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Original Research

Accuracy of pedicle screw placement in posterior lumbosacral instrumentation by computer tomography evaluation: A multi-centric retrospective clinical study

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HIGHLIGHTS

- L_5 and S_1 are not safe when inserting pedicle screws as expected.
- The incidences of high risk breach and inferomedial breach occur more in L_5 and S_1.
- The pedicles of L_5 and S_1 are special on their morphology.

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ABSTRACT

Background: Pedicle screw misplacement rates are relatively high with fluoroscopically guided techniques. However, breach rates in the 5th lumbar and the 1st sacral spines in conventional operations have not been specifically concerned because of their broad cross sections. It's a retrospective study to evaluate the accuracy and safety of pedicle screw placement in posterior lumbosacral instrumentation under CT scan with reconstruction.

Materials and methods: 401 patients were evaluated under CT scan with reconstruction in 3 hospitals by 2 professional observers after posterior lumbosacral instrumentation including 152 3rd lumbar spines (L_3), 219 4th lumbar spines (L_4), 270 5th lumbar spines (L_5) and 95 1st sacral spines (S_1) with screws placed. Patients were followed for potential clinical symptoms.

Results: In a total of 1467 instrumented pedicles, there were 371 pedicle breaches. Of these, the segment of the breached pedicles were L_3: 91/301 (30.2%), L_4: 126/436 (29.0%), L_5: 132/539 (24.5%), S_1: 22/191 (11.5%). For severe violation from L_3 to S_1, 8/91 (8.8%), 8/126 (6.3%), 19/132 (14.4%), 8/22 (36.4%) were confirmed respectively. Furthermore, the inferomedial breach sites quantified from L_3 to S_1 were 43/91 (47.3%), 74/126 (58.7%), 99/132 (75%), 19/22 (86.4%) respectively. And there were 9 cases of cerebrospinal fluid leakage and 3 cases of neurological deficit.

Conclusion: L_3, L_4 and L_5 have no significant differences in pedicle breach rates. The incidences of high risk pedicle breach (grade III, grade IV) are higher in L_5 and S_1, and the breach sites are more common in the inferomedial wall of L_5 and S_1 than that of L_3 and L_4. Many surgeons took it for granted that L_5 and S_1 were safe when inserting pedicle screws, but they are not safe as expected actually.

1. Introduction

As posterior pedicle screw placement was first described by Boucher [1] in the 1950s, this method has steadily improved and gained popularity. Pedicle screws are currently placed in the

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lumbar spine via three main techniques: freehand, fluoroscopy guidance and stereotactic navigation [2]. The implementation of pedicle screws based on anatomical landmarks and intraoperative fluoroscopy seems to be most widespread in spine surgery, especially in developing countries, for its relatively handy equipment and mature technique.

Regardless of improving skills and advanced instruments [3], knowledge of spinal anatomy, established landmarks, and tactile feedback are still critical in posterior pedicle screw placement [4]. As previous literature shows, posterior pedicle screw fixation can provide strongest support for the spinal stability [5]. However, various complications, including cortical breach, vascular or nerve injury, cerebrospinal fluid leakage [6], may occur because of narrow pedicles or unskilled technique. Since many vital tissues like neural elements are in close relationship to the pedicles, neural damage may occur particularly when the medial or inferior cortex of the pedicle is penetrated.

Lumbosacral spines, including the 3rd lumbar spines (L_3), the 4th lumbar spines (L_4), the 5th lumbar spines (L_5) and the 1st sacral spines (S_1), are common sites undergoing posterior instrumentation because of more spinal disorders present. Surgeons always considered L_5 and S_1 as the safest segments for their comparatively wide pedicles. However, the anatomical structures of pedicles of L_5 and S_1 are very special. The goal of the study is to describe the clinical accuracy and safety of different lumbar segments in the placement of posterior pedicle screws via fluoroscopy guidance, especially in L_5 and S_1 due to clinical findings.

2. Materials and methods

2.1. Patient demographics

It was designed as a retrospective study. 401 patients with conventional posterior pedicle screw fixation for degenerative spinal diseases or spinal fractures were recruited from 3 different hospitals. The patient demographics were all collected from January 2014 to April 2015 with similar parameters among 3 hospitals (Table 1 and Table 2). All patients were followed up by outpatient visits or phone calls for three to six months. The lesion segments for operations were from L_3 to S_1. Inclusion criteria: (1) indications included herniated disk, spondylolisthesis, stenosis and fracture; (2) the pedicles were intact with preoperative CT scan; (3) the patients were treated by fluoroscopically guided posterior pedicle screw fixation and the segments for pedicle screw instrumentation ranged from L_3 to S_1. Exclusion Criteria: (1) the patient suffered posterior lumbarosacral surgery previously; (2) the patient did not receive postoperative CT scan and reconstruction. The surgeries were performed by 3 different attending spine surgeons, who all have rich experience in spine surgery from 3 different hospitals.

2.2. Operative procedures

The operation was designed for a conventional open approach and conventional C-arm fluoroscopy was used. Pedicle diameter and length were measured before surgery on CT scans for selection of adequate screw size. Patients were placed in prone position on a radiolucent standard operating table. With a series of sophisticated operations, the anatomical structures, including lamina, transverse process, superior and inferior articular processes, were clearly exposed. The involved segment was localized with the help of C-arm fluoroscopy. Next, the entry point was defined according to the anatomic landmarks [7–9] and the pedicle screws would be driven into lumbar vertebra via pedicles. In this processing, fluoroscopy would be applied for guiding the direction of the screws through the pedicles. The ideal screw position was parallel to the superior endplate of the instrumented vertebrae in lateral view and convergent angulation from lateral to medial in anterior-posterior view. Afterwards, lumbosacral spinal lesions would be treated accordingly. In the end, the anticipated bending rods were installed on the screws for the reduction and fixation. The fixation position would be eventually verified by the conventional C-arm fluoroscopy.

2.3. Radiographic evaluation of accuracy

Postoperatively, the screw positions in the pedicles were verified by using a sophisticated computed tomography protocol with axial, sagittal and coronal images as described in Fig. 1. Images were obtained using a 16-detector-row helical CT scanner (Siemens, Germany). The spine protocol generated 0.7-mm source slices. Dosage parameters were 120 kV and software-based modulated mAs of maximum 200 sure exposure. Sagittal and coronal sections were reconstructed in 0.7-mm thickness from the raw data. In addition, window width and window level of CT images were modulated with the aid of professional software, which could eliminate the great majority of influence of metal artifact. The images were assessed by a resident and a fellow spine surgeon independently. When the assessment was inconsistent with each other, the images would be judged by an attending surgeon eventually. Analysis of the CT scan included the following data as breach grades and locations. Screw breach grade was classified as presented in Table 3 [10–12]. The location of perforation was divided into inferomedial, lateral or superior. Neurological deficits as well as other postoperative complications were registered.

2.4. Statistics

The chi-squared test was used for measuring association between categorical data and the student's t-test for comparison of means between groups. Measurement data were expressed as $\bar{x}\pm s$. A P-value of <0.05 is considered statistically significant. In addition, the study utilized kappa test for the consistence of 2 independent observers in evaluating the CT scan and characterized kappa over 0.75 as excellent, 0.40 to 0.75 as fair to good, and below 0.40 as poor [13].

3. Results

3.1. Pedicle screw accuracy

401 operated patients, with 1467 screws inserted from L_3 to S_1, received CT scan in 24–48 h postoperatively. In evaluating the grades and locations of pedicle breach by kappa analysis, the

Table 1
Demographics and parameters of the patients selected from 3 different hospitals. 4 different pathologies, including herniated disks, spondylolisthesis, stenosis and spinal fractures, were stratified collected.

Patient Demographics and Parameters				
	hospital A	hospital B	hospital C	Total
Patient no.	124	146	131	401
Mean age (y)	58.8 ± 12.4	54.9 ± 11.7	56.2 ± 13.5	56.0 ± 13.0
Male (%)	66 (53.2%)	84 (57.5%)	76 (58.0%)	226 (56.4%)
Female (%)	58 (46.8%)	62 (42.5%)	55 (42.0%)	175 (43.6%)
Indication				
Herniated disk	64	71	38	173
Spondylolisthesis	27	24	10	61
Stenosis	33	14	23	70
Fracture	0	37	60	97