Delayed open treatment of aortic penetration by a thoracic pedicle screw: illustrative case

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BACKGROUND Iatrogenic aortic injury from pedicle screw malpositioning or anterior prominence in posterior spinal fusion represents a rare but potentially devastating complication. While intraoperative aortic injury is associated with hemodynamic instability, delayed presentations of pedicle screw aortic impingement or violation often present insidiously with pseudoaneurysm or vascular remodeling in clinically asymptomatic patients. Currently, there is a lack of guidance in the field for the recommended surveillance, urgency of operative intervention, and optimal surgical management of delayed pedicle screw aortic injuries.

OBSERVATIONS The following case study discusses the open treatment of delayed thoracic aortic penetration from an excessively long T12 pedicle screw in an asymptomatic adolescent patient with idiopathic scoliosis. The pedicle screw prominence anteriorly was corrected by burring the screw tip until it was flush with the vertebral body. The associated aortic injury was addressed with open vascular repair via primary anastomosis supplemented with a bovine pericardial patch.

LESSONS Complete aortic wall penetration from an excessively long thoracic pedicle screw with otherwise stable screw positioning may be addressed most effectively with a single anterior surgical approach for open aortic repair and screw tip burring.

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KEYWORDS aortic injury; aortic repair; pedicle screw; adolescent idiopathic scoliosis; complication

Posterior thoracolumbar spinal fusion with pedicle screw fixation is a highly regarded treatment modality for spinal deformity because it enables robust 3-column stabilization.1–2 However, this common and efficacious procedure is not without complication secondary to pedicle screw malpositioning or anterior prominence.3–5 Specifically, iatrogenic aortic injury from screw penetration represents a rare but potentially devastating complication of thoracolumbar spinal fusion, with a reported incidence from 0.01% to 0.05%.4–7 Cadaveric studies have demonstrated that freehand thoracic pedicle screw placement is technically difficult where, among experienced spine surgeons, pedicle screw cortex penetration rates were as high as 40%.8 Even if pedicle screw trajectory is optimal, complications can result from excessive pedicle screw length resulting in cortical breach of the anterior vertebral wall.3–9 Although the rate of pedicle screw anterior cortical breach is incompletely defined, concern is greater in osteoporotic patients where longer screw lengths are often used to maximize fixation strength.9 In adolescent idiopathic scoliosis (AIS), coronal and sagittal plane imbalance and rotational deformities may increase the likelihood of inappropriate pedicle screw selection and positioning.5,10 While additional safeguards, including preoperative computed tomography (CT) templating and intraoperative O-arm navigation, are commonly used in complex deformity correction, the rates of guided pedicle thoracic pedicle screw misplacement are still reported as high as 10%.11–12

Aortic injury from pedicle screw malpositioning or anterior cortical breach can occur in an acute or delayed fashion.13,14 In the acute intraoperative setting, pedicle screw penetration into the posterior aortic wall leads to hemorrhage and acute hemodynamic instability.5,14 However, delayed presentations of partial or complete pedicle screw aortic penetration are often insidious, presenting months to years after the index surgery.15 While it is possible for patients to present with pulsatile epigastric pain or asymmetrical lower extremity pulses, more frequently cases of delayed intra-aortic screw penetration are clinically

ABBREVIATIONS AIS = adolescent idiopathic scoliosis; CT = computed tomography; TEVAR = thoracic endovascular aortic repair.

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silent and range radiographically from no intraluminal changes to large pseudoaneurysm formation. As a result of the rarity and clinical variability of delayed aortic injury after thoracolumbar fusion, there is a lack of guidance in the field for the recommended surveillance, urgency of intervention, and optimal surgical management. The present case is the first to report on the open treatment of an excessively long thoracic pedicle screw with erosion into the aorta without removal of the pedicle screw at an interval greater than 10 years from the index scoliosis surgery. This case report adds to the literature by demonstrating an alternative methodology for treating this potentially devastating, uncommon complication.

Illustrative Case
A 25-year-old female presented with a history of Prader-Willi syndrome, osteopenia secondary to hyperprolactinemia (z-score = −2.3), and AIS for which she had undergone posterior instrumented fusion from T1 to S1 with T12–L5 laminectomies and T12–S1 interbody cage insertion at age 13 years. Six years prior to presentation (age 19 years) during hospitalization for ileus, an abdominal CT incidentally revealed right T12 pedicle screw protrusion through the anterior T12 vertebral cortex in a juxta-aortic location. A subsequent ultrasound-guided aortogram demonstrated intraluminal positioning of the right T12 screw. The aortogram was complicated by right iliofemoral artery occlusion and acute right limb ischemia for which she underwent thrombectomy and bovine patch angioplasty with complete resolution. Immediate screw removal and aortic repair was discussed; however, a conservative approach with routine radiographic surveillance was preferred by the patient and her family. At annual follow-up with outpatient vascular surgery, CT angiograms demonstrated stable right T12 pedicle screw positioning without unfavorable aortic remodeling, and the patient remained clinically asymptomatic.

At the age of 25 she returned to the clinic, at which time she remained asymptomatic and denied the presence of back pain, abdominal pain, numbness, weakness, or gait disturbance. On examination, she had full strength and intact sensation in the bilateral upper and lower extremities. Lower extremity vascular exam demonstrated normal bilateral dorsalis pedis and posterior tibial pulses. Standing whole-spine radiographs revealed stable posterior fixation without loosening, hardware failure, or proximal junctional kyphosis. Residual thoracolumbar scoliosis with convex right midthoracic curve and compensatory left downward pelvic tilt was noted (Fig. 1). A CT scan was obtained and demonstrated that the right T12 pedicle screw tip extended 5 mm beyond the anterior cortex of the T12 vertebral body into the right posterolateral aortic margin without evidence of hemothoma or pseudoaneurysm (Fig. 2). Although the intra-aortic pedicle screw remained clinically asymptomatic and nonprogressive on imaging, the patient and her family elected to proceed with an operative intervention to prevent future complications.

Surgery was performed in the supine position with a supraumbilical midline approach to expose the supra-renal aorta. Intraoperative intravascular ultrasound confirmed intraluminal pedicle screw aortic penetration to the right of the celiac axis. The supra-renal and infra-renal aortas were briefly clamped to exteriorize the right T12 pedicle screw from the posterolateral aortic wall. The posterolateral aortic wall was closed with interrupted 4–0 Prolene (Ethicon/Johnson & Johnson) suture with felt pledgets, with flow restored after a 2-minute clamp time. After aortic anastomosis was achieved, the protruding T12 pedicle screw was freed from soft tissue with a small angle curette and gel was applied to the T12 anterior surface in anticipation of metal debris.

Discussion

Observations
The delayed vascular sequelae of pedicle screw malpositioning or anterior cortical prominence represent a critical and likely underreported complication of thoracolumbar fusion surgery. This case demonstrates that a long pedicle screw placed without intraoperative aortic injury is capable of eroding through the aortic wall with time. Increased clinical suspicion for pedicle screw aortic injury is warranted in patients undergoing spinal fusion for scoliotic deformity due to spinal aortic tethering, increased aortic mobility, and unpredictable pedicle screw trajectories. In complex spinal deformity surgery, such as the present case, routine intraoperative or postoperative CT may be an effective tool for the early identification of inappropriate pedicle screw length or positioning. Nonetheless, juxta-aortic or intra-aortic pedicle screw locations are often discovered as an incidental, late postoperative complication.

A carbide metal cutting Burr was utilized to remove the anterior screw protrusion, such that the residual screw was smooth and flush with the ventral vertebral surface. A 2-cm bovine pericardial patch was wrapped circumferentially around the supra-renal aorta and secured with 5–0 Prolene prior to wound closure (Fig. 3).

Postoperatively, the patient did well and remained medically stable and neurologically intact. No minor or major complications occurred, and she was discharged home on postoperative day 2. Six months after surgery, a CT angiogram demonstrated that the revised right T12 pedicle screw terminated 5 mm proximal to the aortic wall and the aorta was non-aneurysmal with no contrast extravasation at the anastomosis site. At 2 years postoperatively, the patient remained asymptomatic and denied the presence of any pain or neurological symptoms.
finding in clinically asymptomatic patients. The best-practice management of pedicle screw aortic impingement and violation is highly debated, with current evidence derived only from expert opinion in case reports and small case series. Furthermore, the optimal vascular and spinal techniques for aortic repair and pedicle screw revision/removal remain unknown.

Multiple treatment options exist to address aortic remodeling associated with pedicle screw violation and to mitigate the risk of future aortic compromise. Pedicle screw removal with or without screw replacement and pedicle screw burring represent the most common interventions to address screw misplacement and anterior prominence. Pedicle screw removal may be more appropriate if pedicle cortex penetration or screw loosening is present. After which, screw replacement should be considered in unstable fusion constructs and complete removal of spinal hardware may be warranted in known infections. However, in excessively long pedicle screws with accurate trajectory, anterior vertebral cortex prominence may be addressed by burring the screw tip until it is flush with the vertebral body. The associated aortic injury can be repaired with open (primary repair, patch angioplasty, tube graft interposition) or endovascular (thoracic endovascular aortic repair [TEVAR]) techniques. The role of each of these modalities is dependent on the size, location, and depth of the aortic defect, where the risk of uncontrolled bleeding must be weighed against the morbidity of aortic cross-clamping. In clinical scenarios where it is difficult to determine the extent of aortic wall violation, intravascular ultrasound may be a useful diagnostic modality in preoperative planning to distinguish screw impingement from aortic perforation with confirmed intraluminal positioning. An endovascular approach with TEVAR is favored in aortic impingement, whereas open primary or patch repair may be preferred to address large aortic wall defects with associated remodeling. In the majority of prior investigations, aortic repair was performed before pedicle screw revision to decrease intraoperative hemorrhage risk. However, in patients with pedicle screw impingement without aortic perforation, the utility of prophylactic aortic repair and, if performed, the optimal sequence of vascular and spinal procedures remains controversial. Nonetheless, while aortic repair for pedicle screw violation is theoretically a high-risk procedure, to date there are no reported mortalities in the literature from open or endovascular interventions.

The present case study describes the incidental detection of and delayed operative intervention for thoracic pedicle screw anterior vertebral body cortex penetration with confirmed intraluminal aortic position in an asymptomatic patient with a remote history of posterior spinal fusion for AIS. Although the 6-year period from intra-aortic pedicle screw detection to surgical treatment reflects patient preferences, this long operative delay without resultant neurological or vascular complication demonstrates the potential appropriateness of initial nonoperative management and routine radiographic surveillance in asymptomatic patients.
individuals without evidence of vascular remodeling. In this case, an open vascular repair via primary anastomosis supplemented with a bovine pericardial patch was preferred to allow for the direct visualization of the aortic wall and adequate hemostasis when the right T12 pedicle screw was freed from aortic intimal adhesions. Pedicle screw removal was not deemed to be necessary because the posterior aspect of the pedicle screw was adequately positioned without pedicle cortex violation or aseptic loosening. During burring of the prominent thoracic pedicle pedicle screw tip, reduction of metal debris in the wound was prioritized to limit local inflammatory response and prevent metallosis. Furthermore, screw burring enabled the multidisciplinary surgery to be performed efficiently with a single anterior operative approach without the need for patient repositioning.

Lessons
This case report is not without limitations, including those inherent to extrapolation from a single patient, limited postoperative follow-up, and subjective outcome assessment without patient-reported outcomes available. However, this patient had an uncomplicated postoperative course, remained asymptomatic and pain free at 2 years follow-up, and demonstrated appropriate thoracic pedicle screw positioning on postoperative CT angiogram. Based on these findings, it is our recommendation that surgical intervention should be addressed with the patient as a potential treatment option in addition to observation. For complete aortic wall penetration from an excessively long thoracic pedicle screw with otherwise stable screw positioning, an effective surgical technique is a single anterior approach for open aortic repair and screw tip burring. The relative urgency of operative intervention should be dictated by patient symptomatology and the presence of vascular remodeling. Longitudinal studies are required to determine the safety of delayed operative intervention for stable intraluminal aortic pedicle screws without vascular remodeling, hemorrhage, or pseudoaneurysm formation. Last, further comparative investigations are necessary to elucidate the indications for open versus endovascular repair based on pedicle screw penetration depth and aortic wall defect characteristics.

References

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Author Contributions
Conception and design: all authors. Acquisition of data: Pinter, Levy. Analysis and interpretation of data: Pinter, Levy. Drafting of the article: all authors. Reviewed and submitted version of the manuscript: Pinter, Levy, Hobson. Approved the final version of the manuscript on behalf of all authors: Pinter. Statistical analysis: Levy. Administrative/technical/material support: Levy. Study supervision: Levy.

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