Accuracy of Thoracic Pedicle Screw Using Ideal Pedicle Entry Point in Severe Scoliosis

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Abstract

Background The ideal pedicle entry point for the thoracic spine is described as the base of the superior facet at the junction of the lateral and middle thirds of the pedicle. Investigators have reported its accuracy in curves less than 90°.

Questions/purposes Our aim was to measure the accuracy of this entry point for pedicle screw insertion in severe and rigid scoliotic curves.

Patients and Methods We retrospectively measured the accuracy of thoracic pedicle screws in 26 patients with severe and rigid scoliosis (Cobb angle $\geq 90^\circ$) inserted using the free-hand technique and the ideal pedicle entry point. Placements of thoracic pedicle screws were reviewed on postoperative CT scans, and the incidence and severity of penetration were determined. Screws penetrating medially up to 2 mm and laterally up to 4 mm were considered within the safe zone.

Results One hundred sixty-eight (34.8%) of 482 inserted screws breached pedicle walls; 64 (13.2%) and 104 (21.6%) screws breached pedicle walls medially and

laterally, respectively. Four hundred thirty-seven screws were within the safe zone, representing an accuracy rate of 90.7%. The accuracy rates of inserted screws in upper, middle, and lower thoracic pedicles were 93.4%, 87.7%, and 92%, respectively.

Conclusions Use of the ideal pedicle entry point is safe and accurate for thoracic pedicle screw placement in rigid curves of 90° or greater.

Level of Evidence Level II, prognostic study. See the Guidelines for Authors for a complete description of levels of evidence.

Introduction

Pedicle screw instrumentation has gained acceptance because of many inherent advantages; however, it is technically demanding [2, 5, 7, 8]. In contrast to its biomechanical advantages is the risk of neural, vascular, or visceral injury occurring as a result of misplacement of these screws. Accurate placement of pedicle screws depends in part on the selection of an entry point. For thoracic pedicles, which are smaller than lumbar pedicles, the margin of error is less, and therefore, some studies have described various entry points [4, 13, 24, 25] using the transverse process and superior facet as landmarks. In a deformed spine, the transverse process may be abnormal in shape and size owing to rotation and wedging. Large-magnitude curves ($> 90^\circ$) previously were thought to have such significant deformity, and perhaps pedicle drift, that placement of screws would be prohibited [16], and curves greater than 100° carry a higher risk of neurologic compromise with curve correction [19]. Additionally, the more severe and rigid the curve is, the greater is the abnormality of shape and size of pedicles and transverse processes

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Each author certifies that his or her institution approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.

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owing to an increase in vertebral rotation. In contrast, the base of the superior facet is easy to identify and has a constant anatomic relationship to the pedicle. Previously, Chung et al. [3] proposed the ideal pedicle entry point (IPEP) for the thoracic pedicle as the base of the superior facet at the junction of the lateral and middle thirds using a cadaveric model. Modi et al. [18] confirmed the safety and accuracy of this technique in curves less than 90°. The advantages of this technique are an entry point that is easy to identify, freedom from variation in the anatomy of the transverse process, and a more constant relationship with the pedicles, even in more severe deformities, giving more accuracy and safety in placement of pedicle screws. To confirm the reliability of this IPEP, additional study of the accuracy of thoracic pedicle screw placement in severe scoliosis is mandatory.

We evaluated the reliability of the IPEP and a free-hand technique for placement of thoracic pedicle screws in patients with severe scoliotic deformities ($\geq 90^\circ$). We sought the answers to four questions to establish the reliability of this technique: (1) What is the overall accuracy of thoracic pedicle screws using IPEP? (2) What is the accuracy of pedicle screw placement in different levels of the thoracic spine (ie, upper, middle, lower thoracic levels)? (3) Is the accuracy different in different disorders? (4) Is there any difference in screw displacement between apical and terminal levels or between convex and concave sides?

Patients and Methods

In our study, we included 26 patients (13 males, 13 females) with curves greater than 90° who underwent correction and fusion for scoliosis with transpedicle screw fixation using the free-hand technique in which the IPEP [6] was used as the entry point. All patients enrolled for this study were operated on by one spine surgeon (SWS) between 2005 and 2007. This was a consecutive series of patients selected from our database, all of whom had a Cobb angle greater than 90°. Diagnoses included adolescent idiopathic scoliosis (AIS; five patients) and neuromuscular scoliosis (21 patients: seven with cerebral palsy [CP], six with Duchenne muscular dystrophy [DMD], five with spinal muscular atrophy [SMA], and three with polio). The mean age of the patients was 22.8 ± 8.9 years (range, 12–43 years), and the preoperative Cobb angle at the time of the operation was $107.1^\circ \pm 18.9^\circ$ (range, 90°–150°). Preoperative flexibility was $19.6\% \pm 6.7\%$ (range, 8%–29%), confirming spinal rigidity. All patients with AIS and four with CP were independent ambulators, and three with CP and all with DMD, SMA, and polio were either bedridden or wheelchair ambulators preoperatively.

The surgical techniques involved in the exposure of thoracic facet joints, entry point of thoracic pedicles, insertion of pedicle screws, correction of curves, and fusion were the same as previously described [18]. The entry point of the thoracic pedicles was taken at the junction of the lateral and medial thirds of the facet joint after observing the whole facet joint margin. This entry point is described as the IPEP [3]. Once the entry was made in the pedicle with the entry probe and the integrity of the pedicle wall was checked by a 2-mm ball tip probe, further entry in the pedicle wall was made with a pedicle path finder. After confirming the integrity of the pedicle walls, the screw was inserted. All pedicle screws in the thoracic spine were inserted in the same manner by one spine surgeon with more than 3 years of experience performing scoliosis surgeries. After insertion of pedicle screws, curve correction was performed using the rod derotation technique. Intraoperative neuromonitoring was performed with transcranial motor-evoked potentials (Tc-MEP) in all patients. Additionally, in 18 patients, multilevel vertebral osteotomies were performed for better correction of curves, but anterior release was not performed in any patient [23]. No intraoperative radiographs of the spine were obtained to check positioning of the pedicle screws. Postoperatively, once the patient became stable, postoperative radiography and CT were performed.

Of a total of 699 pedicle screws, 482 were inserted in the thoracic spine and 217 in the lumbar spine. The diameter of inserted screws ranged from 5.5 to 6.5 mm, 5.0 to 5.5 mm, 4.0 to 5.0 mm, and 3.5 to 4.5 mm in the lumbar, lower thoracic (T9–T12), middle thoracic (T5–T8), and upper thoracic (T1–T4) pedicles, respectively. The lengths of screws were 40–45 mm, 35–40 mm, 30–35 mm, and 25–30 mm in the lumbar, lower thoracic, middle thoracic, and upper thoracic areas, respectively. The diameters and lengths of pedicle screws were judged on preoperative CT scans. If we found a pedicle diameter less than the described diameter on the CT scan, we chose a smaller-diameter pedicle screw, especially for the middle thoracic spine or we did not insert a pedicle screw in a very narrow pedicle.

A total of 482 screws were inserted in thoracic pedicles. A spine fellow (HNM) reviewed digitized radiographs and CT scans of all patients taken preoperatively and postoperatively using the PACS system; therefore, all measurements were performed with the help of software at a magnification of 300%. Any penetration of bony cortex was measured in millimeters. We divided the penetration of the pedicle medially or laterally as Grade 0 (fully contained in the pedicle), Grade 1 (≤ 2 mm), Grade 2 (2.1–4.0 mm), Grade 3 (4.1–6.0 mm), and Grade 4 (6.1–8.0 mm) [18]. Screw penetration anterior to the vertebral body was measured in the same manner. Screws displaced

Fig. 1A–F The images show (A) fully contained screws in the pedicle and body, (B) a medially displaced screw encroaching the canal by 3.74 mm (potentially at risk), (C) a laterally displaced screw out of the pedicle by 4.27 mm (outside the safe zone), (D) one screw

displaced medially (outside the safe zone) and the other laterally by 2.5 mm (in the safe zone), (E) a screw penetrating the anterior cortex by 1.3 mm (in the safe zone), and (F) a screw penetrating medially by 1.6 mm (in the safe zone).

medially in Grade 1 (up to 2 mm) and laterally in Grades 1 to 2 (up to 4 mm) were considered in the safe zone whereas the rest of the displaced screws were considered potentially at risk (Fig. 1). We also compared the number of displaced screws between the apical and terminal levels, and between the convex and concave sides. To calculate the numbers of displaced screws at the apical level, we considered the screws at and one level above and below the apical vertebrae, and the rest of the inserted screws were considered at the terminal level.

The magnitudes of the preoperative and postoperative curves were compared using a paired t test. We analyzed the thoracic pedicle screw placement in the upper, middle, and lower thoracic levels using the chi square test. We also analyzed placement of thoracic screws according to the disease groups AIS, CP, DMD, SMA, and polio using the chi square test. Comparisons of displaced screws between apical and terminal levels, and between convex and concave sides also were done using the chi square test.

Results

The average preoperative and postoperative Cobb angles measured were $107.1^\circ \pm 18.9^\circ$ and $48.6^\circ \pm 19.3^\circ$, respectively, indicating a correction rate of 54.7% ($p < 0.0001$) (Table 1). Similarly, preoperative and postoperative pelvic obliquity was $15.5^\circ \pm 8^\circ$ and $7.8^\circ \pm 4.7^\circ$,

Table 1. Patient demographics

Variable	Value
Number of patients (male:female)	26 (13:13)
Age (years)	$22.8^\circ \pm 8.9^\circ$
Preoperative Cobb angle	$107.1^\circ \pm 18.9^\circ$
Postoperative Cobb angle	$48.6^\circ \pm 19.3^\circ$
Preoperative flexibility	$19.6\% \pm 6.7\%$
Preoperative pelvic obliquity	$15.5^\circ \pm 8^\circ$
Postoperative pelvic obliquity	$7.8^\circ \pm 4.7^\circ$
Preoperative thoracic kyphosis	$35.7^\circ \pm 31.1^\circ$
Postoperative thoracic kyphosis	$21.7^\circ \pm 12.1^\circ$
Preoperative lumbar lordosis	$-10^\circ \pm 52.2^\circ$
Postoperative lumbar lordosis	$-28^\circ \pm 14.6^\circ$
Numbers of screws per patient	26.9 ± 4.5

Values are expressed as mean $\pm$ SD.

respectively, showing 49.7% ($p < 0.0001$) correction. Corrections for thoracic kyphosis and lumbar lordosis were from $35.7^\circ \pm 31.1^\circ$ to $21.7^\circ \pm 12.1^\circ$ and from $-10^\circ \pm 52.2^\circ$ to $-28^\circ \pm 14.6^\circ$, respectively ($p = 0.005$ and $p = 0.043$, respectively, paired t test). None of the patients had signs of neurologic deterioration on Tc-MEP intraoperatively or on clinical examination postoperatively. Additionally, there was no deterioration in preoperative ambulatory status in all patients after the surgery.

Of the 482 thoracic screws, 34.8% (168 of 482) of inserted screws penetrated either the medial wall (13.2%;

Table 2. Number of medially, laterally, and anteriorly displaced screws according to level

Level	Medial displacement				Lateral displacement				Anterior displacement				Inserted	Displaced	Safe zone
	< 2 mm	2–4 mm	4–6 mm	> 6 mm	< 2 mm	2–4 mm	4–6 mm	> 6 mm	< 2 mm	2–4 mm	4–6 mm	> 6 mm			
T1	1	0	0	0	0	0	0	0	0	1	0	0	2	1	1
T2	0	1	0	0	5	4	0	0	6	1	0	0	31	10	9
T3	2	0	0	0	10	1	1	0	2	0	1	0	33	14	13
T4	1	3	1	0	4	5	1	0	1	0	0	0	40	15	10
T1–T4	4	4	1	0	19	10	2	0	9	2	1	0	106	40	33
T5	4	3	1	0	6	3	2	0	1	0	0	0	44	19	13
T6	6	4	0	0	5	2	2	0	0	0	0	0	44	19	13
T7	5	2	0	0	4	3	5	0	0	0	0	0	50	19	12
T8	7	1	0	0	2	5	3	0	1	0	1	0	49	18	14
T5–T8	22	10	1	0	17	13	12	0	2	0	1	0	187	75	52
T9	5	1	0	0	0	4	2	0	1	0	0	0	47	12	9
T10	3	3	0	0	4	3	1	0	2	1	0	0	50	14	10
T11	5	0	0	0	1	4	2	0	1	1	1	0	45	12	10
T12	2	2	1	0	1	6	3	0	2	3	0	0	47	15	9
T9–T12	15	6	1	0	6	17	8	0	6	5	1	0	189	53	38
Total	41	20	3	0	42	40	22	0	17	7	3	0	482	168	123

Table 3. Number of medially, laterally, and anteriorly displaced screws according to disease

Disease	Medial displacement				Lateral displacement				Anterior displacement				Inserted	Displaced	Safe zone
	< 2 mm	2–4 mm	4–6 mm	> 6 mm	< 2 mm	2–4 mm	4–6 mm	> 6 mm	< 2 mm	2–4 mm	4–6 mm	> 6 mm			
AIS (n = 5)	9	4	1	0	10	10	9	0	3	2	1	0	101	43	29
CP (n = 7)	13	6	1	0	9	6	3	0	4	2	0	0	120	38	28
DMD (n = 6)	9	2	0	0	14	9	3	0	5	1	0	0	124	37	32
SMA (n = 5)	6	4	1	0	7	10	4	0	1	1	2	0	92	32	23
Polio (n = 3)	4	4	0	0	2	5	3	0	4	1	0	0	45	18	11

AIS = adolescent idiopathic scoliosis; CP = cerebral palsy; DMD = Duchenne muscular dystrophy; SMA = spinal muscular atrophy; polio = poliomyelitis.

AIS = adolescent idiopathic scoliosis; CP = cerebral palsy; DMD = Duchenne muscular dystrophy; SMA = spinal muscular atrophy; polio = poliomyelitis.

64 of 482) or the lateral wall (21.6%; 104 of 482), whereas 27 screws (5.6%) penetrated the anterior wall by an average of 1.9 mm (range, 0.6–5.8 mm). Thus, 65.2% of the screws were in the pedicle walls. However, considering the safe zone, 123 of the 168 displaced screws (73.2%) were in the safe zone, making a total of 437 of 482 inserted screws in the safe zone, which represented an accuracy rate of 90.7%.

Of the 168 misplaced screws, 23.8% (40 of 168), 44.6% (75 of 168), and 31.5% (53 of 168) were displaced in the upper, middle, and lower thoracic spine, respectively. Thus, 76.2%, 55.4%, and 68.5% of the screws were in pedicle walls in the upper, middle, and lower thoracic spine, respectively. However, considering the safe zone, the accuracy rate was 93.4% (99 of 106), 87.7% (163 of 187), and 92% (174 of 189) in the upper, middle, and lower thoracic spine, respectively (Table 2). There was no difference ($p = 0.193$) in the number of displaced screws in the safe zone and screws at risk among the upper, middle, and lower thoracic regions. Similarly, there was no difference ($p = 0.350$, chi square test) in the accuracy of thoracic pedicle screws among the upper, middle, and lower thoracic regions.

The accuracy rate of thoracic pedicle screw placement was similar ($p = 0.06$, chi square test) for patients with different diseases: AIS, CP, DMD, SMA, and polio (86.1%, 91.7%, 95.9%, 90.2%, and 84.4%, respectively) (Table 3).

The screw displacement rates at the apical and terminal levels were 34.9% (42/124 screws) and 35.8% (128/358 screws) which did not show any statistical difference in displacement rate between both levels. Similarly screw displacement rates for convex and concave sides were 34.4% (86/251 screws) and 35.5% (82/231 screws), respectively which did not exhibit any difference in screw displacement between convex and concave sides (Table 4).

Discussion

The IPEP for the thoracic spine is described as the base of the superior facet at the junction of the lateral and middle thirds of the pedicle. Investigators have reported its accuracy in curves less than 90° [18]. Our purpose was to determine the overall accuracy of thoracic pedicle screws, the accuracy of pedicle screw placement into different levels of the thoracic spine, and the accuracy in different disorders.

There are a few limitations to this study. First, we could not evaluate on CT scans how many screws were attributable to improper selection of the entry point. We did not evaluate this point owing to the small number of patients and also to prevent any biased information. However, we think the study of displacement based on proper selection

Table 4. Numbers of displaced and total inserted screws

Disease	Apical screws		Terminal screws		Total screws		Convex side		Concave side	
	Displaced	Inserted	Displaced	Inserted	Displaced	Inserted	Displaced	Inserted	Displaced	Inserted
AIS	15	27	28	74	43	101	20	52	23	49
CP	9	28	31	92	38	120	20	64	18	56
DMD	6	29	31	95	37	124	17	64	20	60
SMA	9	27	23	65	32	92	19	48	13	44
Polio	3	13	15	32	18	45	10	23	8	22
Total	42	124	128	358	168	482	86	251	82	231
p Value	0.705					0.775				

AIS = adolescent idiopathic scoliosis; CP = cerebral palsy; DMD = Duchenne muscular dystrophy; SMA = spinal muscular atrophy; polio = poliomyelitis.

of the entry point would further strengthen the reliability of this technique. Additionally we could not compare the accuracy rates between apical and terminal levels, and convex and concave sides in this study; however, the overall screw displacement rates did not show any difference between the apical and terminal levels, and between convex and concave sides which are positive aspects of this technique. Additionally, the accuracy rates of the upper, middle, and lower thoracic spine did not show any difference. This suggests our technique has similar accuracy in the most rotated and the least rotated vertebral bodies. Chung et al. [3], in a cadaveric experiment studying this technique, reported the difference in the trajectory of pedicle screws in the transverse and sagittal planes. In their study, the maximum transverse screw angles were at T1 and T2, $29 \pm 1.87^\circ$ and $29.50 \pm 2.50^\circ$, declining first rapidly to $15.80 \pm 2.25^\circ$ at T3 then gradually to $9.40 \pm 2.88^\circ$ at T10 before increasing to $11.20 \pm 1.60^\circ$ at T12. Although we did not analyze the coronal and sagittal angulations of trajectory to evaluate the accuracy of pedicle screws, we considered this point while calculating the trajectory for pedicle screws on preoperative CT scans. We believe in addition to the entry point at the medial two-thirds and lateral one-third of facet joints, surgeons should keep the trajectory of the pedicle in mind. Another limitation is that the majority of the patients in our study had neuromuscular scoliosis. This group of patients is less likely to have deformed pedicles; thus the pedicles are more likely to be in the anatomic location. Also, the pedicles generally are likely larger than for other forms of spinal disorders. Therefore, results of our study are valid only for patients with closer to normal pedicle morphology, rather than abnormal pedicles. Thus, we cannot directly translate this information to use for patients with severe idiopathic or congenital scoliosis.

Large-magnitude curves ($> 90^\circ$) were thought to have significant deformity, and perhaps pedicle drift, that would prohibit placement of screws [16]. Patients with curves

greater than 100° have an approximately 10% risk for neurologic compromise with curve correction [19]. To improve the accuracy of thoracic pedicle screws, various insertion techniques, such as the free-hand technique, fluoroscopy, computer-assisted surgery [1, 12, 15, 17], intraoperative EMG [14, 17, 21, 23], somatosensory evoked potentials, and MEP monitoring have been described. Image-guided techniques are expensive and time consuming. The free-hand pedicle screw insertion technique, however, is simple and inexpensive and exhibits accuracy in experienced hands similar to accuracy rates for image-guided techniques [13, 24]. The free-hand technique relies on an accurate entry point, correct screw trajectories in the transverse and sagittal planes, and palpation of all walls of the pedicles during each step of insertion. Therefore, it is imperative that there be a constant entry point that is easy to identify. Chung et al. [3], in their study on cadavers, introduced the IPEP for the thoracic pedicle using the free-hand technique, which is situated at the base of the superior facet at the junction of the lateral and medial thirds. Modi et al. [18], in their clinical study of patients with scoliosis with a Cobb angle less than 90° , reported an accuracy rate of 93% [18]. Using the same criteria for accuracy, we report a similar (90.7%) accuracy rate for thoracic pedicle screws in 26 patients with severe and rigid scoliosis with a Cobb angle of 90° or greater. Our study confirms IPEP for the thoracic pedicles is equally safe and accurate in any kind of curve. Our results confirming the accuracy of thoracic pedicle screws using IPEP with the free-hand technique in severe and rigid curves further confirmed its reliability as a technique.

Some studies have shown rates of misplacement between 28% and 43% [13, 15, 17, 21, 22, 24] and only one study had a rate less than 5% [1]. Various postoperative investigations, such as radiography, CT, or MRI, have been described to measure the accuracy [1, 15, 17, 21, 22] of placement of pedicle screws. CT has been found to be more reliable than radiography [9, 10]. Therefore, we used an

analysis with postoperative CT. Suk et al. [24] reported only 67 screw malpositions (1.5%) in 48 patients treated for idiopathic and congenital scoliosis with a deformity correction of 69% using postoperative radiography. Kim et al. [13] reported 93.8% accuracy in thoracic pedicle screw fixation using postoperative CT with the free-hand technique mainly in patients with idiopathic scoliosis and Scheurmann kyphosis. Some previously reported studies measured accuracy of pedicle screw placement in Cobb angles less than 90° [14, 17, 18]. Kuklo et al. [14], however, reported the accuracy of thoracic pedicle screws of 96.3% in 20 patients with AIS with curves greater than 90° (total number of screws, 352; mean curve, 100.3°). In our study, we had an accuracy rate of 90.7% for 482 thoracic pedicle screws in 26 patients who mostly had neuromuscular scoliosis (only five patients had AIS).

Belmont et al. [1] reported 99% accuracy in thoracic pedicle screw fixation in the safe zone and concluded higher accuracy was possible using the fluoroscopically guided in-out-in technique, but their rate of breaching the pedicle wall was 43%. We had a pedicle breaching rate of 34.2% and 123 (73.2%) of 168 displaced screws were in the safe zone. Gertzbein and Robbins [11], in their study of 71 thoracic screws between T8 and T12, had a 26% incidence of medial cortical penetration of as much as 8 mm with only two minor neurologic injuries. They hypothesized a 4-mm safe zone for medial encroachment was needed, which included a 2-mm epidural space and a 2-mm subarachnoid space. Lateral wall penetration or lateral extrapedicle screw placement of as much as 6 mm resulting from the intentional use of the in-out-in technique also was considered acceptable, especially in the upper and middle thoracic spine where pedicle diameters typically measure only 4 to 5 mm. In our study, using an even narrower margin of error for the safe zone, 34.2% of the screws perforated the pedicle walls, with 13.2% on the medial side and 21.6% on the lateral side. Vaccaro et al. [25] reported a 23% medial cortical perforation with a mean spinal canal compromise of 5 mm in a cadaveric study without the use of fluoroscopy. Other in vivo investigations, with the majority of screws confined to the lower thoracic spine, had medial cortical perforation rates between 8% and 24% [20]. The percentages of screw misplacement between the various levels in the thoracic spine did not vary as much as expected. The narrowest diameters of pedicles are found between T3 to T7 [20] and a higher percentage of screw misplacement is expected at these levels, but in this study by Reynolds et al., they did not show the percentages expected. In our study, the displacement rates were 37.7%, 40.1%, and 28% with accuracy rates of 93.3%, 87.7%, and 92% in the upper, middle, and lower thoracic regions, respectively, indicating a slightly higher perforation rate in the middle thoracic

spine. The probable reason for the low accuracy in the middle thoracic region might be the narrow pedicle size as reported in the literature [6, 20]. We tried to estimate the diameter of the pedicle screw on preoperative CT scans, and if we found a smaller diameter than expected, we chose to insert a smaller-diameter pedicle screw, especially in the middle thoracic spine.

Regarding the Cobb angle, pelvic obliquity, thoracic kyphosis, and lumbar lordosis, we achieved improvement in all parameters postoperatively. In addition, none of our patients experienced any neurologic or vascular complication intraoperatively on neuromonitoring or postoperatively. Kuklo et al. [14] reported neurologic deterioration was observed on MEPs for one patient during correction of a curve greater than 90°. We believe, because the IPEP is more laterally located than other pedicle entry points, the rate of neurologic complications is decreased with this technique.

We also acknowledge the fact that this is a retrospective review of successful screw placements and none of these patients was allowed to finish surgery with screws in a position recognized as clinically unacceptable. Intraoperatively, surgeon skill and experience identifying breach in continuity of pedicle walls with a ball-tip probe are key to avoiding malposition and to recognizing poor placement before it becomes a problem.

Pedicle screw fixation with the free-hand technique using IPEP in the thoracic spine appears to be a safe and reliable method with acceptable accuracy for treatment of scoliosis and should be considered even for patients with severe and rigid scoliosis with a Cobb angle of 90° or greater during thoracic pedicle screw instrumentation.

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