0%)
Thoraco-Lumbar	1 patients (1,78%)	0 patients (0%)
Lumbar	18 patients (32,14%)	17 patients (30,35%)
Lumbo-Sacral	0 patients (0%)	5 patients (8,92%)
Number of screws implanted	**CT-fluoro-matching neuronavigation**	**2D fluoroscopy Freehand**
THORACAL	46 (23.11%)	32 (42.66%)
LUMBAR	153 (76.88%)	43 (57.33%)

Table 2. Mirza et al. 2 mm increment grading system.

Classification	**Borders**
Grade 0 (optimal)	the screw correctly fits the pedicle
Grade 1 (minor)	under 2 mm of displacement
Grade 2 (moderate)	between 2 to 4 mm of displacement
Grade 3 (severe)	over 4 mm of displacement

Postoperative imaging was analyzed by the senior author (AB) and an independent radiologist. Statistical analyses included descriptive (frequency, mean, standard deviation) and inferential statistics. The Shapiro-Wilk test was applied to determine the distribution of the analyzed data series. For analyzing the quantitative variables the t-Student test was applied for unpaired data and for analyzing the qualitative variables the Fisher test was applied. The significance threshold chosen for the p value was 0.05. Statistical analysis was performed using the GraphPad Prism trial variant.

RESULTS

Between March 2018 and March 2019, a total number of 69 patients underwent spinal instrumentation surgery in the thoracolumbar regions for degenerative or traumatic pathology. Out of these, 56 patients (81.16%) had complete documentation and were included in our study. Second surgery for repositioning of screws was necessary in 2 screws (2 cases).

A total of 274 screws were placed with a mean number of 4.89 screws per patient, ranging from 4 screws to a maximum of 10 screws. In our study, traumatic pathology was represented by 60.71% (n=34) of cases, and the lumbar spine was the most frequent region involved with 39.29% of cases (n=35). Table 1 summarizes the clinical data and demographic distribution of the patients.

The CT fluoro matching neuronavigation method was used in 72.63% of cases, which resulted in a total of 199 screws implanted; the rest of 75 (27.37%) screws were implanted using the" freehand" technique under fluoroscopy guidance. The distribution of screws by region and the type of technique used is seen in Table 1.

The results of the Mirza 2 mm increment staging system are presented in Table 3 for medial and lateral displacement and Table 4 for the correlation between the severity of displacement and anatomic region.

From 20 mispositioned screws implanted under neuronavigation guidance, 11 screws were in the lumbar area and 9 screws in the thoracic area. The misplaced screws in the thoracic area represented 19.57% of the total number of 46 screws implanted, whilst in the lumbar area, the misplaced screws represented 7.19% of the total of 153 screws implanted. All severly placed screws were in the thoracic area (Table 4). There is a statistically significant association between the region of screw implantation and the malposition rate (p = 0.023, Fischer's test).

Table 3. Grade of screw misplacement using the 2 mm increment (Mirza score) classification and screws direction tendency of cortex perforation.

Severity	Minor (%)	Moderate (%)	Severe (%)	Total (%)	P
Lateral misplacement with Neuronavigation	6 (3.01%)	4 (2,01%)	1 (0,50%)	11(5,52%)	0.55
Lateral misplacement with Fluoroscopy	1 (1,33%)	1 (1,33%)	1 (1,33%)	3 (4%)	
Medial misplacement with Neuronavigation	8 (4.02%)	1 (0,50%)	0 (0%)	9 (4,52%)	0.99
Medial misplacement with Fluoroscopy	5 (6,66%)	1 (1,33%)	0 (0%)	6 (8%)	

Table 4. Grade of screw misplacement using the 2mm increment (Mirza score) classification relative to the vertebral region.

2D Fluoroscopy Freehand	Number of screws (%)	Misplacement rate (%)			p value
		Minor	Moderate	Severe	
Thoracal	32 (42.66)	4 (8.69%)	4 (8.69%)	1 (2.17%)	0.1585
Lumbar	43 (57.33)	10 (6.53%)	1 (0.65%)	0 (0.00%)	
Total	75	20			
CT- fluoro- Matching Neurnavigation					
Thoracal	46 (23.11%)	4 (12.50%)	1 (3.12%)	1 (3.12%)	0.0231
Lumbar	153 (76.88%)	2 (4.65%)	1 (2.32%)	0 (0.00%)	
Total	199	9			

Discussions

This study tries to reflect our experience in transpedicular screw implantation. We focused on the accuracy of transpedicular screw implantation using the two implantation procedures that are used at our institution: freehand technique under fluoroscopy guidance and neuronavigation with CT-2D fluoro-matching.

There are few articles in the literature about pedicle screw implantation that include CT-fluoro-matching neuronavigation or compare this technique with the freehand technique under fluoroscopic guidance (15), and to our knowledge this is the first series presented. This might be because intraoperative 3D fluoroscopy or intraoperative CT has become widely available.

Scoring the screw misplacement is still a difficult task as there are reported more than 35 classifications that analyze pedicle screw misplacement and, in most of them, there is no clear description of the assessment methods used to determine the accuracy of the pedicle screw positioning (2,6). Evermore there are publications showing that moderate lateral or medial displacement of the screws with violation of the pedicle cortex does not commonly relate with neurologic, vascular, and/or visceral complications (8).

We have chosen Mirza scoring system(10) because this seems to be the most widely accepted and one of the most precise scale for scoring pedicle screw placement. (1)

Our overall accuracy rate of pedicle screw placement using the freehand technique guided by 2D fluoroscopy was 88.00%. With the use of the neuronavigation, the accuracy increased to 89.96%. Nevertheless, our results are comparable to different other papers:

- The screw misplacement rate in our study was of about 12% in the fluoroscopy technique group, and pedicle cortex perforation over 4 mm (severely misplaced screw) was seen in 1.33%, comparable to the results previously published by Guedes and Verma (2),(16).
- In our CT-fluoro navigation group, a slight increase in the overall accuracy was noted. Even if this increase in accuracy is not statistically significant, these results are similar to the ones of Kosmopoulous (6), showing over 90% accuracy rate for both techniques, and might be partially explained by good fluoro screw positioning technique.
- Gelalis (3) concluded that neuronavigation increases the accuracy of pedicle screw placement and when using freehand technique there is an increased tendency of medial perforation of pedicle cortex as opposed to neuronavigation where the tendency is to perforate the cortex laterally which decreases the risk of neurological complication even in case of inaccuracy. Our results seem to reconfirm this as in the CT-fluoro group we noted a slight increase in the lateral displacement (5,52% vs. 4%) but also a 50% reduction of medial misplacement (4.52% vs. 8%) (Table 3.)

There are also inherent limitations to CT-fluoro matching neuronavigation technique: due to the acquisition of the preoperative spine CT in the supine position and the prone position in the operating room, a spine displacement most likely occurs and interferes with the accuracy(8). Scanning patients in prone position or spine curvature detection algorithms might further improve this technique. Inaccuracies are also given by the need to fuse a 3D vertebral body model to a 2D intraoperative fluoroscopy, and a less than perfect thoracic imaging allows for navigation errors and screw misplacement that is higher than the rate we obtained in lumbar spine, but still lower than freehand fluoroscopy technique.

Conclusion

Despite its shortcomings, the CT-fluoro matching technique has similar or slightly better results than freehand fluoroscopy and can be used in departments where there is no intraoperative O-arm or 3D fluoroscopy available and a more affordable neuronavigation solution is required.

Conflicts of interest

The authors of this paper state that they have no conflict of interests to disclosure.

Abbreviations

MRI: magnetic resonance imaging
CT: computer tomography
2D: two-dimensional
3D: three-dimensional

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