The Egyptian Journal of Hospital Medicine (April 2021) Vol. 83, Page 1096-1100

Clinical Correlation with Postoperative Computed Tomography Assessment of the Accuracy of Lumbar Pedicular Screws Insertion

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ABSTRACT

Background: Pedicle screw instrumentation is widely used in the lumbar spine as a means of stabilization to enhance arthrodesis. For accuracy, pedicle screw instrumentation may be guided by anatomic landmarks, preoperative imaging, and intraoperative imaging tools such as plain radiography, fluoroscopy, and, more recently, image-guided technology. **Objective:** Improving accuracy of lumbar pedicular screws insertion and clinical outcome of patients undergoing lumbar pedicular fixation.

Patients and Methods: This cohort study was done at Neurosurgery Department at Alexandria Armed Forces Hospital and Neurosurgery Department in Zagazig University. Assuming that attendance rate of patients for lumbar pedicular fixation is 3 patients per month, the sample size was 36. All patients were taken as a comprehensive sample. Patients confirmed to have been underwent transpedicular lumbar fixation.

Results: In assessing 153 pedicle screws inserted in 36 patients. Out of 51 misplaced screws; lateral screw misplacement was observed in 28 screws (54.9 %) and medial pedicle wall violation in 22 screws (43.1 %) and inferior misplacement in one patient. The remaining 102 screws (67.55 %) were judged as correctly inserted. Of the 51 misplaced screws, 34 misplaced screws were classified as minor (cortical perforation ≤ 2 mm), 15 screws moderate (2–4 mm), and 2 screws severe penetration (> 4 mm).

Conclusion: Pedicle screw insertion carries risk of pedicular wall violation even in experienced hands even though intraoperative fluoroscopy is used. However; most violations are minimal with no clinical consequences and can be evaluated best by CT scan not plain X-ray.

Keywords: CT, Lumbar Pedicular Screws Insertion, X-ray.

INTRODUCTION

Pedicular lumbar screws are widely used in spine surgery for stabilization to enhance arthrodesis. Indications for pedicular lumbar screws include stabilization in setting of trauma, deformity, tumors, infections, degenerative conditions and reconstruction [(1)]. The accuracy of pedicle screw insertion is crucial for the efficiency and stability of the surgical procedure and to minimize the risk of iatrogenic injury of vital anatomic structures surrounding the pedicle dural sac (medially), the nerve roots (superiorly and inferiorly) and the vascular structures (anterolaterally) [(2)]. For accuracy, instrumentation may be guided by anatomic landmarks, preoperative imaging and intraoperative imaging tools as plain radiography, fluoroscopy and more recently image-guided technology [(1)].

Concerns regarding safety, potential complications of screw misplacement and pedicle wall violation have focused attention on screw placement techniques [(3)]**.** In open surgery free hand pedicle screw insertions are reported to carry a risk of screw malposition up to 40% [(4)]. Although neurological deficits related to screw malposition are less common, asymptomatic violation of cortical bone can result in a weakened biomechanical construct [(5)].

Postoperatively new complaints of pain or neurological deficit must be evaluated. With the use of pedicle screw system. It becomes imperative that a causal relation between the screws and neurological complications should be ruled out [(3)]. CT imaging is more accurate than conventional radiography in determining pedicle screw location [(6)].

AIM OF THE WORK

Improving accuracy of lumbar pedicular screws insertion and clinical outcome of patients undergoing lumbar pedicular fixation.

PATIENTS AND METHODS

This cohort study was done at Neurosurgery Department at Alexandria Armed Forces Hospital and Neurosurgery Department in Zagazig University. Assuming that attendance rate of patients for lumbar pedicular fixation is 3 patients per month, the sample size was 36. All patients were taken as a comprehensive sample. Patients confirmed to have been underwent transpedicular lumbar fixation.

Inclusion criteria: Inclusion criteria included any patient undergoing lumbar spine pedicle screw fixation for degenerative, traumatic, or neoplastic lesions. No age or sex restrictions were applied.

Exclusion criteria: Deformity.

Tools and Instrument: Full history taking. General examination, back examination. Neurological examination. Lumbar radiographs and postoperative CT scan.

Received:17 /6 /2020
Accepted:26 /8 /2020

Operational design: All cases were subjected to clinical and radiological examination.

Clinical examination:

1. **Full personal history taking:** Including name, age, sex and symptomatology including back pain and lower limb pain.
2. **Examination:** Vital signs. Sensory deficits. Motor deficits. Sphincter dysfunction. Back examination and deformity. Straight leg raising test. Examination after effort.
3. **Investigations:** (i) Routine laboratory investigations. (ii) Radiological investigations: (a) Plain X-ray of lumbosacral spine. (b) Computed tomography of lumbosacral spine. (c) Magnetic resonance imaging.

Surgery: The screw entry point was identified by using anatomical landmarks locating the intersection of the transverse process with the corresponding facet and the trajectory of the screw was confirmed by intraoperative radiographs.

Preoperative preparation: This included history taking, clinical examination, laboratory and radiological investigations, selection for surgery, fasting of the patient at the night of surgery, prophylactic antibiotics, shaving of skin at the operative field and proper sterilization using betadine antiseptic solution. The indications for surgical fixation in our cases were as follows, 19 patients with spondylolisthesis, 6 patients with traumatic fracture, 5 patients with recurrent disc prolapsed, two patients with disc prolapse and 4 patients with lumbar canal stenosis.

Postoperative management: Preoperative antibiotics were continued for 10 days postoperatively. Narcotic analgesics were used in the first 24 hours. Non-steroidal anti-inflammatory drugs were used for seven to ten days. Corticosteroids were used in some cases. Oral diet rich in protein, vitamins and calcium was started in the second day. Patients were ambulant in the second postoperative day.

Postoperative evaluation: Postoperatively all patients were evaluated neurologically to assess new radicular pain or deficits if present. Postoperative routine anteroposterior and lateral plain radiographs was performed within 48 hours after surgery. CT scan with 2 mm axial slices with bone window was performed in all cases to evaluate implant position 2 weeks after surgery. These images were inspected for evidence of pedicle violation and the screws were classified according to their position within or outside the pedicle. Misplaced screws were classified according to direction to superior, inferior, lateral and medial. Also they were classified according to degree of misplacement to minor (<2 mm), moderate (>2 mm and <4 mm) and severe (>4 mm). Pain was assessed according to VAS score in the back and lower limbs after surgery and followed up for 3-6 months. Correlation between clinical symptoms and radiological violation was reported.

Ethical approval and written informed consent: **An approval of the study was obtained from Zagazig University Academic and Ethical Committee.** Every patient signed an informed written consent for acceptance of the operation.

Statistical analysis: Recorded data were analyzed using the statistical package for the social sciences, version 20.0 (SPSS Inc., Chicago, Illinois, USA). Quantitative data were expressed as mean± standard deviation (SD), median, and range. Qualitative data were expressed as frequency and percentage. Independent-samples t-test of significance was used when comparing between two means. Chi-square (X^2) test of significance was used in order to compare proportions between two qualitative parameters. P-value <0.05 was considered significant. P-value <0.001 was considered as highly significant. P-value >0.05 was considered insignificant.

RESULTS

The age and sex distribution of patients included in this study are shown in table 1.

Table (1): Age and sex distribution (N=36)

		Age	
Mean± SD		39.91±12.06	
Median (Range)		42.0 (21-60)	
		N	%
Sex	**Male**	23	63.9
	Female	13	36.1
	Total	36	100.0

66.7% of the patients improved regarding motor outcome and 86.1% as regard sensory outcome (Table 2).

Table (2): Outcome distribution among studied group at immediate post

		N	**%**
Motor	**Not**	12	33.3
	Improved	24	66.7
Sensory	**Not**	5	13.9
	Improved	31	86.1
	Total	36	100.0

72.2% improved regarding motor outcome and 100.0% regarding sensory outcome (Table 3).

Table (3): Outcome distribution among studied group at late postoperative

		N	**%**
Motor	**Not**	10	27.8
	Improved	26	72.2
Sensory	**Not**	0	0.0
	Improved	36	100.0
	Total	36	100.0

Minimal breach group significantly associated with better post sensory result and late motor result (Table 4).

Table (4): Relation between motor and sensory outcome and breaching

			CT Finding		Total	P
			Minimal	**Moderate and severe**		
Post Motor	**Not**	**N**	5	7	12	0.091
		%	22.7%	50.0%	33.3%	
	Improved	**N**	17	7	24	
		%	77.3%	50.0%	66.7%	
Post Sensory	**Not**	**N**	0	5	5	0.003*
		%	0.0%	35.7%	13.9%	
	Improved	**N**	22	9	31	
		%	100.0%	64.3%	86.1%	
Late Motor	**Not**	**N**	3	7	10	0.018*
		%	13.6%	50.0%	27.8%	
	Improved	**N**	19	7	26	
		%	86.4%	50.0%	72.2%	
Late Sensory	**Not**	**N**	0	0	0	1
		%	0%	0%	0%	
	Improved	**N**	22	14	36	
		%	100.0%	100.0%	100.0%	
Total		**N**	22	14	36	
		%	100.0%	100.0%	100.0%	

*: Significant difference.

No significant difference was found between groups regarding VAS (Table 5).

Table (5): VAS comparison between different degrees of breaching

	Minimal	**Moderate and severe**	**P**
VAS back	5.18±1.36	5.57±1.56	0.453
VAS LL	5.91±1.3	5.71±1.72	0.703
Post VAS back	2.59±0.85	2.5±0.94	0.766
Post VAS LL	1.74±0.51	2.1±0.07	0.202
Late VAS back	0.86±0.25	1.07±0.37	0.205
Late VAS LL	0.27±0.08	0.35±0.12	0.604

Significant decrease in VAS in studied group (Table 6).

Table (6): Change assessment of VAS

	Mean	**Std. Deviation**	**P**
VAS back	5.3333	1.49284	<0.01*
Post VAS back	2.5556	0.87650	
VAS LL	5.8333	1.46385	<0.01*
Post VAS LL	1.7222	1.03126	
VAS back	5.3333	1.49284	<0.01*
Late VAS back	0.9444	0.47476	
VAS LL	5.8333	1.46385	<0.01*
Late VAS LL	0.3056	0.46718	

*: Significant difference.

The clinical and radiological correlation about misplaced screws that were corrected surgically are shown in table 7.

Table (7): Clinical and radiological correlation about misplaced screws that were corrected surgically

Surgical, radiological level	L3	L4	L5
Direction of displacement Medial	1 screw	1 screw	1 screw
			1 screw
Lateral		2 screw in the same vertebra	
Degree of displacement	Severe	Moderate	Moderate
		1 moderate and 1 severe	Moderate
Technique of insertion	Open	Open	Open
		Open	Open
New onset of symptoms	Pain and weakness	Pain and weakness	Pain and weakness
			pain
Outcome after repositioning	Improved	Improved	Improved
		Reoperated for good fixation	Improved

DISCUSSION

The technique used for insertion of pedicle screws was the standard surgical technique as described for open surgery [7]. Evaluation of screw placement was performed according to the criteria published by **Learch *et al.*** [8].

Screw placement was considered correct when the screw was completely surrounded by the pedicle and no portion of the screw perforated outside the cortex. Penetration of the pedicle screw was measured in millimeters using the scale on the CT image. If the penetration of the pedicle screw was 2 mm or more along the pedicle inferiorly, superiorly, laterally, medially, or anywhere from the corpus, it was assessed as misplaced. Penetration was further subdivided—based on measurement of the distance that the edge of the screw thread extended outside the pedicle cortex—into minor (≤ 2.0 mm), moderate (2.1–4 mm), and severe (> 4 mm). Depending on the direction of the pedicle violation, the screw misplacement was noted as lateral, medial, inferior, or superior, and right or left. The incidence of intra and postoperative complications not related to screw position as well as hardware failures were also registered, with a minimum follow-up duration of 6months [9].

When reviewing our results, the incidence of misplaced screws evaluated using CT scan to detect cortical breach even less than 2 mm was 51/153 screws (33.33 %). This general incidence of misplaced screws in our study is in accordance with most published literature results evaluating incidence of misplacement of pedicle screws following lumbar insertion [10, 11].

Farber *et al.* [12] inserted 76 pedicle screws in 16 patients and evaluated the sensitivity of radiographic assessment of cortical perforation using CT as the gold standard. In their study 21/74 (28%) of pedicle screws breached the medial pedicle cortex on postoperative CT evaluation, even though they have done intraoperative palpation of pedicles though midline laminectomies during screw insertion.

When comparing the incidence of misplacement in X-ray in our study, we didn't find a single case of screw violating the pedicle or considered as misplaced, however, when assessment is done using the CT scan postoperatively, we found 51 screws breached the cortex. In 2004, **Ahlgren *et al.*** [10] has also compared CT scan and plain radiography of lumbar pedicle screw accuracy and has documented 10 times definite violation than did plain X-ray.

We definitely attribute this to the fact that we inserted all screws under fluoroscopic imaging by which screws in rostral caudal orientation are clearly visualized, however, postoperative CT scan visualized also mediolateral penetrations, which were not clearly identified intraoperatively. This fact is agreed by authors who conducted cadaveric studies as pedicle screw insertion using fluoroscopy [13].

As we focus on the anatomical incidence of CT assessed penetration of the pedicle by inserted screws in our study, we found that the incidence of lateral wall penetration was more common than medial penetration. Where lateral wall penetration occurred in 28 screws, while medial wall penetration occurred in 22 screws. Our interpretation for this occurrence is the fact that surgeons while inserting screws are aware that medial penetration is more likely to cause neurological injuries, thus they tend to keep entry and trajectory in mind, so as to minimize possibility of medial penetration. In addition, most cases are concluded by laminectomies through which the surgeon evaluates the corresponding pedicles for possible feeling of screw sensation using surgical instruments, as also was described by other authors [14]. In 2004, **Krag *et al.*** [15] while conducting a morphometric study using reconstructed computerizing tomography of pedicular isthmic screws also found that incidence of lateral perforations were more common than medial perforation.

The main interest in conducting such studies is to evaluate the clinical impact of screw positions on the patient's symptomatology. In clinical practice, the incidence of neurological deficit resulting from pedicle screw insertion may result from perforation of cortex and compression or injury of neurological structures adjacent to the pedicle including nerve roots or thecal sac in the central canal. Anatomically, the pedicle is separated from the dura by skinny layer of epidural fat of about 2 mm thickness. Thus injury is more likely with medial perforation [10, 11].

When evaluating our results, we found that patients who developed new symptoms related to screw insertion were few. Only 3 (8.3%) patients had developed symptoms that can be explained by cortical violation and nerve root irritation. Lumbar levels cortical perforation was in L5 is 14 /58 (24.1%) screws, in L4 22/58 (37.9%) screws, in L3 12/22 (54%) screws, in L2 3/7 (42.8%) displaced screw and in L1 no displaced screws.

We and others agree that it is more likely to violate the pedicle when more pedicular inclinations are present [16].

We had no cases of central canal encroachment causing cauda equina lesion. However, we had only 3 (8.3%) patients who developed pain and weakness following fixation that had radicular symptoms and could be related to screw position. In those 3 cases, screws had done medial perforation, and required correction. They had improved after correction.

In all other cases where radiological CT has demonstrated pedicle wall perforations, these cases were asymptomatic except one case with bilateral displacement L4 screws that was reoperated for good fixation. Ultimately patient symptoms are probably the most impacted factor in determining acceptable positioning of the screw [11].

In a study done by **Lotfinia *et al.*** [17] radicular pain and neurological deficit were observed in 8 patients of 53 who underwent pedicular screw fixation (15.09%) of all patients.

CONCLUSION

Pedicle screw insertion carries risk of pedicular wall violation even in experienced hands even though intraoperative fluoroscopy is used. However; most violations are minimal with no clinical consequences and can be evaluated best by CT scan not plain X-ray. Minor displacements don't require corrections, while screws causing symptoms must be redirected

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