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Late diagnosis of perforation of the aorta by a pedicle screw

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Although the clinical and biomechanical advantages of pedicle screws are well documented, the accuracy of their insertion is always a concern. Injury of neurovascular structures could be devastating. Perforation of the aorta from posteriorly placed screws is fortunately rare but could end up being lethal.

We present a review of the current literature along with two illustrative cases with aorta perforation from posterior pedicle screws. An 82-year-old female with a history of thoracic kyphosis and a 26-year-old female with scoliotic deformity were referred to our institution owing to back pain. Both patients had undergone correction of their deformities and posterior fixation using posterior pedicle screws and rods 5 years previously. During the diagnostic work-up, which included CT scans, we incidentally found one pedicle screw to be malpositioned, exiting the vertebral body and perforating the aorta. The patients were offered a combined orthopaedic and vascular procedure, including screw removal and endovascular stenting of the aorta. Potential complications from the presence of a screw inside the pulsatile aorta, and the complexity of revision surgery should be well considered before proceeding to such a difficult surgical procedure. Systemic postoperative follow-up imaging and safer intraoperative practices during screw placement are important.

Keywords : pedicle screw ; thoracic spine ; aorta ; perforation.

INTRODUCTION

Pedicle screws have been used successfully for posterior spinal fixation for over 2 decades (*10*). Their biomechanical superiority and advantages in terms of fusion rates, coronal balance restoration and functional outcome over former methods of posterior spinal fixation are well established (*8,9*). Pedicle screw insertion requires thorough knowledge of the pedicle and vertebral anatomy. The most common techniques of screw placement include the freehand technique and intraoperative fluoroscopic guidance. EMG screw stimulation is also used to

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inspect for possible pedicle breach. However, the accuracy of pedicle screw placement has always been a major drawback, in association with possible injury of vital structures such as major vessels (aorta, vena cava) or spinal cord.

INCIDENCE OF AORTIC INJURY FROM PEDICLE SCREWS

Several reports have shown that the rate of pedicle cortex penetration is high, particularly in the thoracic spine due to the specific anatomic characteristics of this region (*3,6,20*). Moreover, intentional anterior vertebral body cortex penetration, which is preferred by some spine surgeons in order to enhance the biomechanical stability of fixation, may place major vital structures at risk (*10*).

Sjostrom *et al* investigated pedicle screw tracts after routine implant removal after thoracolumbar fracture healing (*28*). In 48 pedicles that underwent instrumentation superior and inferior to the fractured vertebra, a correlative comparison to post implantation CT was possible. Thirty-one pedicles had evidence of increased width and 14 had radiographic deformation indicative of fracture of the lateral wall that could be attributed to screw insertion. Fortunately, the total number of associated complications, such as neurologic, vascular or pulmonary injuries was limited (*10*).

The incidence of major vascular injuries caused by malpositioned spinal screws is probably very low. In a recent systematic review, aortic abutment was noted in only 6 of 8147 screws (incidence 0.07%) in 8 studies that specifically reported this finding (*10*). In another study Foxx *et al* retrospectively reviewed a series of 182 consecutive patients who underwent thoracic, lumbar, and lumbosacral fusion using pedicle screw instrumentation, to determine the frequency of intraoperative vessel contact (*7*). From a total of 680 inserted pedicle screws, 33 were shown on postoperative imaging to be in contact with, but not deforming, a major vessel (aorta, iliac artery, iliac veins) (*7*).

A small number of publications present cases with major iatrogenic vascular injuries during anterior instrumentation procedures, but only four during posterior procedures using pedicle screws (*11,15,30*). In all cases, perforation of the aorta was discovered intraoperatively or during the first postoperative days and was acutely revised.

ANATOMIC RELATIONSHIP OF THE AORTA TO THE SPINE

The close anatomic relationship of the aorta places it at risk during spinal procedures (*19,33*). Most iatrogenic vascular injuries have been associated with lumbar discectomies. Vascular injuries related to pedicle screw placement are more common in the thoracic spine. Azygos vein, inferior vena cava or segmental vessels may be injured on the right side, and the descending aorta or segmental vessels on the left side, according to an anatomic study presented by Vaccaro *et al* (*32*). These structures are found to be within 5 mm of the anterior vertebral cortex. In patients with scoliotic deformities, the aorta is placed more laterally and posteriorly relative to the spine, and therefore is more prone to injury in these cases. The degree of aortic displacement is increased with larger curve magnitudes, greater axial rotation, and hypokyphosis.

Sucato and Duchene, using the preoperative magnetic resonance images, described the relationship of the aorta to the spinal structures in patients with right thoracic scoliosis (*29*). The aorta was found more laterally and posteriorly adjacent to the vertebral body from the fifth to the 12th thoracic level in patients with scoliosis compared with the situation in patients without scoliosis. This difference would render the aorta susceptible to irritation or injury from laterally oriented pedicle screws. In a similar MRI study including patients with right thoracic curves, Sarlak *et al* found that T4-T8 pedicle screws on the concave side may pose a risk to the aorta as well as T11-T12 on the convex side (*27*).

Qiao *et al* illustrated different changes in position of the aorta relative to vertebrae between thoracolumbar/lumbar curves with different convexities (*24*). In right-sided curves, the risks of aorta impingement were mainly from left pedicle screws while in left-sided curves, they were mainly from right screws. The aorta was more proximal to entry points in right sided lumbar curve when compared

with left-sided curve, thus placing pedicle screws more at risk in right-sided thoracolumbar/lumbar curves.

Moreover, Jiang *et al* showed that the aorta shifts more anteromedially and more closely to the spine at the T5-T10 levels when patients with right idiopathic scoliosis change from the supine to the prone position (*14*). Thus, in the prone position, the aorta is potentially at a higher risk for injury from anterior and lateral cortex penetration by the left pedicle screws.

The majority of pedicle screw perforations occur laterally or anterolaterally. In a cadaveric model, Cinotti *et al* found that the pedicle width is narrowest in the midthoracic region (T4-T8) (*4*). Moreover, Kothe *et al* found that the medial pedicle walls are two to three times thicker compared to the lateral wall, making medial perforation more difficult to occur (*17*).

PHYSICAL HISTORY OF CHRONIC SCREW IMPINGEMENT ON THE AORTA

The orthopaedic knowledge on the physical history of these cases is limited. Foxx *et al* have raised an interesting question, and their data suggest that pedicle screws whose tips touch, but do not deform, great vessels can probably be safely followed up over time (*7*). Specifically, 33 screws presenting with aortic or iliac artery involvement were followed up over a period of 44 months (range : 5-109 months) but no clinical issues related to vascular injury developed.

However, there is a number of case reports in the current literature showing that a pseudo-aneurysm could be formed within a period that ranges from a month to 20 years after surgery (*1,23*). Faro *et al* conducted an *in vivo* study in a bovine model trying to evaluate the radiographic, histologic and biomechanical consequences of thoracic vertebral screw impingement on the aorta and showed that major impingement of vertebral screws may cause acute and chronic histopathologic and biomechanical changes in the vessel wall, which can end up in a marked compromise of the vessel wall integrity (*5*).

The main concern about a delayed vascular injury is associated with the fact that, at the time of a haemorrhagic event, the patient may no longer be in the hospital. Therefore, urgent access to medical assistance could be significantly delayed, with fatal consequences.

As the number of posterior spinal procedures with the use of pedicle screws has increased during the last years, it is evident that the need for more accurate screw insertion is necessary (*10*). The correct choice of the entry point into the pedicle and the appropriate angle of insertion are of key importance (*30*). Especially in the thoracic spine, limiting the length of pedicle screws as reasonably possible could be a safe practice (*30*). Computed tomography-based navigation systems, as well as two-dimensional and three-dimensional fluoroscopy based navigation systems are now available, and their assistance in more accurate pedicle screw insertion is invaluable (*12,13,16,18,21*). Ughwanogho *et al* demonstrated that a potentially unsafe screw is 3.8 times less likely to be inserted with navigation (*31*). The odds of a significant medial breach are 7.6 times higher without navigation.

DIAGNOSIS

In most of the cases, the diagnosis of aorta perforation is made intra-operatively (*10*). If this is suspected, it is advised not to remove the screw, because a massive bleeding from aorta perforation after removal of the screw would not be easy to be controlled, especially with the patient in prone position (*33*). Diagnosis should be immediately confirmed by CT angiography or digital aortography, and a vascular surgeon should be involved (*26,33*).

There are reports showing that delayed vascular injuries associated with spinal injuries may occur after chronic irritation of the aorta against the metallic implant. Matsuzaki *et al* reported on a thoracic aortic perforation from an anteriorly placed pedicle screw (*19*). That case was recognized only on follow-up CT scans 6 weeks postoperatively. The authors estimated that the aortic injury had been sealed by scar tissue and the pedicle screw itself, which prevented haemorrhage.

CT scans are not ordered on a routine basis in many institutions and CT images without contrast enhancement may be of lesser quality, due to

artifacts (*10*). If there is a suspicion of aorta impingement or perforation from a pedicle screw, a CT angiography should be considered, to confirm diagnosis, define the integrity of the vascular wall, and demonstrate leaking or formation of a pseudoaneurysm (*1,23*).

TREATMENT

Although intra-vascular presence of a screw could be terrifying for both the patient and the attending physician, one should carefully evaluate the available options of management. Several authors have published on treatment strategies after an acute aortic injury from pedicle screw misplacement (*11, 22*). The potential future complications from the presence of a screw near or inside a pulsatile aorta, and the complexity of revision surgery should be balanced.

Surgical treatment consists of simultaneous screw tip burring or removal and endovascular stenting or extravascular repair of the aorta with a patch (*1,11,22,33*). Thoracic aortic injuries are preferentially treated using endovascular stents. Endovascular aortic repair is associated with decreased perioperative morbidity because avoidance of thoracotomy and cross-clamping results in a lower incidence of paraplegia and pulmonary complications compared to open procedures. However, long-term graft migration or endoleak (presence of blood flow around the graft while the latter remains inside the vessel) are potential complications of the endovascular surgery. It is therefore important that the site of injury is completely covered by the stent, and that the proximal and distal "landing zones" are normal in order to achieve adequate sealing.

The potential complications of the surgery should not be underestimated especially in patients with multiple comorbidities and the elderly (*33*). However, in younger patients the possibility of aortic rupture in the mid or long term and the lethal consequences thereof should be explained in every detail.

ILLUSTRATIVE CASES

We present two cases of descending thoracic aorta perforation from pedicle screws, which were diagnosed late. We describe the physical history of these cases over time, and we aim to highlight the significance of systematic postoperative follow-up imaging, and necessity for safer intraoperative practices during screw placement, in order to prevent severe or even catastrophic complications.

Case 1

An 82-year-old female with a history of multiple spinal surgeries presented to our outpatient clinic due to recurrent, progressive thoracic kyphosis and unrelenting spinal pain. She was first operated at an outside facility at the age of 70 for severe late kyphosis, which was initially managed with partial correction of the deformity and posterior spinal fusion extending from T4 to L4 using multi-axial pedicle screws and rods. Early postoperative course was reportedly uneventful although the patient did not provide the preoperative and the postoperative radiographs. Two years later she had a revision of the spinal instrumentation due to an unspecified history of postoperative infection with reportedly loosening of the cranial part of the original spinal instrumentation. During the revision surgery partial removal of instrumentation was performed and for non-clearly defined reasons, the total length of the latest posterior instrumentation was shorter, extending from T7 to L4 ; subsequently recurrence of kyphotic deformity developed progressively over the following 3 years, at the levels above T7 that were not fused.

Five years postoperatively, though, she visited our outpatient department complaining of unrelenting back pain, progressive kyphosis and a palpable hump above the level of instrumented fusion. She was neurologically intact with no symptoms of recurrence of infection. She denied fever, and all inflammatory indices were within normal limits.

A CT scan was ordered to evaluate the mechanical integrity, to better assess the progressive deformity, and to disclose other potential causes of pain. Studying these CT images, we were confronted with a left pedicle screw, which was protruding through the anterolateral wall of the T10 vertebral body and perforating the aorta (Fig. 1). The patient's chart records and surgical notes had no comments

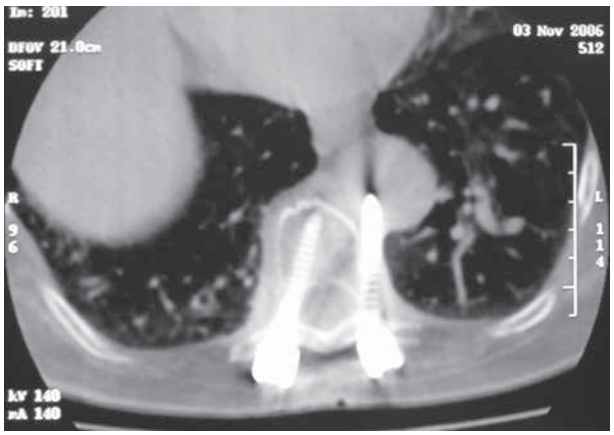

Fig. 1. — CT image of case 1 showing a left pedicle screw, which protrudes through the anterolateral wall of the T10 vertebral body and perforates the aorta.

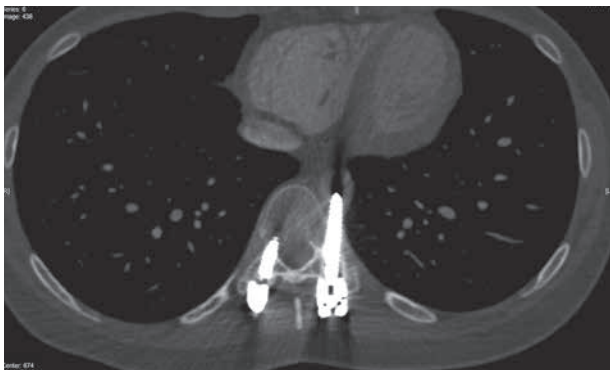

Fig. 2. — CT images of case 2 demonstrating a misplaced T10 left transpedicular screw, which penetrates the lateral cortex of the vertebral body and perforates the aorta.

on a pedicle screw malposition or intraoperative event of acute bleeding or hypotension. No CT imaging was obtained after the second surgery because postoperative plain radiographs were reportedly normal without any signs of screw malpositioning.

The dilemma on whether to replace or leave in place the perforating screw was significant. The correction of the kyphotic deformity, which was definitely the source of her symptoms, would need a cranial extension of the spinal fusion ; however, intraoperative corrective maneuvers could potentially displace the perforating screw with lethal consequences. After receiving consultation from a vascular surgeon, the patient was offered a surgery consisting of screw removal, endovascular stenting of the aorta and correction of the recurrent kyphotic deformity.

The patient and her family were very concerned about the intra and perioperative risks of the procedure, due to the patient's co-morbidities, and denied any further intervention. She was then referred to the department of anaesthesiology for pain management. A spinal morphine pump was placed two months later with palliative outcome. Two years later (and 7 years post initial diagnosis), the patient was alive without any established complication from the aortic penetration.

Case 2

A 26-year-old female visited our outpatient department 5 years after a posterior instrumented surgical correction of her idiopathic scoliosis at another institution. The reason she presented to us for her routine follow-up visit was because her attending spine surgeon died.

The instrumentation consisted of two longitudinal rods and transpedicular screws extending from T10 to L4. The scoliosis correction was satisfactory, and the perioperative course was reportedly uneventful.

She complained of atypical mild pain to the thoracic spine, while plain radiographs were suspicious for a T10 left transpedicular screw misplacement.

Clinical examination showed no abnormal findings and the exact site of the referred pain was not specified. The patient referred that the pain was not constant and there were long periods of time without symptoms. The only reason why we decided further investigation was the suspicion of the T10 left screw misplacement on the plain radiographs.

A non-contrast enhanced computed tomography (CT) scan was conducted in order to better assess the origin of back pain. These CT images demonstrated a misplaced T10 left transpedicular screw, which penetrated the lateral cortex of the vertebral body and impinged into the aorta (Fig. 2).

The CT was repeated with contrast enhancement to define more accurately the position of the screw

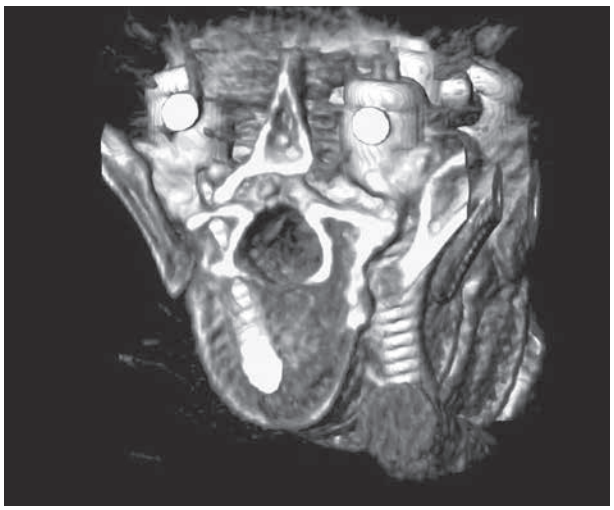

Fig. 3. — CT images of case 2 with contrast enhancement and 3D reconstruction showing more accurately the position of the screw and perforation of aorta.

relative to the aorta : it showed that the artery was clearly perforated by this specific screw (Fig. 3).

After vascular surgeon consultation we discussed with the patient on the potential complications from the presence of the screw inside the aorta, and offered her a revision surgery including endovascular prophylactic aortic stenting and removal of the pedicle screw. Potential complications from surgery were also discussed extensively. However, the patient – at the moment – considers that the risks of a new surgery outweighs the potential future complications from this screw malposition, which was otherwise "silent" for 5 years and asked to delay any surgical intervention, as she was not psychologically ready to decide what to do.

CONCLUSIONS

Late detection of aorta perforation by pedicle screws is rather exceptional. Routine postoperative imaging with CT scans should probably be implemented in all posterior instrumented cases, especially when the thoracic spine is involved and severe preoperative spinal deformities exist. Operative treatment with combined orthopaedic and vascular interventions is usually selected. All potential future complications from the presence of a screw inside the pulsatile aorta, and the complexity of revision surgery should be balanced, and treatment selection should be individualized.

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