CONFIRMATION OF ACCURACY/INACCURACY OF LUMBAR PEDICLE SCREW PLACEMENT USING POSTOPERATIVE COMPUTED TOMOGRAPHY

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INTRODUCTION

Transpedicular screws are extensively utilized in the lumbar spine to address instability (i.e., degenerative lumbar spondylolisthesis/deformity, infection, tumors, and other). Computed tomography (CT) scans best document adequate screw position, while also excluding other pathology (i.e., hematomas/seromas).

Routine intraoperative conventional fluoroscopy used for pedicle screw placement has been associated with up to a 40% rate of iatrogenic neural/vascular/other injury, in some cases warranting surgical revision.
Here, we compared the utility of 24–48 h postoperative X-rays versus 2-week postoperative CT scans in confirming the adequacy of pedicle screw placement or the documentation of extent of medial/lateral pedicle breaches.

MATERIALS AND METHODS

Over a period of 6 months, a consecutive series of 612 pedicle screws were primarily or secondarily placed from L1-L5 in 145 patients. Lumbar fusions were performed for degenerative lumbar disease, degenerative spondylolisthesis, spinal deformity, trauma, or neoplastic lesions [Tables 1 and 2]. The series included 93 males (64.1%) and 52 females (35.9%), averaging 39.3 years of age (range 21–60 years old). Notably, patients presented with varied clinical syndromes and neurological deficits [Table 1].

Surgery

Intraoperatively, pedicle screws were placed utilizing fluoroscopy alone. Routine anteroposterior and lateral plain radiographs were then obtained within 48 h postoperatively, while CT studies were performed at 2 postoperative weeks (i.e., the time of postoperative visits) CT grades for pedicle screw placement included: adequate screw location, or minor (<2 mm), moderate (>2 and <4 mm), or severe (>4 mm) misplacement. In addition, screw positions were correlated with outcomes (i.e., using visual analogue scale [VAS] scores) and with back/lower extremity pain lower limb (LL), both immediately, at 48 h, and 6 months postoperatively.

Data analysis

Data were analyzed using the Statistical Package for the Social Sciences, version 20.0 (SPSS Inc., Chicago, Illinois, USA), and P <0.05 was considered statistically significant.

RESULTS

We found that 467 (76.3% of total) pedicle screws were adequately placed, while 104 (16.9%) had minor, 34 (5.6%) had moderate pedicle breaches; none required repeated surgery. The most common level for a breach was at the L4 level (i.e., 28.3% of L4 screws were misplaced) [Table 2]. The incidence of lateral wall penetration was more common than medial penetration (81 screws vs. 64 screws, respectively) [Figures 1 and 2, Table 3]. Postoperative neurological events after pedicle screw insertion were documented in 7 patients (1.1% of total screws).

Severe pedicle breaches were all requiring urgent/emergent surgical correction. At these latter reoperations, the entry points were rechecked with biplanar intraoperative fluoroscopy [Table 4].

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Table 1: Demographic data and presenting symptoms.

| n=145 | % |
|---|---|
| Age (year) | 39.9±11.902 |
| Gender | |
| Male | 93 | 64.1 |
| Female | 52 | 35.9 |
| Indication of operation | |
| Disc prolapse/instability | 12 | 8.3 |
| Lumbar canal stenosis (LCS) | 20 | 13.8 |
| Recurrent disc prolapse (LDP)/instability | 21 | 14.5 |
| Spondylolisthesis | 68 | 46.9 |
| Traumatic | 24 | 16.5 |
| Motor manifestations | |
| Full motor power | 104 | 71.7 |
| Unilateral 3–4/5 iliopsoas/quadriceps | 8 | 5.5 |
| Paraparesis 0-2/5 | 5 | 3.5 |
| Unilateral 3–4/5 dorsiflexor/plantar flexor | 28 | 19.3 |
| Sensory manifestations | |
| Hypoesthesia | 9 | 6.2 |
| Paresthesia | 3 | 2.1 |
| Sciatica | 133 | 91.7 |

Table 2: Level and inserted screws distribution.

| Vertebral level | Number of inserted screws | Number of breaching screws (%) |
|---|---|---|
| L1 | 18 | 0 (0.0) |
| L2 | 42 | 3 (7.1) |
| L3 | 98 | 27 (27.5) |
| L4 | 244 | 69 (28.3) |
| L5 | 210 | 46 (21.9) |

Table 3: Comparison of VAS between patients with different degrees of breaching.

| Mean of VAS | Degree of screw breaching by CT | Test |
|---|---|---|
| | Minimal | Moderate | Severe | KW | P |
| VAS back | 6 (4–8) | 7 (2–8) | 4 (3–5) | 2.298 | 0.235 |
| Immediate postoperative VAS back | 1.5 (0–3) | 1 (0–6) | 1 (1–1) | 2.464 | 0.292 |
| Late postoperative VAS back | 0 (0–1) | 0 (0–1) | 0 (0–0) | 0.942 | 0.624 |
| P (Fr) | <0.001** | <0.001** | 0.135 |
| VAS LL | 5 (3–7) | 6 (3–8) | 6.5 (6–7) | 2.783 | 0.249 |
| Immediate postoperative VAS LL | 2 (2–4) | 3 (1–4) | 2.5 (2–3) | 0.224 | 0.894 |
| Late postoperative VAS LL | 1 (0–2) | 1 (0–1) | 1 (1–1) | 0.263 | 0.877 |
| P (Fr) | <0.001** | <0.001** | 0.135 |

Table 4: P values for independent sample t-tests, *=Mann–Whitney U-test, F repeated measure ANOVA, Fr Friedman test, **P<0.001 is statistically highly significant, LL: Lower limb, VAS: Visual analog scale, CT: Computed tomography.
Postoperative neurological improvement

Nearly 87% of the patients showed immediate postoperative improvement in sensory function that increased to 100% at 6 postoperative months. Motor recovery was immediately seen in 70% of patients, with only minimal additional improvement (73.1%) at 6 postoperative months.

DISCUSSION

CT grading of screw placement and safety zones

In this study, we grade pedicle screw position as adequate (within the pedicle), or minor (< 2 mm), moderate (2–< 4 mm), and severe (>4 mm) [Table 5].

Notably, there is a "safe zone of 4 mm," comprised 2 mm of epidural space and 2 mm of subarachnoid space (i.e., which can accommodate part of a misplaced screw). If the infringement is more than 4 mm, it should be considered critical and revision should be planned.[13] New postoperative neurological deficits after pedicle screw insertion are reported as occurring from 0.4 up to 16.6% of the time; here, this was encountered in 7 (4.8% of total breached screws) patients. We readily diagnosed these seven patients utilizing CT studies at 2 postoperative weeks; clearly these CT scans should be optimally performed intraoperatively or within 24–48 h of surgery to more timely perform needed revisions.

Figure 1: (a and b) Images of two axial cuts of computed tomography (CT) scan at L4 level in a case of transpedicle screws fixation from L1 to L5 due to lumbar canal stenosis with instability. Although the medial breach was located in the right pedicle, the patient was clinically silent. An anterior vertebral body breach with protrusion of the screws through cortical bone >4 mm at the left screw. (c) Sagittal reconstruction of CT scan with reasonable screws locations in the lateral view. (d) Intraoperative fluoroscopy image with good alignment of screws in the lateral plane.
In a study by Kleck et al., numbers of pedicle breach by transpedicular screws were as follows: Grade I

Table 6: Data from other studies for the postoperative CT evaluation of the pedicle screw insertion in the lumbar spine degenerative disease/instability.

| Study/year         | Surgical technique         | Percentage of pedicle breach | Percentage of revision surgery | Most common level for pedicle violation | Intraoperative dural injury detection | Postoperative clinical manifestation |
|--------------------|----------------------------|------------------------------|--------------------------------|----------------------------------------|---------------------------------------|--------------------------------------|
| Smith et al./2014  | Percutaneous               | 37/601 (6.2%)                | 0%                             | L3 (10.2%)                             | No                                   | Transient radiculopathy in two cases |
| Saarenpää et al./2017 | Conventional open surgery | 15.2% (127/837) for surgeon 1 13.4% (112/837) for surgeon 2 (Up to 2 mm; surgeon 1 11.6% and 10.3% for surgeon 2 ≥4 mm; surgeon 1 3.6% and 3.1% for surgeon 2 ≥6 mm; surgeon 1 1.9% and 1.8% for surgeon 2) | 0% No early revision. Total 24 patients out of 147 (16.3%) Re-surgery was mainly for re-fusion. | L5 (20.7% for surgeon 1 and 16.1% for surgeon 2) | No | No |
| Kleck et al./2018  | Navigation guided percutaneous | GI 181/187 (96.8%) | 0% | S1 | No | No |
| Murata et al./2020 | 394 percutaneous screws, 445 conventional open | Percutaneous screws (28.9%), conventionally inserted screws (11.9%) | 0% | L4 for percutaneous, L1 and L2 for open. | No | No |

CONCLUSION

In our series, transpedicular screw insertion in the lumbar spine carried up to 1.1% be risk of pedicle violation/misplacement as best confirmed on CT scans. In the future, CT studies should ideally be performed intraoperatively or no later than 24–48 h postoperatively so that necessary revision surgery may be performed in a more timely fashion to offer patients optimal outcomes.

Declaration of patient consent

Patient’s consent not required as patients identity is not disclosed or compromised.

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Conflicts of interest

There are no conflicts of interest.

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