Pneumothorax complicating “in-out-in” thoracic pedicle screw placement for kyphotic deformity correction in a child

Case report

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The authors describe a rare case of pneumothorax as a complication of thoracic pedicle screw placement in an 11-year-old girl undergoing posterior segmental instrumentation for a kyphotic deformity. Spontaneous pneumothorax after posterior fusion for adolescent idiopathic scoliosis has been reported in the orthopedic literature; however, to the best of the authors’ knowledge, pneumothorax directly related to pedicle screw placement for spinal deformity has not been previously described. The authors discuss the anatomical and technical aspects leading to this complication and the lessons learned from it. (DOI: 10.3171/PED.2008.2.12.379)

Key Words • complication • pedicle screw • pneumothorax • spinal deformity • spine surgery

In the surgical correction of spinal deformities, the addition of internal fixation serves the dual function of improving solid arthrodesis by rigid immobilization of the instrumented segments and correcting preexisting deformities by facilitated application of the corrective forces. Since the introduction of spinal PSs by Boucher in the late 1950s and the Harrington instrument in the early 1960s, spinal internal PS fixation has gained widespread use and popularity in the correction of spinal deformities.

The noted advantages of PS fixation include 3-column fixation; improved coronal, sagittal, and rotational correction; lower pseudarthrosis rates; fewer implant failures; and few postoperative external orthosis requirements compared with hook and wire constructs.

Despite the established role of PSs at the thoracolumbar, lumbar, and lumbosacral spine, their use in the thoracic spine has achieved limited acceptance among spine surgeons because of concerns related to the small pedicle size and tight proximity of vascular, nervous, and visceral structures in the thoracic cavity and the thoracic spine itself. Since the early 1990s, however, spine surgeons have been using PSs in the management of thoracic deformities and have not observed any serious vascular or visceral complications.

To our knowledge, this is the first report of a pneumothorax directly related to posterior fusion with segmental PS fixation. In the present study we detail a case of pneumothorax after “in-out-in” thoracic PS fixation for a kyphotic deformity correction in a child, review the technical aspects of extrapedicular screw placement, and discuss lessons learned from this complication.

Case Report

Presentation. This 11-year-old girl presented with a 1-year history of increasing episodes of falling. On examination, she had 4+/5 strength in her hip flexors bilaterally, and full strength in the rest of her lower extremities. She was myelopathic with hyperreflexia, clonus, impaired proprioception, and a spastic gait. Her postvoid residual was 250 ml. Magnetic resonance imaging revealed an extradural, dorsally positioned arachnoid cyst with spinal cord compression. She underwent a T6–10 laminoplasty with resection of the arachnoid cyst, and had been maintained in a thoracolumbar sacral orthosis postoperatively. By the 3-month follow-up visit, the myelopathy and strength in her proximal lower extremities had improved significantly; however, she was noted to have a significant midthoracic hump. Scoliosis radiography demonstrated increased kyphosis in her thoracic spine centered at T-8, measuring 73° (Fig. 1).

Abbreviation used in this paper: PS = pedicle screw.
Operation. Given the interval development of significant kyphosis, our patient was offered surgical correction and stabilization. As she had previously undergone a laminoplasty, PS fixation was believed to be a superior biomechanical choice compared with a laminar hook construct. However, the patient’s thoracic pedicles were small and sclerotic, making direct placement of thoracic PSs unlikely to succeed. Consequently, the in-out-in technique was used.

Our patient was taken to the operating room where she underwent a T4–11 posterior segmental fusion. We were unable to place PSs at T-6 and consequently omitted this level. Intraoperatively, her bone was noted to be quite soft and osteoporotic. After placement of the PSs using the in-out-in technique (Fig. 2), Smith-Petersen osteotomies were performed from T-5 to T-11. The rods were then placed and the osteotomies were closed as the rods were locked. We were retrospectively notified by the anesthesiologist of a sudden, but brief intraoperative drop in the patient’s tidal volume. Postoperative radiographs revealed a left pneumothorax (Fig. 3).

Postoperative Course. Postoperatively, the patient was neurologically at her baseline and her respiratory status was stable on room air. Consequently, her pneumothorax was managed conservatively, and resolved by postoperative Day 2. She was mobilized aggressively with her thoracolumbarsacral orthosis, and by postoperative Day 5 was ambulating without assistance. The patient was discharged the next day in good condition. Postoperative imaging demonstrated satisfactory correction of the kyphosis to 50° (Fig. 4).

Follow-Up. As of the 3-month follow-up examination, the patient no longer requires her external orthosis, and remains neurologically well. She has continued to maintain the correction of her preoperative kyphosis, but has developed some compensatory exaggeration of the lumbar lordosis. However, she does not have any back pain or evidence of adjacent-level disease at this time. A CT scan of her thoracic spine demonstrated continued bone fusion. The patient will return for follow-up at our clinic with repeated radiographs in 3 months.

Discussion

Complications of Thoracic PSs

Although PS-based instrumentation systems are biomechanically favorable to those using hooks and sublaminar wires, safety concerns have led to hesitation in using PSs in the thoracic spine above the thoracolumbar junction.24 Screw placement in the smaller thoracic pedicles can be more technically demanding than the thoracolumbar, lumbar, and lumbosacral spine due to the proximity of the spinal cord and other vital elements to the thoracic vertebrae.

Medially positioned thoracic PSs are quite common,2 but neurological complications from screws that breach the medial pedicle wall are rarely reported in the literature.28,31 No neurological complications were reported in several large studies in patients with scoliosis who underwent PS placement.2,5,17,21,23 Gertzbein and Robbins12 hypothesized a 4-mm “safe zone” of medial encroachment (2 mm of epidural space and 2 mm of subarachnoid space); however, this safe zone is probably much smaller in children.

When advanced beyond the anterior vertebral cor-
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text, the screws on the right side can endanger superior intercostal vessels, the esophagus,\textsuperscript{27} the azygous vein, the inferior vena cava, and the thoracic duct. Screws on the left side can endanger the esophagus and the aorta. Three cases of severe vascular complications\textsuperscript{6,14,16,26} caused by overpenetration of instrumentation into the thoracic cavity have been reported: impingement of the descending thoracic aorta wall requiring stent placement as the T-5 screw was withdrawn; aortic pseudoaneurysm formation caused by an errant T-6 screw requiring surgical repair; and a fatal cardiac tamponade caused by a prick of the right coronary artery by the K-wire during thoracic instrumentation for a T-11 burst fracture.

Laterally malpositioned screws can injure the pleura, lung, or segmental vessels,\textsuperscript{34,35} especially when using the in-out-in technique of PS placement as in our case. Pleural effusion with fever has been associated with a laterally positioned left T-5 screw that entered the thoracic cavity.\textsuperscript{9} The authors of another case series\textsuperscript{31} described a patient with idiopathic scoliosis in whom spontaneous pneumothorax developed which required chest tube placement after posterior instrumented fusion; however, the authors did not find that it was directly related to screw placement. Table 1 summarizes the reported complications of thoracic screw placement.

\textit{In-Out-In Technique of PS Placement}

The “in-out-in” technique, extrapedicular screw placement, or pedicle/rib screw fixation may be a useful salvage technique when intra- or transpedicular screw placement is not possible because of small pedicle (mediolateral) width or when a more lateral approach is preferred for safety reasons and maximum fixation is not required.\textsuperscript{10} The pull-out strength of screws placed with the in-out-in technique reaches $\sim 70\%$ of that of intrapedicular screws. Here, the screw traverses the transverse process and engages the lateral wall of the pedicle and medial aspect of the rib head in the continuation of the paravertebral space before entering the vertebral body (Figs. 2 and 5).

\textit{Causes of Pneumothorax}

The thoracic paravertebral space is a wedge-shaped anatomical compartment adjacent to the vertebral bodies (Fig. 5). The space is defined anterolaterally by the parietal pleura, posteriorly by the superior costotransverse ligament, medially by the vertebra and intervertebral foramina, and superiorly and inferiorly by the rib heads.

With the “in-out-in” technique of thoracic PS placement, the more lateral entry point confers less risk of injuring the spinal cord but a greater risk of injuring vas-
ular structures and viscera and its coverings, such as the lungs and pleura. Because of the close relationship of the paravertebral space to the parietal pleura, incorrect, or even slightly more lateral, instrument or screw placement may cause pleural perforation or lung injury, resulting in pneumothorax.

In our case, postoperative work-up, the clinical status of the patient, and the stable size of the pneumothorax did not seem to indicate direct lung injury. Final PS position based on postoperative CT appeared to be satisfactory and unlikely to be the culprit for the formation of the pneumothorax. Instead, we surmise that injury to the parietal pleural with the pedicle finder or ball-tipped probe occurred at the time of surgery, allowing air to enter the pleural cavity and resulting in a stable pneumothorax.

**Lessons Learned**

Thoracic PS placement is fraught with danger to the patient in the form of life-threatening neurological, vascular, and visceral complications. These risks are even greater in the setting of spinal deformity, the immature or osteoporotic spine, or congenital anomalies of the spine in which the anatomy may be distorted, small, or less straightforward. In these cases, the newest generations of 3D image-guided spine surgery systems may prove beneficial. Until they become widely available, spine surgeons will continue to use free-hand techniques or 2D imaging modalities such as fluoroscopy to aid in screw placement.

In our case, we found that the use of even blunt-tipped instruments such as the pedicle finder, ball-tipped

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**TABLE 1**

**Summary of previously reported complications related to thoracic PS placement**

<table>
<thead>
<tr>
<th>Authors &amp; Year</th>
<th>Complication</th>
<th>Treatment</th>
</tr>
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<tbody>
<tr>
<td>Matsuzaki et al., 1993</td>
<td>erosion of thoracic aorta by screw</td>
<td>burring of screw &amp; repair of aorta w/ tube graft</td>
</tr>
<tr>
<td>Heini et al., 1998</td>
<td>undetected prick injury to coronary artery by K-wire during verification of T-10 pedicle hole leading to pericardial effusion</td>
<td>patient died 12 days after surgery</td>
</tr>
<tr>
<td>Choi et al., 2001</td>
<td>false aortic aneurysm at T-6 due to PS diagnosed after screw removal</td>
<td>repair w/ Dacron tube graft</td>
</tr>
<tr>
<td>Suk et al., 2001</td>
<td>transient paraparesis due to medial breach of pedicle &amp; subsequent epidural hematoma</td>
<td>removal of screw &amp; laminectomy for evacuation of hematoma</td>
</tr>
<tr>
<td>Minor et al., 2004</td>
<td>aortic erosion by T-5 PS found incidentally injury to esophagus from T-3 PS</td>
<td>removal of screw &amp; endovascular repair of aorta</td>
</tr>
<tr>
<td>O’Brien et al., 2006</td>
<td>laterally placed T-5 PS leading to fever &amp; pleural effusion</td>
<td>revision to shorter PSs w/ no further complications</td>
</tr>
<tr>
<td>Di Silvestre et al., 2007</td>
<td>perforation of thoracic aorta by T6 pedicle screw</td>
<td>removal of screw w/ resolution of symptoms</td>
</tr>
<tr>
<td>Kakkos &amp; Shepard, 2008</td>
<td></td>
<td>burring of screw &amp; direct repair of aorta</td>
</tr>
</tbody>
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**Fig. 5.** Artist’s illustration showing extrapedicular screw placement on the right but perforation of the parietal pleura in the paravertebral space by a ball-tipped probe on the left.
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probe, and tap, leading up to final PS placement have the potential to cause the aforementioned complications, especially in an osteoporotic patient. When sounding the osseous channel with a ball-tipped probe, it is essential to follow the same trajectory and path created by the pedicle finder or tap. The ball-tipped probe is flexible and small enough that it may find its own way into the paravertebral space via defects in the surrounding ligaments and joint capsules, potentially injuring the parietal pleura and lung (Fig. 5). These instruments probably have a greater potential for injury than the screw itself, as the PS is nonself-tapping, and the final PS trajectory, direction, and placement relies solely on the osseous channel sequentially prepared by the other instruments.

Finally, we confirm the most fundamental of principles in the operating room—effective communication between the anesthesiologist and surgeon is essential throughout the operation. The surgeon did not recognize pneumothorax as a possible complication of thoracic PS placement and consequently did not discuss this with the anesthesiologist preoperatively. Thus, although the anesthesiologist noted a sudden but transient decrease in tidal volume during PS placement, the situation was not relayed to the surgical team because the significance of this finding was not appreciated. In hindsight, we could perhaps have further investigated this change in respiratory status, diagnosed pneumothorax intraoperatively rather than postoperatively, and instituted treatment earlier rather than later.

Conclusions

Thoracic PS fixation is a powerful tool for the surgical correction of spinal deformities. However the proximity of critical neurovascular structures and cardiopulmonary organs leaves small margin for error. To the best of our knowledge, pneumothorax complicating posterior segmental instrumented fusion for spinal deformity in a child has not been previously reported as a direct result of thoracic PS placement. We report this case of pneumothorax related to PS placement as a reminder for spine surgeons, particularly pediatric spine surgeons, to be aware of this complication and include this complication in preoperative discussions with the patient, the family, and the other members of the surgical and anesthesia team.

Disclaimer

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

References


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