SPINE Volume 32, Number 15, pp 1655–1661

Complications of Thoracic Pedicle Screws in Scoliosis Treatment

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Study Design. A retrospective study.

Objective. To analyze complications with thoracic pedicle screws in scoliosis treatment at our Department over a 3-year period (1999–2001).

Summary of Background Data. The use of pedicle screws remains controversial for thoracic scoliosis for fear of complications.

Methods. A total of 115 consecutive patients who underwent posterior fusion using 1035 transpedicular thoracic screws were reviewed. All patients presented a main thoracic scoliosis with a mean Cobb angle of 75.4° (range, 60°–105°). For thoracic screw placement, a mini-laminotomy technique was used, inserting a spatula inside the vertebral canal to palpate the borders of the pedicle. Postoperative CT scan was used in 25 patients (21.7%) to study a total of 311 screws, when the screw position was questionable.

Results. An independent spine surgeon retrospectively reviewed medical records and radiographs of the patients, at a mean follow-up of 4 years. There were 18 screws misplaced (1.7%) in a total of 13 patients (11.3%). Screw malposition was symptomatic only in 1 patient (pleural effusion and fever) and asymptomatic in the other 12 cases (10.4%). Other complications included intraoperative pedicle fractures in 15 patients (13%), dural tears (without neurologic complications) in 14 cases (12.1%), and superficial wound infections in 2 (1.7%). Another operation for screw removal was performed in 5 patients (4.3%), due to pleural effusion (in 1 case), asymptomatic late lateral loosening of a malpositioned screw (in 1), and the possible future risks related the intrathoracic screw position despite the lack of any symptoms (in 3). Two cases (1.7%) were retreated due to wound infection, without removing instrumentation. There was no loss of correction at follow-up.

Conclusions. The thoracic pedicle screw placement in scoliosis patients requires utmost caution. The mini-laminotomy technique was beneficial in increasing safety of the procedure with an acceptable incidence of complications.

Key words: scoliosis, surgical treatment, thoracic pedicle screws, complications. **Spine 2007;32:1655–1661**

The use of thoracic pedicle screws has become increasingly widespread in the treatment of scoliosis and has led to a significant improvement in deformity correction,[1–5] even in large-magnitude curves.[6] However, the use of thoracic screws in scoliosis remains controversial because of the technical difficulties[3] and the risk of complications.[7,8] Complications related to thoracic screws have been reported in scoliosis treatment,[2,6,7,9] but they involve single cases compared with the over 900 patients[2–6] treated all together using 8559 thoracic screws.

To make thoracic pedicle screw placement safer various techniques are used, from guide pins into the pedicles[2] to the C-arm intensifier,[4] from triggered EMG[10] to image-guided systems based on computed tomography (CT).[11] The use of EMG monitoring appeared to be of limited value in the thoracic spine: in the study by Reidy *et al*,[10] postoperative CT showed that 8.8% of screws had breached the walls of the pedicle and so it did not improve significantly the reliability of safe thoracic screw placement. Computer-assisted screw pedicle installation permitted an increased accuracy in using screws, thus decreasing the incidence of misplaced screws,[11] but it entails preoperative CT scanning, high costs, and long operative time. Safe methods for thoracic screw placement include the "anatomic" techniques, such as the free hand method[5] and the open-lamina technique[12]: the latter provides direct visualization of the medial wall of the pedicle. A similar method to the open-lamina technique,[12] but more economical in resecting the lamina, is the mini-laminotomy,[13] which allows palpation with a spatula inside the canal the borders of the thoracic pedicles.

The mini-laminotomy technique is the one currently used at our Department for thoracic screws placement. The purpose of the study was to review the complications of thoracic screws in the treatment of scoliosis at our Department, for a period of 3 years using this technique.

Materials and Methods

A total of 115 consecutive patients who underwent posterior instrumented fusion using 1035 transpedicular thoracic screws by 3 different surgeons at our Department from 1999 to 2001 were reviewed: these patients represented the initial use of thoracic pedicle screws in scoliosis treatment at our Department. The mean age was 33.4 years (range, 12–54 years) at time of surgery. All patients presented a main thoracic scoliosis; the mean Cobb angle was 75.4° (range, 60°–105°). The etiologic diagnoses were adolescent idiopathic scoliosis (n = 75), congenital scoliosis (n = 11), adult idiopathic scoliosis (n = 19), and scoliosis associated with various syndromes (n = 10). The size of the thoracic pedicles was evaluated on preoperative ra-

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Acknowledgment date: August 15, 2006. First revision date: December 14, 2006. Acceptance date: December 20, 2006.
The manuscript submitted does not contain information about medical device(s)/drug(s).
No funds were received in support of this work. No benefits in any form have been or will be received from a commercial party related directly or indirectly to the subject of this manuscript.
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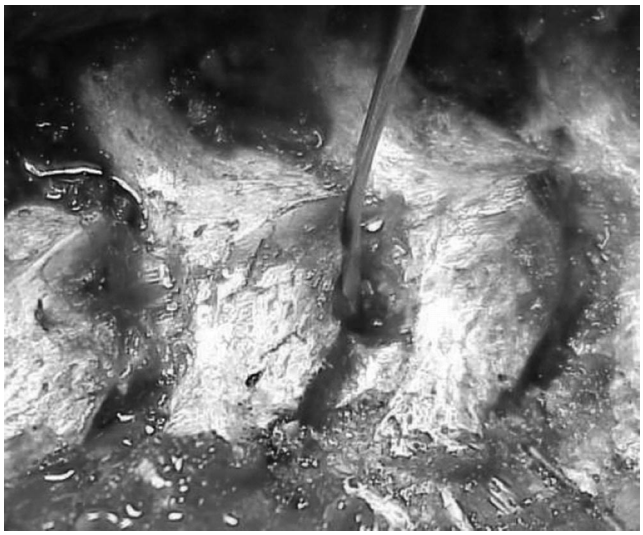

Figure 1. Mini-laminotomy technique. After excision of the spinous process, the ligamentum flavum is completely removed with a small portion of the lamina in the upper part. This technique permits inspection with a spatula inside the canal of the borders of the pedicle.

diographs, using above all supine radiographs and side bending films to visualize rotated pedicles. All thoracic screws were inserted by 3 different surgeons using the following technique.

Technique. After a standard posterior midline incision, a meticulous exposure of the posterior elements of the thoracic spine was made to the tip of the transverse processes bilaterally.

Mini-laminotomy. At each level where a screw was applied, a mini-laminotomy was performed in the cephalad part of the lamina,[13] which is similar to, but more economical than, the open-lamina technique.[12] After excision of the spinous process, the ligamentum flavum was completely removed with a small portion of the lamina in the upper part (Figure 1). This technique allowed[13] for inspection with a spatula inside the canal of the superior, medial, and inferior borders of the pedicle, and was the first part of the posterior release, which was then completed more laterally, once all screws had been placed. Gel foam was applied to control bleeding from the canal.

Pedicle Entry Point. Besides the probe inside the canal, to determine the pedicle entry point, the well-known anatomic landmarks were used.[2,8,14] The entry point at the T11 and T12 was checked at the junction of the bisected transverse process and lamina at the lateral aspect of the pars; for the vertebrae of midthoracic region, the entry point was more medial and cephalad, while above the midthoracic vertebrae the entry point tended to be slightly lateral and caudad, as well described by Kim *et al*.[5]

Screw Placement. The presumed pedicle entry point was prepared with a rongeur. The pedicle was entered using a small curette: the instrument was inserted by applying mild pressure for 20 mm in the proximal thoracic pedicles, for 25 mm in the mid thoracic region, and for 30 to 40 mm for the lower thoracic pedicles, directed along the axis of the pedicle in the frontal and sagittal plane. The screw tract inside the pedicle was checked with a pedicle sound to palpate five distinct bony borders: a floor and four walls. Metallic pins were inserted in the thoracic holes. Intraoperative fluoroscopy was performed.

Pedicle screws were inserted with slow and gentle force using a screw diameter corresponding to about 80% of the pedicle diameter.[2] During surgery, the fluoroscopic images (especially in the anteroposterior and oblique views) provided decisive indications for the choice of screw diameter. The screw length was chosen to be about 70% of the vertebral body on lateral view of fluoroscopy. Screws were inserted into every segment on the concave side of the thoracic curve, generally every third on the convex side. The direction of the screw was more convergent medially in the upper thoracic spine, whereas it was convergent in the midthoracic spine and quite straight at T11 and T12. Screw placement was confirmed by fluoroscopy, using the anteroposterior, lateral, and oblique views. The oblique view permitted a further check for screw placement inside the pedicle and also for the tip of the screw and the anterior border of the vertebral body. That way, if the tip of the screw presented beyond the anterior border of the body, it was immediately removed, its tract was palpated, and a new screw was inserted with the appropriate shorter length.

After screw placement, the posterior release was completed by removing the superior articular facet and partially the inferior facet of the cephalad vertebra, bilaterally. The deformity was corrected using the translational technique and rod rotation maneuver. Arthrodesis was carried out using autologous bone (ribs resected for posterior thoracoplasty) and banked bone (obtained from femoral epiphyses).

The mean operating time was 220 minutes (range, 190–290 minutes). The mean blood loss was 680 mL (range, 570–950 mL).

■ Results

An independent spine surgeon reviewed all medical records and radiographs of the patients (preoperative and postoperative and follow-up radiographs) to find screw-related complications, at a mean follow-up of 4 years (range, 3.1–5.4 years). Postoperative CT scans were performed in 25 patients (21.7%) because 30 screw positions were questionable.

There were 115 patients and a total of 1035 thoracic screws were inserted, more precisely, 53 in T3, 73 in T4, 89 in T5, 81 in T6, 65 in T7, 95 in T8, 95 in T9, 115 in T10, 160 in T11, and 209 in T12. The diameter of the screws was of 5.5 mm with a length of 30 to 35 mm between T1 and T10, and 6.5 mm diameter with a 35 to 40 mm length between T11 and T12. On average, 12 thoracic screws were inserted for each patient, ranging from a minimum of 6 to a maximum of 14. The mean preoperative thoracic curve of 75.4° (range, 60°–105°) showed a mean correction of 67.8% (range, 57.2%–75.3%) at follow-up.

In this group of 1035 thoracic screws implanted, there were complications such as screw misplacement, pedicle fractures, and dural lesions. However, no neurologic complications occurred.

The operation was repeated in 5 patients (4.3%) for screw removal: it was due to pleural effusion (in 1 case) late loosening of a malpositioned screw (in 1) and proximity to the aorta or very lateral displacement in 3 other

Table 1. Patients Reoperated for Screw Malposition

Case No.	Age (yr)	Scoliosis	Fusion	No. of Thoracic Screws	Screws Misplaced	Symptoms	New Surgery
7	53	Idiopathic T7–L3 (80°)	T3–L3	10	Left T5 lateral; right T5 lateral	Pleural effusion; fever	1 screw removed (T5 left)
10	18	Friedreich's ataxia T3–L4 (100°)	T3–L4	12	Left T3 lateral; right T3 lateral; left T5 lateral; right T5 lateral	No	4 screws removed (left and right T3; left and right T5) and replaced by 3 new hooks
31	18	Syringomyelia C3–T4 T5–L3 (105°)	T5–L3	6	Left T5 lateral	No	1 screw removed (left T5) and replaced by 1 transverse hook
15	15	Idiopathic T4–L1 (55°)	T4–L1	13	Left T9 lateral; right T9 medial	No	2 screws removed (left and right T9)
20	25	Idiopathic T5–T11 (55°); T12–L4 (50°)	T5–L4	10	Right T6 lateral	No	1 screw removed (right T6)

cases despite the lack of symptoms. In 2 other cases (1.7%), a superficial wound infection required incision and drainage, without removing instrumentation.

Screw Misplacement

Screw misplacement was documented by the review of postoperative radiographs. The presence of a different screw angulation from the other screws was very indicative of misplacement. Postoperative CT was performed in only 25 of the 115 patients (21.7%), and thus not in all patients, when standard and oblique postoperative radiographs raised well-founded doubts regarding the positioning of 30 screws, using established 2-mm increments (intrapedicular, 0 or <2 mm pedicle breach, 2 to 4 mm of breach, >4 mm breach).[3] The total number of screws examined by CT was 311.

Eighteen screws (1.7%) of the total of 1035 were misplaced in a total of 13 patients (11.3%): compared with the 311 screws examined by CT, these 18 misplaced screws represent, however, 5.7%, *i.e.*, a much higher rate. No other suspected screws on radiographs resulted malpositioned after CT examination. The positions of these 18 malpositioned screws were: 3 screws in T3, 2 in T4, 6 in T5, 3 in T6, 2 in T7, and 2 in T9. Malposition of the screws occurred more often in severe curves: 15 screws in curves >80° and 3 screws in curves <80°. Of the 13 patients with malpositioned screws, 5 presented adolescent idiopathic scoliosis, 4 congenital curve, 2 adult idiopathic scoliosis, and 2 scoliosis associated with a syndrome.

The malposition was medial in 3 (3 of 18, 16.6%), with medial pedicle breach between 1.0 and 2.0 mm. More often, malposition was lateral; it occurred in 12 screws (12 of 18, 66.6%), of which 9 were positioned on the concavity and 3 on the convexity of the curves: mean pedicle breach was 2.2 mm (range, 1.0–3.5 mm). The malposition was superior in 2 screws and inferior in one, with pedicle breach between 1.5 mm and 2.5 mm. None of the cases experienced anterior cortex penetration.

Screw malposition was symptomatic in the postoperative period in only 1 patient (0.8%) (Table 1): the patient (Case 7) presented fever on day 3 following surgery. CT showed pleural effusion and lateral malposition of the left screw in T5; the right screw also showed moderate lateral violation (Figure 2). In the 12 other patients, screw malposition did not cause clinical symptoms.

Five patients were treated again due to screw malposition (4.3%) (Table 1).

In the patient (Case 7) with postoperative pleural effusion and fever (Figure 2), the left T5 screw was immediately removed, while the right T5 screw was left in place; the fever resolved in 2 days. At the most recent follow-up, at 4 years, there was no loss of correction and the patient currently leads a busy working life.

Also, 4 other patients (Cases 10, 15, 20, and 31) underwent repeated surgery despite the lack of any symptoms, due to the possible future risk related to proximity to the aorta (<5 mm) in 3 cases and the increase at 5 months follow-up of lateral loosening of a left T5 screw (in another patient) (Figure 3). A girl affected by Friedreich's disease (Case 10) with severe scoliosis (100°) presented 4 misplaced screws, removed on postoperative

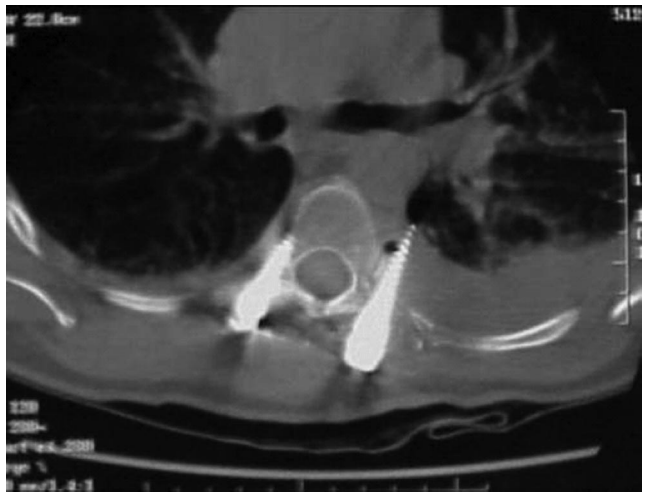

Figure 2. Case 7. The patient presented with fever on day 3 following surgery. CT showed pleural effusion and lateral intrathoracic malposition of the left T5 screw and moderate lateral violation of the right T5 screw. The left screw was immediately removed. Fever resolved in 2 days.

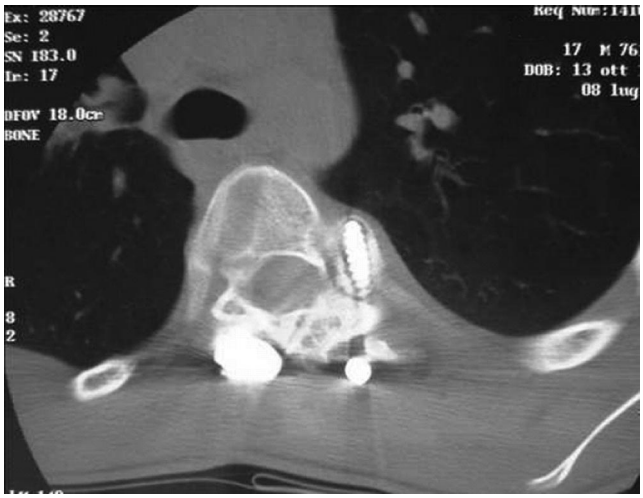

Figure 3. Case 31. Severe scoliosis (105°) with syringomyelia extending from C7 to T4. Five months after instrumentation, CT showed asymptomatic lateral loosening of the left T5 screw, initially misplaced. It was replaced by a transverse hook.

day 5 and replaced with 3 hooks; at 3-year's follow-up, the curve correction remained unchanged with respect to the postoperative one. Another girl (Case 15) with idiopathic scoliosis, 5 days later underwent surgery again to remove the two screws at T9, for severe lateral violation with regard to the left one and medial violation with regards to the right one; at 3-year's follow-up, there were no variations in the clinical and radiographic control. A 25-year-old woman (Case 20) underwent repeated surgery on day 6 after surgery to remove a laterally misplaced screw at T6: at 3-year follow-up correction was stable, without any clinical or radiographic variations. Lastly, 5 months following instrumentation, the CT scan of another patient (Case 31) affected by severe scoliosis (105°) with syringomyelia extending from C3 to T4 revealed an asymptomatic increase in lateral loosening of the left T5 screw with respect to the postoperative radiograph; furthermore, this screw was the proximal one of the left rod of instrumentation: therefore, we preferred to remove the screw and replace it with a hook (Figure 3): at 3-year follow-up, the instrumentation was stable and there were no clinical or radiographic changes.

In the other 8 patients (6.9%) with 8 misplaced screws, screw malposition did not present evidence of risks and did not cause any symptoms. These malpositioned screws presented a moderate lateral cortical perforation and were not in proximity to the aorta (they were at least 5 mm away): consequently, it was decided to leave the misplaced screws in place. At a mean follow-up of 4 years (range, 3.2–5 years), there were no changes in the radiograph control and no symptoms.

Pedicle Fracture

Intraoperative fractures occurred in 15 patients (13%) due to repeated attempts to position the screw in the scoliosis concavity with significant rotation. Fractures were recognized immediately during screw insertion in 12 cases, thanks to the probe into the canal: the hole was sealed with bone wax, without inserting the screw. In the other three cases, the pedicle fracture occurred during the rod rotation maneuver: the screws were removed and the hole sealed with bone wax. There were no fractures in the postoperative or follow-up period.

Dural Lesion

Dural lesions occurred in 14 patients (12.1%), evidenced by leakage of cerebrospinal fluid while preparing the screw holes. They all occurred when entering concave thoracic pedicles, while using the small curette, at T5 in 2 cases, at T6 in 4 cases, at T7 in 6 cases, at T8 in 1, and at T9 in 1 patient. The scoliosis curves were >80°. A hemilaminectomy was performed immediately to have a direct view of the lesion and to repair it rapidly with suture thread and fibrin glue. No spinal fluid leaks were noted after surgery. In all cases, the dural tear was a small hole.

Infection

There were infections in 2 patients (1.7%). In both cases, it was a superficial infection with fever, consisting of secretion from the wound between the 11th and 13th postoperative day. The infection was treated immediately with incision and drainage and healed in both cases, without removing instrumentation. A prolonged antibiotic therapy was used, extended for 2 months after the wound had healed.

■ Discussion

Thoracic screw fixation is potentially dangerous in the surgical treatment of scoliosis.[7,8] The technical difficulties posed by thoracic screws in scoliotic deformities have been emphasized.[3] However, only a few screw-related complications have been reported in the literature,[2,7,9,15,16] anyway, less severe than those reported in the treatment of thoracic and thoracolumbar fractures.[17–20]

Two cases[15,16] of severe complications in thoracic scoliosis have been reported, caused by screw overpenetration in the thoracic cavity. One case[15] was a 77-year-old woman with a T5 screw, which was impinging the descending thoracic aortic wall, as seen on a postoperative CT scan: successful treatment required a thoracic stent graft deployed under fluoroscopic guidance as the misplaced screw was manually retracted. The other case[16] was a delayed false aortic aneurysm due to a screw at T6, which was surgically repaired, in a 50-year-old man, treated 14 months before of removal of a Cotrel-Dubousset instrumentation and complaining of a severe stinging pain around the rods in his back: a pulsating mass 6.0 cm in diameter (associated with a continuous bleeding through the posterior wound) was found in the subcutaneous layer of the left paravertebral back. If such a delayed aortic injury is suspected, a CT scan with intravenous contrast or aortographic scan is recommended.[21] Another case of severe intrathoracic screw-related complication has been described, but in the treatment of a vertebral fracture[18]: a fatal cardiac tamponade occurred (caused by a prick injury of the right coronary artery) due to a Kirschner wire during thoracic instru-

mentation for a T11 burst fracture. Pleural effusion with fever occurred in one patient in our series: a left T5 screw was lateral and inside the thoracic cavity (Figure 2). It is questionable if pleural effusion was directly related to the misplaced screw; however, it resolved in 2 days after screw removal. In one case in a series presented by Liljenqvist *et al*,[1] a laterally penetrated screw led to a small hematoma without clinical relevance. A spontaneous pneumothorax in one patient with idiopathic scoliosis, which required insertion of a chest tube, was described by Suk *et al*,[2] but it was not directly related to a screw.

Conversely, asymptomatic intrathoracic screws[1,3,4] are commonly found in postoperative CT scans in 16.6%[1] to 29%[3] of screws implanted. Of these malpositioned screws, only a few were prophylactically revised, by others,[1,3,4] despite being asymptomatic. Screws <5 mm from the aorta in our experience must be removed even if they are asymptomatic, due to the risk of possible subsequent vascular lesions: erosion of the aorta by anterior spinal implants may occur.[22] Otherwise, malpositioned screws with moderate lateral cortical perforation (range, 3.0–6.0 mm) can be left where they are without causing complications, as we and other authors have done.[5,11] On the contrary, long screws must be always avoided, to preserve the anterior vertebral cortex: in the upper thoracic spine the screw insertion must be more convergent and the length not more than 25 to 30 mm[2], due to the proximity of the azygos vein and of the parietal pleura on the right and the thoracic aorta and the esophagus on the left.[8]

Neurologic complications are rarely reported in the literature in thoracic scoliosis treatment with screws.[2,9] Papin *et al*[9] reported a case with unusual disturbances due to spinal cord compression (epigastric pain, tremor of the right foot at rest, and abnormal feeling in legs) due to 2 screws (at T8 and T10), which had penetrated by 4 mm. The symptoms did not resolve spontaneously, but required screw revision surgery, and complete recovery occurred 1 month later. Suk *et al*,[2] in a series of 4604 thoracic pedicle screws inserted in 462 patients, found only one case with neurofibromatosis, which presented transitory paraparesis due to medial perforation of the pedicle causing delayed epidural hematoma: the paraparesis resolved after screw removal and decompressive laminectomy. In our series of 115 consecutive patients, no neurologic complications occurred, as in other large series of patients with scoliosis treated by thoracic screws.[3–6]

On the contrary, reports of medially positioned thoracic screws are quite common, but their rate and acceptability remain controversial.[3] Medial wall penetration ≤2 mm is well tolerated and the screws can be considered acceptably positioned[1]; these screws are thought to be accompanied by cortical expansion and benign pedicle wall fracture. Gerbsten and Robbins[17] studied postoperative CT scans of 71 thoracic screws (T8–T12) used in thoracolumbar fractures: they found a 26% incidence of medial cortical penetration of up to 8 mm and noted 2 "minor" neurologic complications; these authors hypothesized a 4-mm "safe zone" of medial encroachment (2 mm of epidural space and 2 mm of subarachnoid space). Others[5] hypothesize a "definite safe zone" within 2 mm and "probable safe zone" within 2 and 4 mm, and a "questionable safe zone" of 4 to 8 mm of medial encroachment. That could explain why the screw-related neurologic complications occurred in isolated cases[2] or were absent in ours or other large series[4–6] of patients treated for thoracic scoliosis, despite the 4 of 4604 (0.09%) medially misplaced thoracic screws in the series studied by Suk *et al*,[2] 10 of 3204 (0.3%) in that studied by Kim *et al*,[5] and 3 of 1035 (0.2%) in our series. Anyway, surgeons should be aware of shift of the dural sac toward the concavity in thoracic curves, when using pedicle screws. Liljenqvist *et al*[23] found with magnetic resonance imaging that the width of the epidural space was <1 mm at the thoracic apical level on the concave side, which means there is no safety zone on the concavity.

The rate of misplaced screws, however, increases notably up to 14%, when all the inserted screws were evaluated by CT in the postoperative period[3,5,6,24,25]; also, in our series the screw malposition rate increased to 5.7%, when assessed by CT postoperative examination. A conventional radiograph, indeed, may indicate correct placement of a screw that is incorrectly placed,[26] and without the help of CT many more misplaced screws might go unrecognized. However, it should be noted that, on re-exploration of screws violating the concave medial wall on CT scans, it was found that the pedicle track was instead intact, thus suggesting that the CT appearance may have been due to possible plastic deformation of the pedicle wall.[5]

For thoracic screw fixation, in the 115 consecutive patients in our series treated from 1999 to 2001, the mini-laminotomy technique was used in scoliosis treatment because the spatula inside the canal can make thoracic screw placement safer. It has also been possible to reduce the intraoperative use of fluoroscopy, not always helpful[27] in scoliotic curves. Extended use of fluoroscopy greatly increases surgery time and might increase the risk of contaminating the surgical field, thus exposing the surgeon to evaluation errors, due to the fact that fluoroscopy cannot provide alone completely reliable indications on correct screw positioning. Excision of the spinous process and complete removal of the yellow ligament with a small portion of the upper part of the lamina permit a posterior release to be performed anyway, which is then completed laterally when the screws have been placed. Posterior release is fundamental to improve the chances of correcting scoliosis, especially when screw fixation is performed.

The mini-laminotomy[13] technique used by us is one of several "anatomic" procedures for thoracic screw placement, such as the free hand method[5] and the open-lamina technique.[12] The number of malpositioned thoracic screws in our series was 18 of 1035 (1.7%) in a total of 13 patients (11.3%) of 115 consecutive cases treated. This percentage is not much higher than that of other series: 15.9% in a cadaveric study by Xu *et al*[12]

using open-lamina technique, 6.2% by Kim *et al*[5] using the free hand method (randomly studied, however, with CT scan), and 1.5% by Suk *et al*.[2] The use of the spatula inside the canal enabled us to limit the rate of medially positioned thoracic screws, which was 3 of 1035 (0.2%) in our series and 10 of 3204 (0.3%) in that studied by Kim *et al*.[5] Our malpositioned screws were mostly lateral; 12 screws (1.1%), of which 9 were positioned on the concavity and 3 on the convexity of the curves.

One disadvantage of the mini-laminotomy technique is the increased bleeding from the canal, which was stopped by gel foam. Another disadvantage is the increased number of dural lesions. In our series, these lesions occurred in 12.1% of patients, albeit without consequences. In other series, these complications were not reported, except by Suk *et al*[2] who reported 3 dural tears in a total of 462 patients; they also did not observe consequences related to the dural tears. Dural tears in our series occurred by entering concave thoracic pedicles, while using the small curette at T5 in 2 cases, at T6 in 4 cases, at T7 in 6 cases, at T8 in 1 and at T9 in 1 patient, in severe scoliosis curves that were >80°. The dural lesions in our patients were always exposed by hemilaminectomy followed immediately by suturing. None of them led to spinal fluid leaks after surgery.

Another common complication in our series was the intraoperative pedicle fractures that occurred in 15 patients (13%) due to repeated attempts to position the screw in scoliosis concavity with significant rotation. Fractures were recognized immediately during screw insertion in 12 cases, thanks to the probe into the canal: the hole was sealed with bone wax, without inserting the screw. In the other 3 cases, pedicle fractures occurred during the rod rotation maneuver: the screws were removed and the hole sealed with bone wax. There were no fractures in the postoperative or follow-up period. The rate of this complication was, in fact, rather high. Suk *et al*[2] reported a far lower rate (0.24%), probably because they refer to the total number of screws implanted and not to the number of patients, as we did (15 of 115).

Finally, we observed infection in 2 patients (1.7%). In both cases, it was a superficial infection with fever, consisting of secretion from the wound between the 11th and 13th postoperative day. The infection was treated immediately with incision and drainage and healed in both cases, without removing instrumentation. The rate of this complication is in line with that reported in the literature, *i.e*., 1.9% for Suk *et al*.[2] Prolonged antibiotic therapy, however, is recommended, for at least 2 months after the wound has healed.

Using the mini-laminotomy technique, as with other procedures, thoracic screw fixation might sometimes be impossible, when thoracic pedicles have too small a diameter. In a cadaver study at T6, a transverse diameter <4.3 mm was noted in 68% of specimens.[28]

Although the use of screws in thoracic scoliosis is still controversial, the risks of instrumentation with thoracic hooks must not be underestimated; they are inside the canal and are thus invasive, and may cause complications themselves.[29] Hooks can be more dangerous than screws because of their position and less rigid fixation, which can lead to dislocation during rod rotation or subsequently.[30] Screws in thoracic scoliosis have helped to simplify and optimize the corrective technique in translational and rod rotation maneuvers. In the hook rotation maneuver, they must be kept in distraction so they remain stable in their fixation site: this pretension increases column rigidity and limits the obtainable corrective effect.[30] However, this pretension is not necessary when screws are applied, as they are immediately stable following fixation. In scoliosis, thoracic screws on the concavity are the crucial anchor points for corrective purposes in order to restore thoracic kyphosis.[30] However, these anchor points are often subject to intraoperative pullout using hooks, with frequent intraoperative laminal fractures.

■ Conclusion

There is no consensus of opinion in the literature about the criteria to determine which asymptomatic screws must be revised and which must be observed. With regards to lateral malpositioned screws, we think they should be prophylactically revised, despite being asymptomatic, if they are in direct proximity to the thoracic aorta (<5 mm), due to the risk of possible subsequent vascular lesions; otherwise, malpositioned screws with moderate lateral cortical perforation (range, 3.0–6.0 mm) can be left where they are. On the contrary, long screws must be always removed. Medial wall penetration ≤2 mm would appear well tolerated and the screws can be considered acceptably positioned, although in one study[23] magnetic resonance imaging revealed that the width of the epidural space was <1 mm at the thoracic apical level on the concavity. In this study, 115 consecutive patients who underwent posterior instrumented fusion using 1035 transpedicular thoracic screws by 3 different surgeons at our Department from 1999 to 2001 were reviewed. Eighteen screws (1.7%) of all the screws were misplaced in 13 patients (11.3%). Postoperative CT was performed, however, in only 25 of the 115 patients (21.7%), when standard and oblique postoperative radiographs raised well-founded doubts regarding the positioning of 30 screws. Therefore, compared with the 311 screws examined by CT, these 18 misplaced screws represented instead 5.7%, *i.e*., a much higher rate. The mini-laminotomy technique was, however, beneficial in increasing the safety of the procedure with an acceptable rate of complications.

■ Key Points

- A total of 115 consecutive patients who underwent posterior instrumented fusion using 1035 transpedicular thoracic screws by 3 different surgeons at our department from 1999 to 2001 were reviewed.

- The thoracic pedicle screws were inserted with a mini-laminotomy technique. There were 18 screws misplaced (1.7%) in a total of 13 patients (11.3%) and another operation for screw removal was performed in 5 patients (4.3%). There were no neurologic complications.
- Thoracic pedicle screw placement in scoliosis patients requires utmost caution, but the mini-laminotomy technique was beneficial in increasing safety of the procedure with an acceptable incidence of complications.

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