Computer tomography assessment of pedicle screw insertion in percutaneous posterior transpedicular stabilization

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Abstract Percutaneous insertion of cannulated pedicle screws has been recently developed as a minimally invasive alternative to the open technique during instrumented fusion procedures. Given the reported rate of screw misplacement using open techniques (up to 40%), we considered it important to analyze possible side effects of this new technique. Placement of 60 pedicle screws in 15 consecutive patients undergoing lumbar or lumbosacral fusion, mainly for spondylolisthesis, were analyzed. Axial, coronal, and sagittal reformatted computer tomography images were examined by three observers. Individual and consensus interpretation was obtained for each screw position. Along with frank penetration, we also looked at cortical encroachment of the pedicular wall by the screw. Thirteen percent of the patients (2/15) had severe frank penetration from the screws, while 80% of them (12/15) had some perforation. On axial images the incidence of severe frank pedicle penetration was 3.3% while the overall rate of screw perforation was 23%. In coronal images the overall screw perforation rate rose to 30% while the rate of severe frank pedicle penetration remained unchanged. One patient (6.6%) suffered S1 root symptoms due to a frankly medially misplaced screw, requiring re-operation. This study has shown that percutaneous insertion of cannulated ped-

icle screws in the lumbar spine is an acceptable procedure. The overall rate of perforation in axial images is below the higher rates reported in the literature but does remain important. Frank penetration of the pedicle was nevertheless low. It remains a demanding technique and has to be performed with extreme care to detail.

Keywords Lumbar spine · Pedicle screws · Minimally invasive surgery · Radiological studies · Complications

Introduction

Spinal fusion using pedicle screws has become popular world-wide in treating a variety of disorders of the spine. The standard open technique for insertion of screws nevertheless requires extensive tissue dissection in order to expose the entry points, resulting in tissue damage and associated blood loss. For that reason percutaneous insertion of cannulated pedicle screws was initially investigated in cadavers [6, 7] and applied in clinical practice in combination with posterior (PLIF) or transforaminal lumbar interbody fusion (TLIF) procedures [4, 7, 16]. The advent of this new type of instrumentation and its gain in popularity raises the question of possible side effects, particularly related to misplacement of pedicle screws. It is in fact known that screw misplacement using the standard open technique can be as high as 40% [1]. The purpose of our study was to define the incidence of screw perforation and compare it with published data on open and percutaneous pedicle placement techniques.

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Material and methods

Sixty screws were implanted in 15 consecutive patients undergoing percutaneous lumbar or lumbosacral stabilization using the Sextant pedicle screw system (Medtronic, Memphis, TN, USA). This was performed during TLIF mainly for spondylolisthesis but also for foraminal decompression and fusion in degenerative scoliosis (one patient) and lumbar Chance fractures (two patients). All surgeries were performed by the same senior surgeon (C.S.) using this procedure in the reported patients for the first time. Under fluoroscopy, the projections of the pedicle centers were marked on the skin. Stab incisions were made 2.5 cm lateral to the center of the pedicles. Guide wires were introduced ensuring that on the AP projection the wires did not occupy the medial half of the oval projection of the pedicles until the posterior vertebral wall level was reached on lateral fluoroscopy. Cannulated 6.5 mm titanium pedicle screws were introduced after tapping of the bone using the appropriate cannulated tap. At the end of the procedure longitudinal bars were introduced using the appropriate instrumentation.

Postoperative computer tomography (CT) was obtained for all 15 patients in order to assess implant position using an eight-detector row Lightspeed CT unit (GE Medical Systems, Milwaukee, WI, USA). Our protocol for lumbar spine multi-detector row CT was acquired in helical mode. The scanning direction was craniocaudal. The series consisted of 2.5-mm-thick CT sections (collimation, 8×2.5 mm) reconstructed at 2 mm intervals with a pitch of 0.875:1; acquisition parameters were 120 kVp and 280 mAs. The raw data were used to reconstruct transverse 2.5-mm-thick CT sections every 2 mm with a field of view adequate for visualization of the spine, as well as sagittal and coronal reformats of the lumbar spine.

Image interpretation was performed on hard copy films by three observers (a senior spinal surgeon, senior radiologist and a fully trained orthopedic surgeon). Both individual as well as consensus interpretation was

obtained for each screw. Evaluation of screw placement was performed according to the criteria published by Learch modified to include assessment in the coronal and sagittal reformatted images [12]. A screw was classified as cortical encroachment if the pedicle cortex could not be visualized and if bone in excess of 2-mm was visible on the opposite direction. Frank penetration was defined when not only the cortex was invisible but also when the screw trajectory was obviously outside the pedicular boundaries. Frank penetration was further subdivided according to Wiesner and defined as minor (less than half of the screw thread i.e. <3 mm), moderate (less than the full screw thread i.e. 3–6 mm) and severe (more than one screw diameter i.e. >6 mm) [17]. Finally we looked for possible disk penetration on the sagittal reconstructions.

Results

Inter-observer agreement was substantial for screw placement in axial and coronal images (κ 0.74 and 0.67, respectively). By contrast it was found to be fair (κ of 0.39) in judging screw position in the sagittal images. For that reason consensus interpretation was used in reporting screw placement in only the axial and coronal images (Table 1).

In the axial images one screw showed frank pedicle penetration laterally, and one medially, both classified as severe (>6 mm). Twelve screws encroached the pedicular cortex without frank penetration (six medially and six laterally).

In the coronal images five screws showed frank pedicle penetration (four laterally and one medially). From those only two were classified as severe penetrations, the same ones showing frank penetration on the axial images. The remaining three were all lateral and classified as minor penetrations (<3 mm). Thirteen screws encroached the pedicular cortex without frank penetration (four laterally, seven caudally, and two cranially).

Table 1 Summary of location and severity of perforation for the 60 screws placed in this study

	Axial images			Coronal images				
	Lateral	Medial	Total	Lateral	Medial	Caudal	Cranial	Total
Encroachment	6 (10%)	6 (10%)	12 (20%)	4 (6.7%)	0	7 (11.6%)	2 (3.3%)	13 (21.7%)
Frank penetration								
Minor (<3 mm)	0	0	0	3 (5%)	0	0	0	3 (5%)
Moderate (3–6 mm)	0	0	0	0	0	0	0	0
Severe (>6 mm)	1 (1.7%)	1 (1.7%) ^a	2 (3.3%)	1 (1.7%)	1 (1.7%) ^a	0	0	2 (3.3%)
Total	7 (11.6%)	7 (11.6%)	14 (23.3%)	8 (13.3%)	1 (1.7%)	7 (11.6%)	2 (3.3%)	18 (30%)

^a Clinical symptoms with S1 radicular pain

From the two severe frankly misplaced screws seen in both the axial and coronal images, only the medial one produced clinical symptoms with S1 radicular pain (Fig. 1a, b). It required repositioning the following day using an open technique. The patient made an uneventful recovery. Our severe frank penetrations concerned two patients and were not encountered in the beginning of our learning curve but during our sixth and tenth procedures. Only three out of the fifteen patients did not have any screw violations. We found no correlation between operated level and screw mal-positioning.

Finally we did not observe any disk penetration in the sagittal reconstructions, but this may be due to the poor inter-observer reliability in evaluating screw position using the sagittal images.

Discussion

Insertion of pedicle screws is a demanding technique and carries potential risks among others to neurological structures. The accuracy of placing pedicle screws using the classical open technique has been the subject of several imaging studies. Castro reported a 39.8% perforation rate of the pedicle wall in a series of 123 pedicle screws. Of note is that 5.7% were severe medial penetrations (>6 mm). In this previously reported series the incidence of neurological deficit attributed to screw mal-position was 16.6% (5 out of 30 patients). Percutaneous insertion of pedicle screws has already been used for temporary fixation of the lumbar spine mainly in a diagnostic setting, the so called “external fixation test” [2, 13]. Evaluation of this type of percu-

taneous screw insertion has been undertaken using a human cadaver model [17]. The overall perforation rate at dissection of the specimens was found to be 10% and mainly medial. The same authors evaluated screw position of percutaneous external fixation using axial CT images in a different study, involving 51 patients [18]. The screw perforation rate was found to be 6.6% mainly medially and more often affecting the S1 pedicles. Even though their study had limitations (single observer) it was the first to analyze the placement accuracy of percutaneous transpedicular screws. The screws used were nevertheless non cannulated which could explain the frequency of S1 pedicle penetration, due to medial slipping of the screw from the drilled track caused by impingement on the iliac crest. Cannulated screws should therefore in theory increase placement accuracy, at least at S1. It is of interest that our only neurological injury occurred in a S1 severely misplaced screw. From recent publications on small series of percutaneously inserted cannulated pedicle screws [4, 6, 7, 16] only one addressed the accuracy of screw positioning [7]. This group was comprised of only three patients with a single perforated screw. The larger series to date reporting results of percutaneous fixation does not provide information on screw placement. However, the re-operation rate reported due to screw misplacement, presumably with neurological symptoms, was 4% in that study (2 out of 49 patients) [16].

In our group of 15 patients with a total of 60 screws the overall rate of screw perforation was 23% with an incidence of severe frank pedicle penetration of 3.3% as seen on axial images. However we found that in coronal images the overall screw perforation rate rose

Fig. 1 Axial (a) and coronal (b) CT images of a frankly misplaced pedicle screw impinging on the right S1 nerve root

to 30% even though the severe frank pedicle penetration incidence was unchanged. The incidence of screw misplacement in our series falls within the reported rates ranging from 10% [14] to 40% [1]. It is interesting to note that a big variation exists in the reporting of screw placement accuracy. This is partly due to the variation in assessment methods including the definition of misplacement. In a recent study, misplacement was defined as the position of the central axis of the screw out of the outer cortex of the pedicle wall seen in axial CT images [8]. This would correspond to moderate/severe frank penetration according to Wiesner [17]. The authors did report an 8.2% frank misplacement rate but their series was on deformed spines (43 scoliosis and six kyphosis patients). Even though CT has its limitations it does nevertheless provide more information than plain films [3]. Most series looked mainly at axial images which in our series showed a lower incidence of screw perforation than coronal reconstructions. It could be that the true incidence of misplacement is higher when CT images are screened critically including coronal views. This could be due to the fact that not only mediolateral screw placement accuracy is judged, but also cranial and caudal placement. This probably accounts for the seemingly high overall perforation rate in our series. We did nevertheless include every single cortical

encroachment by a screw in every direction. It could be argued that such a screw position (Fig. 2) should not be regarded as misplacement and it could be that other studies have not included such cases in their misplacement reporting. We acknowledge that we did not compare our perforation rate to that occurring in open techniques since we only requested post operative CT in patients with new or unexplained neurology following standard open pedicle screw fixation. The neurological injury incidence was 6.6% in our percutaneous series which appears well within reported incidences ranging from 2% [15] to 5% [5], and even as high as up to 16.6% [1]. Only computer assisted surgery has been reported to achieve more accurate screw insertion with a misplacement rate of around 4% at the expense of operative length [9–11]. Our small number of patients does not allow us to draw conclusions on the overall incidence of implant related neurological lesions but does provide insight in the placement accuracy at our institution using this type of implants. Studies with more patients and inclusion of a control group of open screw insertion cases could help in verifying our findings.

Conclusions

Percutaneous insertion of pedicle screws in our institution showed an acceptable neurological complication rate when compared with the highest rates published in the literature. Screw misplacement was comparable to average rates reported in open techniques but lower than some of the higher rates of other studies. Nevertheless it remains a demanding technique and larger series might be needed in order to establish the average rate of neurological injuries associated with screw misplacement.

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Fig. 2 Axial CT image of a screw that was included in the overall perforation rate on the basis that the medial pedicle cortex (arrows) could not be visualized

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