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Accuracy of pedicle screw insertion: a prospective CT study in 30 low back patients

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Abstract A prospective study of the accuracy of titanium pedicle screw placement in 30 low back operations was performed. The postoperative plain radiographs and CT reformation images were evaluated by two independent radiologists. Thirty-two out of 152 screws (21%) perforated the pedicle cortex. One-tenth of the perforations was detected with conventional radiography. In ten patients (33%) all the screws were located within the pedicle. The clinical significance of this study lies in the finding that pedicle perforations are more frequent than is generally believed and that, in spite of the many malplacements, no screw that perforated by less than 4.0 mm caused neurological problems. Only one nerve root lesion was detected.

Key words Spinal surgery · Pedicle screws · Complications · CT

Introduction

Transpedicular lumbar screw fixation is a demanding technique and involves a risk for neurological complications due to screw malplacement. The screw positions are usually examined with plain radiography. However, CT has been reported to be ten times more sensitive for detection of medial pedicle perforations [3]. Clinical studies with stainless steel screws and postoperative CT evaluation have shown malplacement rates of between 28 and 40% [1, 5]. In cadaver studies 6–31% of the screws have been found to perforate the pedicle wall [1, 4, 8, 9]. Titanium screws cause less artefacts on CT and MRI than stainless steel and are often used when postoperative imaging of the spinal canal is planned [10].

The purpose of this prospective study was to evaluate the accuracy of titanium pedicle screw placement in low back operations with a new CT reformation technique at the ORTON Orthopaedic Hospital, Invalid Foundation, Helsinki.

Patients and methods

Thirty consecutive lumbar spine operations with titanium pedicle screw fixation suitable for an exact CT analysis were performed between December 1994 and April 1995. There were 14 women and 16 men. The average age of the patients was 47 years (range 29–73 years). The indications for operation were: spondylolysis in 12 patients, postdiscectomy instability in 8, painful disc degeneration in 6 and spinal stenosis in 4 patients. Twenty posterolateral fusions, five Graf stabilisations, three posterior lumbar interbody fusions and two circumferential fusions were performed. There were 15 L4-S1 operations, 5 L5-S1, 4 L3-4, 2 L4-5, 2 L3-S1, 1 L2-4 and 1 L2-S1 operation.

Two experienced spine surgeons performed the operations. The screw holes were prepared according to anatomical landmarks through the Weinstein approach with a curved blunt bone probe and checked for perforation using a flexible sounding probe (AcroMed, Cleveland, Ohio) [9]. The screw positions were confirmed with lateral fluoroscopy after insertion.

The postoperative radiological status was evaluated with recumbent plain anteroposterior and lateral views as well as with CT scanning (Picker PQ 2000, Cleveland, Ohio). Volume scanning technique allows multiplanar postprocessing of scanned data (Cemax workstation, Cemax VIP 1.7 software, Fremont, Calif.). The scanning technique and acquisition parameters were tailored to achieve optimal volumes and diagnostic images. Slice thickness in scanning was 3 mm. Pedicles were scanned and images were reconstructed with 2 mm interspace in the plane of the screws. Additionally, images were reformatted in a curved frontal plane perpendicular to the longitudinal axis of the pedicles (Fig. 1). In these

reformation images it is possible to detect malplacements in all directions.

Two radiologists evaluated the radiographs and CT images independently. On plain radiographs the position of the screw was staged as: screw inside the pedicle, partial perforation and screw outside the pedicle. On CT the staging was: screw inside the pedicle, perforation of the pedicle cortex up to 2.0 mm, 2.1–4.0 mm, 4.1–6.0 mm and screw outside the pedicle. The location of the perforation was classified as medial, inferior, lateral or superior to the pedicle (Fig. 2). In cases of discrepancies in interpretations the images were re-evaluated and a final interpretation resolved in conference.

Neurological symptoms were recorded.

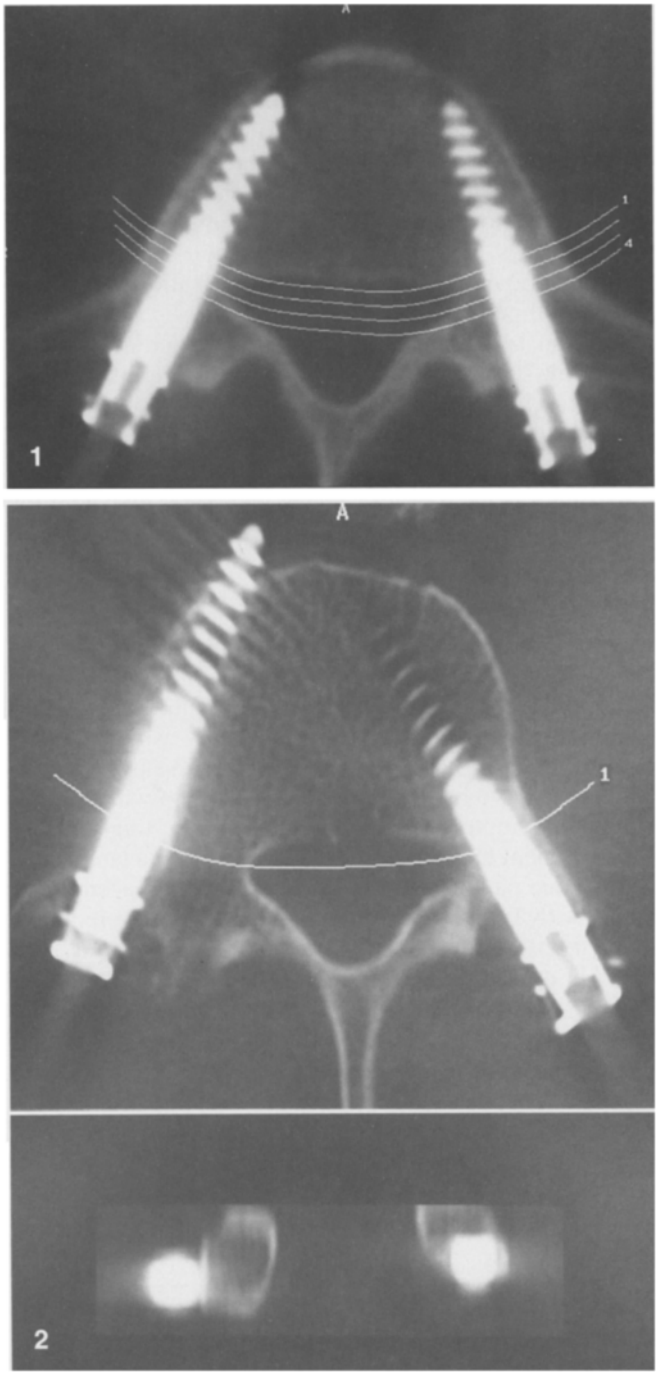

Fig. 1 Curved CT reformation planes perpendicular to the pedicles of an L5 vertebra

Fig. 2 One CT reformation plane of a scoliotic L4 vertebra with one screw totally missing the pedicle laterally on one side and an inferior perforation of up to 2.0 mm on the other

Results

The total number of screws was 152 (Diapason 122, Graf 30). According to the CT evaluation 120, out of 152 screws (79%) were inside the pedicle. The number of screws per level, and extent, location and level of perforations on postoperative CT are shown in Figs. 3, 4 and 5.

Eleven patients (37%) had one or more screws inferior or medial to the pedicle. In eight of them (27%) the per-

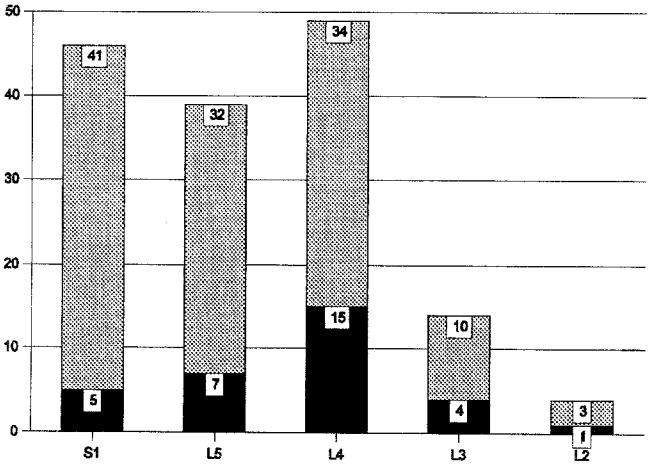

Fig. 3 Number of ideally placed pedicle screws (*grey columns*) and pedicle perforations (*black columns*) (n = 152) by instrumented level

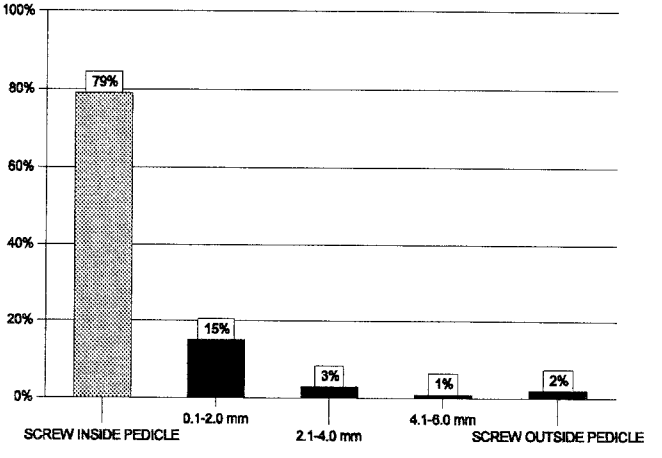

Fig. 4 Extent of pedicle screw perforation (n=152)

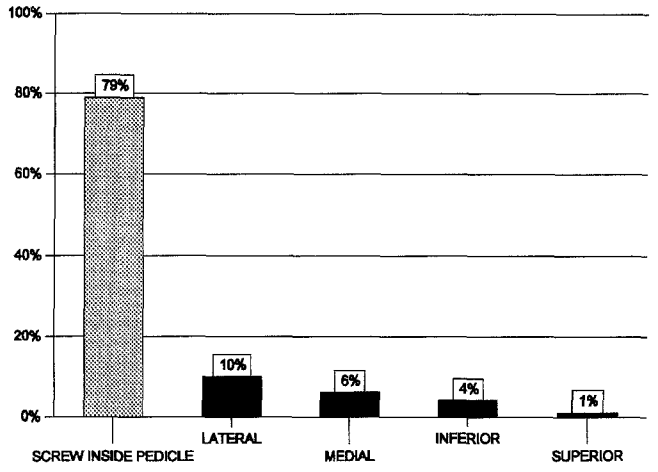

Fig. 5 Location of pedicle screw perforation (n = 152)

foration was less than 2.0 mm, in 2 (7%) between 2.0 and 4.0 mm and in one patient (3%) the screw was totally medial to the pedicle and caused nerve root irritation. Ten patients (33%) had all the screws placed inside the pedicle.

Four screws (3%) were recognized to be malplaced on plain radiographs. On CT two of these were totally outside the pedicle and two perforated the pedicle cortex by up to 2.0 mm.

Discussion

Pedicular screw placement carries an obvious risk for neural damage – about 5–7% [2, 7]. Neurological complications may be either due to the screws or to the decompression procedure.

Wide variance in pedicle anatomy has to be considered when inserting screws [11]. The common anatomical landmarks may be missing due to previous operations. The risk for neural damage is probably highest when the perforation is medial or inferior to the pedicle. Lateral and superior perforations are regarded as safer. Gertzbein and Robbins considered that 4 mm of canal encroachment can be tolerated without impinging on the spinal cord or cauda equina at the thoracolumbar level and that there is a "safe zone" of 0–4 mm adjacent to the pedicle in relation to the intradural contents [5]. The nerve roots in the lower lumbar area are mobile during flexion and extension and can give way, to some extent, to an improperly placed screw [6]. Postoperative scar formation, howewer, may reduce root mobility.

To our knowledge, this is the first CT study of the accuracy of pedicle screw placement with titanium screws. The position of the screws could be defined accurately on CT reformations, while only 13% of malplaced screws could be detected on plain radiographs. The misplaced screw that caused neural compromise was missed by both radiologists on plain radiography. Farber et al. had similar results; only 10% of medially placed screws were detected on plain radiographs [3].

Castro et al. reported 40% of the screws (30 low back patients, 131 steel screws, postoperative CT evaluation) perforated the pedicle wall, 29% medially in the risk area. They had five nerve root complications and stated that a deviation of more than 6 mm medially carried a high risk for nerve root damage [1]. Farber et al. had 12% of the screws "out" and 18% "questionable" (16 patients, 74 steel screws, postoperative CT evaluation). No neurological complications occurred [3]. Gertzbein and Robbins studied thoracolumbar instrumentations (40 patients, 167 steel screws, postoperative CT evaluation) and found 28% of the screws to penetrate the pedicular cortex, two of them causing minor neurological complications (6- and 7-mm medial perforations) [5].

We had 148 out of 152 screws (97%) within the 4-mm "safe zone". Thirty-two screws (21%) violated the pedicular cortex. We insert the screws rather laterally into the pedicles to save facet joints and upper-level integrity as well as to achieve screw convergence for a three-dimensional grip of the vertebrae. This technique increases the risk of lateral perforation, as half of the malpositioned screws (15/32) in our study were lateral in a relatively safe area.

The majority (79%) of our screws were optimally inserted, but only one-third of the patients (33%) had all of them inside the pedicles. One-tenth (10%) of the screws were medially or inferiorly malplaced, but, again, 11 patients (37%) had at least one screw in this risk area. Eight of these patients had the screws perforating by less than 2.0 mm and two by between 2.0 and 4.0 mm without neurological symptoms. One patient with a total medial malplacement had S1 nerve root irritation. In a later series we had one patient with a medial screw malplacement of 5 mm with L4 nerve root paresis, which recovered after screw repositioning. Our findings confirm the 4-mm "safe zone" in the low back region.

This is not, however, only a question of nerve root damage. Malpositioned screws reduce the stability of the construct and may cause screw loosening. Our only nerve root irritation did not occur until the malplaced screw loosened 2 months postoperatively. On CT a correctly prepared screw channel was seen. Thus, the screw may be inserted in a false direction even though, using a sounding probe, the pedicle walls have been found to be intact.

Conclusions

Perforations of the pedicle wall were registered in 32 out of 152 titanium lumbar pedicle screws (21%) inserted according to conventional techniques using anatomical landmarks and postinsertion fluoroscopy. Plain radiographs give a false impression of accuracy and safety in pedicular screw placement. CT scans show that more

screws than previously considered, by up to tenfold, violate the pedicular cortex. Our CT reformation method gives accurate information on the screw location. The clinical significance of this study is that despite the fact that only ten patients (33%) had all the screws inside the pedicles, neurological symptoms were recorded in only one patient (3%). No screw with less than 4.0 mm perforation caused any clinical neurological problems.

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