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Location of transpedicular screws for fixation of the lower thoracic and lumbar spine

Computed tomography of 45 fracture cases

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Postoperative CT examinations of an unselected group of 45 patients with fractures of the thoracolumbar and lumbar spine including 1 patient with traumatically activated spondylolisthesis were analyzed for the location of the 200 screws, the angles of insertion, and the screw vs pedicle diameters. In all cases transpedicular systems had been used for fixation, i.e., the AO-Fixateur Interne in 28 patients, a combination of Teinturier plates and USI screws in 11 patients, and the VSP system in 7 patients. Using a standardized surgical technique and image intensification in 2 planes throughout, 92 percent of all pedicles were instrumented with acceptable deviations from the anatomic axes. Mismatches between the pedicle and the screw diameters were found in 3 instances, and 2 screws were placed in the transverse processes only. Canal encroachment in 13 patients did not impede neural structures. Slight perforation of the anterior cortex of the vertebral body was recorded in 3 percent of cases, but did not cause any complications.

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Transpedicular fixation systems have become the best method in the surgical management of thoracolumbar and lumbar spinal fractures (Dick 1984, Roy-Camille et al. 1986). The stability achieved with these systems critically depends on the accuracy of screw placement.

I have evaluated screw placement in 200 pedicles by CT in 45 patients.

Patients and methods

45 consecutive, unselected patients were analyzed. Except in 1 patient with traumatically activated spondylolisthesis, surgery was necessitated by vertebral fracture. The AO-Fixateur Interne (FI) was used in 28 patients with Schanz screws placed in 118 pedicles. Teinturier plates in combination with USI screws (TP-USI) were implanted in 11 patients (12 implants; in 1 patient 2 fractures at different levels were stabilized separately) with screws placed in 54 pedicles. In 6 patients with 7 implants (1 patient with fractures at different levels requiring separate instrumentation) the VSP system was used with screws in 28 pedicles.

The vertebrae to be instrumented and the appropriate landmarks were identified and the position of the pedicles was determined by image intensification in 2 planes. Depending on the surgeons' preferences, 2 different techniques were used for screw insertion:

1. 2-mm Kirschner wires were inserted into the center of the pedicles and, after checking their position on the image intensifier, a toothed sleeve was slipped onto the Kirschner wires and a canal was drilled into the cortex with a 3.2 mm drill, after removing the wires. In the case of the FI, Schanz screws were then inserted. For the other systems, the canals were tapped and the screws were then inserted into the threaded canals.

2. The point of insertion was leveled with Luer's forceps or a rongeur and the pedicles were widened with a Steinmann pin or a pedicle probe before the screws were inserted.

With both techniques, the force applied during screw placement was minimal to allow for self-centering of the instruments and the screws.

In all instances care was taken to place the screws in line with the pedicle axes. Both the Schanz screws and those of the USI system were inserted as deeply into the vertebral bodies as possible without deliberately perforating the anterior cortex. When placed in line with the pedicle axis, the length of the currently available VSP screws automatically limits the insertion depth.

Postoperative CT was done after acute wound pain had ceased, but before the patients were mobilized. Metal artefacts were minimized by using appropriate window settings. Insertion angles were determined by using the techniques reported by Gertzbein and Rob-

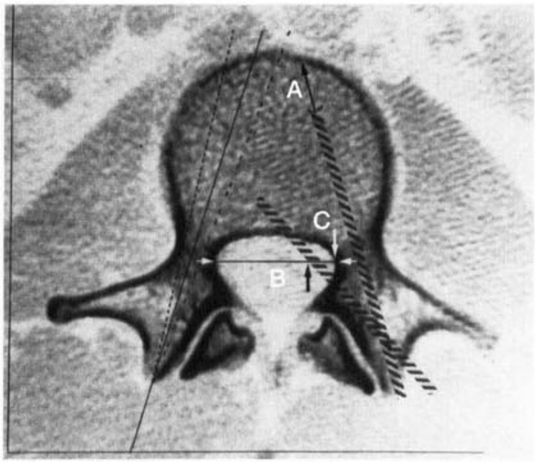

Figure 1. The measuring technique.
——— Pedicle axis—optimal screw placement.
--------- Excessively steep screw placement.
-- -- -- -- Excessively flat screw placement.
A (↑) Distance between screw tip and anterior cortex.
B (→ ←) Maximal spinal canal diameter.
C (↑↓) Extent of canal encroachment by the screw .

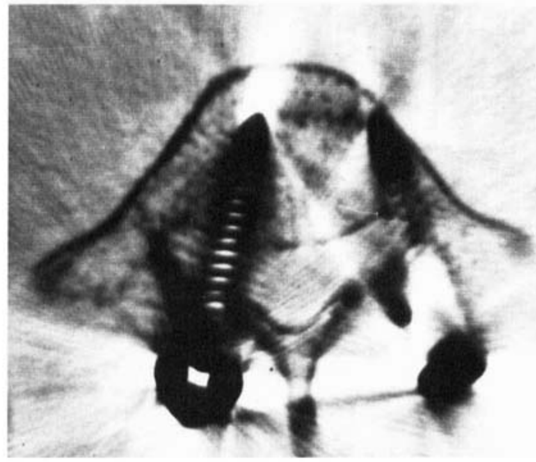

Figure 2. Problems with screw placement in the pedicles of L5 due to the underlying anatomy. Note deviation from ideal screw path bilaterally.

bins (1990) and Krag et al. (1988) (Figure 1). Evaluable measurements were obtained in all cases.

Canal encroachment by incorrectly placed screws was evaluated, as described by Gertzbein and Robbins (1990). The insertion depth of the screws, i.e., the distance between the screw tip and the anterior cortex of the vertebral body, and the extent of perforation were determined along the screw axis. Deviations from the pedicle axes (steeper or flatter screw placement) were determined separately for both sides (Table 1).

Results

Screw placement (Tables 2–4)

Incorrect centripetal placement was due to incorrect angles of insertion in 4 instances combined with too distant central points of entry in another 2. In the remaining 4 cases the latter factor was the only determinant of incorrect centripetal screw placement (Figure 2).

The underlying anatomy, i.e., an extremely thin pedicle, was responsible for incorrect screw placement in 3 cases. Incorrect centrifugal placement was due to incorrect angles of insertion in 2 instances, to an excessively lateral point of entry at the correct inser-

Table 1. Instrumented vertebrae and deviations of angles of insertion from anatomic pedicle axis (degrees)

Vertebra		Pedicle axis		Right insertion angle							Left insertion angle						
	Left/Right			Ideal	Steeper			Flatter			Ideal	Steeper			Flatter		
		mean	(range)	n	n	mean	(range)	n	mean	(range)	n	n	mean	(range)	n	mean	(range)
T8	1	11	(11)	0	1	3		0			0	1	4		0		
T10	4	7	(0–12)	1	1	4		2	5	(5)	3	1	1		0		
T11	15 /16	7	(–8–13)	5	6	2	(1–4)	5	7	(2–16)	7	4	4	(1–7)	4	11	(2–20)
T12	18/19	7	(–5–25)	7	2	5	(1–8)	10	6	(1–15)	6	4	8	(5–15)	8	6	(2–15)
L1	14/15	9	(5–15)	9	3	5	(2–7)	3	6	(3–11)	7	4	4	(2–6)	3	5	(2–9)
L2	25/26	10	(4–20)	8	11	3	(1–6)	6	6	(4 –10)	7	9	6	(1–17)	10	3	(1–6)
L3	11	14	(10–20)	3	7	5	(3–12)	1	2		3	6	5	(2–12)	2	2	(1–3)
L4	3	14	(7–18)	1	1	2		1	7		0	2	5	(1–8)	1	3	
L5	6	20	(13–20)	0	5	9	(2–18)	1	2		1	5	15	(5–30)	0		
S1	1	25		0	1	15		0			0	1	20		0		

Table 2. Incorrect screw placement, extent of resultant spinal canal encroachment, and levels affected

	AO-Fixateur Interne	Teinturier plates, USI screws	Variable Screw Placement system
Spinal canal encroachment	8 screws (5 pts) 6.7%	2 screws (2 pts) 7.1%	3 screws (2 pts) 10.7%
Mean narrowing (mm)	4.3 (2–7)	3.5 (3–4)	7 (4 –13)
Level / n	T11/3; L1/2; L2/2; L3/1	T12/2	T11/2; L5/1
Incorrect lateral placement	1 screw within transverse process and body of T11	1 screw within transverse process of L2 only	2 screws (2 pts) within transverse process of L5 only within transv. process and body of L5

Table 3. Distances of screw tips from anterior cortex of vertebral body and extent of perforation by fixation systems, number of vertebrae, mean distance of screw tip from anterior cortex or *extent of perforation* (range) in mm

Level	Schanz screws		USI screws		VSP screws	
T8	2	5 (5)	–		–	
T10	7	6 (3–8)	2	3 (3)	–	
T11	20	7 (0–11)	6	7 (0–17)	4	9 (4–14)
Perf.	*3*	*2 (1–2)*	–		–	
T12	22	4 (0–8)	11	4 (0–10)	2	1 (1)
L1	14	6 (0–10)	9	4 (0–10)	6	13 (3–18)
L2	38	6 (0–12)	11	11 (2–22)	2	1 (0–1)
L3	7	4 (0–8)	10	7 (0–12)	4	13 (10–15)
L4	2	8 (4–12)	2	2 (1–2)	2	15 (15)
L5	3	5 (3–7)	2	7 (3–10)	5	12 (3–18)
Perf.	*1*	*7 (7)*	–		–	
S1	–		–		1	5 (5)
Perf.	–		–		*1*	*2 (2)*
Total	114	6 (0–12)	53	6 (0–22)	26	10 (0–18)
Perf.	*4*	*3 (1–7)*	–		*1*	*2 (2)*

Table 4. Spinal canal encroachments by screws in this series and in a comparable study, percentages

	n 200	n 167
Within pedicle	92	72
0–2 mm	0.5	9.6
2.1–4	3	9.0
4.1–6	2	4.8
6.1–8	0.5	1.8
> 8.1	0.5	–
Lateral to pedicle	2	3.6

tion angle in 1 case and to an extremely thin pedicle in another.

2 of the screws (1 TP-USI and 1 VSP screw) only had contact with the transverse processes, while their tips were outside the vertebral bodies. Another 2 came to lie slightly lateral (Table 2), but well within the vertebral bodies (Table 3). In none of the patients was there any objective evidence of neurologic deficits attributable to incorrect screw placement. The anatomy-related problems encountered in placing screws at the level of L5 are illustrated in Figure 2. Table 3 lists the distances between the screw tips and the anterior cortex of the vertebral bodies.

Pedicle and screw diameters

Mismatches between the screw and pedicle diameters were not seen in any of the patients with FI fixation, but in 2 of the patients in the VSP and in another one of the TP-USI group (Figure 3). In 1 of the VSP cases satisfactory screw placement at the level of L4 was nevertheless obtained; in the other canal intrusion of 4 mm bilaterally at the level of T11 was, however, present. Unilateral 4-mm canal encroachment at the level of T12 was also seen in a patient with combined TP-USI fixation.

Discussion

Preoperative CT should not be confined to the fracture level. To facilitate planning for the optimal screw diameters, angles of insertion and screw lengths it should at least be extended to include the two neighboring segments.

Krag et al. (1988) found the CT data recorded in cadaver vertebrae to correlate closely with the pertinent postmortem findings. Gertzbein and Robbins (1990) reported results of screw placement in 167 pedicles of 40 patients, all of them trauma patients except for 3. Theirs is the only report known to us which lends itself for comparison with our data (Table 4). The differences in outcome, which are quite considerable in some respects, appear to have a dual explanation. In the present study a standardized surgical tech-

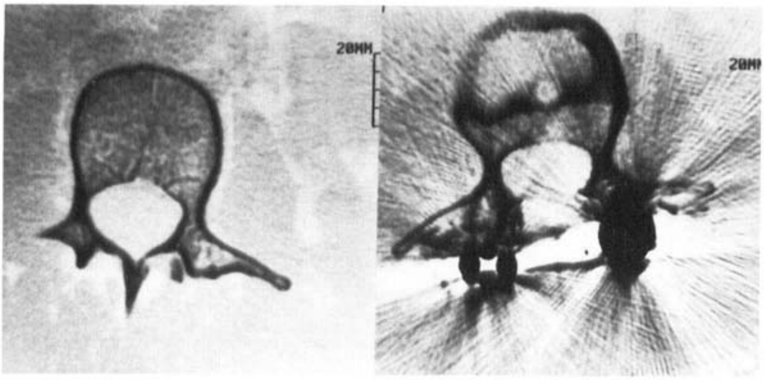

Figure 3. Extremely thin pedicles (left) before and (right) after instrumentation. Scale shown in right upper corner.

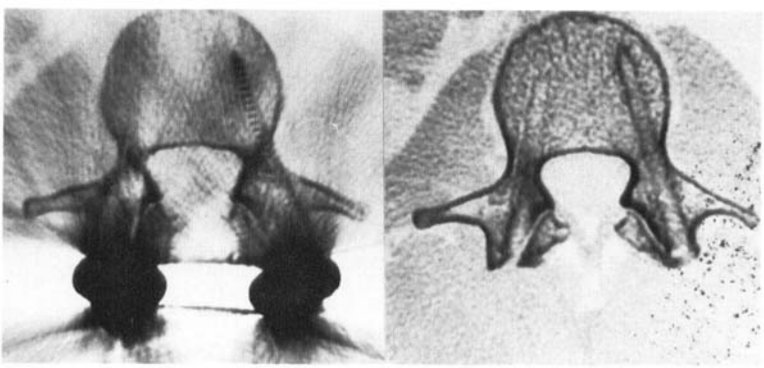

Figure 4. Apparently incorrect screw placement. CT after screw insertion (left) and after implant removal (right). Note also that, on the opposite side, an articular facet was damaged by the screw.

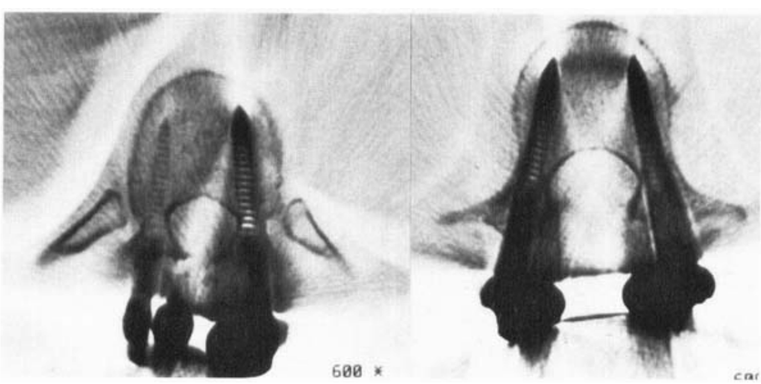

Figure 5. Ideal placement of screws in the pedicles of T11 (left) and L1 (right).

nique was used from the outset and only a few surgeons were involved. Gertzbein and Robbins (1990) reported that the accuracy of pedicular screw placement improved from 72 percent to 84 percent in the last 25 percent of screw insertions and attributed this improvement to a learning curve. Roy-Camille et al. (1986) reported an accuracy rate of about 90 percent.

Direct AP insertion was deliberately avoided in our series, because it tends to be inaccurate, with a higher risk of perforating the anterior cortex.

Unlike others, Gertzbein and Robbins (1990) and Kluger and Gerner (1986), we regard image intensification in 2 planes as mandatory. Not only does it explain our comparatively satisfactory results with screw placement. It also helps to control the insertion depth (Whitecloud et al. 1989). In fact, the rate of anterior perforations was no more than 3 percent (Table 3).

Metal artefacts were a problem, but they did not affect the evaluability of the scans in any one case. As they were, of necessity, also encountered by others, a comparison of the results would appear to be permissible. Metal artefacts may well mimic incorrect screw placement so that a final assessment cannot be made until the CT study is repeated after removing the instrumentation (Figure 4). This may well be a point of forensic interest. Discrepancies between the mean pedicle angles recorded in some segments and those reported by Zindrick et al. (1987) are attributable to the difference in the number of vertebrae evaluated. The data of Zindrick et al. (1987) were obtained from 2,905 pedicles.

The importance of the insertion angle correlates with the pedicle width: the wider the pedicle, the greater the tolerances (Figure 5). In thick pedicles the angle may, in fact, be modified deliberately to gain additional stability (Kluger and Gerner 1986). But this is no longer a serious problem, because most of the current systems feature transverse stabilizers anyway. The thinner the pedicles, the smaller the tolerances, i.e., the more accurate the placement should be.

Like Zindrick et al. (1987) we found mismatches between the screw and the pedicle diameters to be uncommon. Pedicle perforations which may be caused by such mismatches, despite the use of the smallest available screws, may be tolerated or even deliberately accepted in view of the anatomy of the thoracolumbar and lumbar spine, provided they are small and confined to the medial pedicular wall. Perforations of the inferior wall of the pedicle may cause radicular lesions and those of the lateral wall are associated with poorer stability. Consequently, both should definitely be avoided.

While neural lesions were absent in our material, lesions of the dura or the epidural veins cannot altogether be avoided on account of the close topographic relationships. Clinical symptoms suggestive of major CSF leakage or massive venous bleeding were not seen in our series.

The experiences reported in this contribution obviously raise an important question: Can the results be improved? The use of targeting devices was not found to offer any benefits in cadaver studies. Lateral tilting of the operating table by precisely the angle of the preoperatively determined pedicle axis with the X-ray beam parallel to the top and bottom plates of the vertebrae may perhaps be helpful, because it is apparently easier to insert the screws vertically than to place them in line with the anatomic pedicle axis. But the meticulous adjustment of the X-ray unit needed for this purpose will, no doubt, limit the use of this approach, and data based on a sufficiently large series are not available. Some of the incorrect screw placements are, no doubt, explicable by the relatively poor resolution of the image intensifier systems so that improved imaging techniques may be expected to improve the results.

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