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Spine Tips & Tricks: Performing a Pedicle Subtraction Osteotomy (PSO)

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Introduction

First described by Thomasen et al., the pedicle subtraction osteotomy (PSO) is a useful technique in the treatment of adult spinal deformity (ASD).[1] The PSO involves a transpedicular wedge resection from the posterior elements through the vertebral body and can provide correction in the sagittal plane of up to 30 to 40 degrees without the need for a combined anterior and posterior approach in the setting of rigid curves[2]pedicles, and vertebral body through a posterior approach. In addition, this posterior-only osteotomy can provide significant correction without lengthening the anterior column, avoiding injury to the anterior abdominal structures.[2–5]pedicles, and vertebral body through a posterior approach

Despite its ability to provide such great sagittal correction, there is a high number of complications associated with the PSO, especially rod failures. Naturally performed with 2 rods, when correction is achieved following wedge closure this can create a large amount of stress at the apex of the osteotomy. Rod failure rates have been reported as high as 15.8%.[6] The technique described below has been shown to prevent these rod failures, utilizing a four-rod construct.[7] It allows for distribution of the stress along two smaller rods placed immediately above and below the osteotomy sites with 2 additional long rods that bridge across the osteotomy without being connected to the smaller rods, decreasing the vulnerability of the rods for rod fracture and reduces the rate of pseudarthrosis.

Technique

Indications for the PSO include fixed sagittal malalignment and prior anterior column fusion[8]. Decision-making regarding the PSO level depends on several factors. It is more commonly performed below the conus in the lumbar spine to reduce neurological complication from thecal sac manipulation and wedge closure. However, it can be performed at the thoracic or cervical level in certain cases such as post-traumatic kyphosis. In these cases, retraction of the thecal sac should be avoided.

The level of the PSO itself should depend on the location and the type of the pathology. If the patient has a focal fixed-angled sagittal deformity, the PSO should be performed at the level of the kyphosis. However, in the absence of such kyphosis, a lumbar PSO should be performed.

Careful planning beginning outside the operative room is paramount to achieving improved efficiency of the procedure itself and prevent complications.

Exposure

The surgeon should take great care in providing extensive, meticulous exposure with excellent hemostasis. One should preserve the interspinous and the supraspinous ligaments in the area of the upper instrumented vertebra, to prevent PJK.[9]with corresponding torques recorded. Data were collected after a series of 6 posterior procedures. Differences with P value < 0.01 were considered significant and those with P value < 0.05 marginally significant. RESULTS: Supratransverse process hook, supralaminar hook, pedicle screw placement, or pedicle screw removal done, bilaterally, produced similar, small (range, 2.09%-6.03% With careful attention to the anatomical variation in size, angulation, and rotation of the pedicles, screws are then placed above and below the planned level of the PSO at multiple levels, with two being the minimum.

Decompression

The posterior laminectomies and decompression are then performed. At the level of the PSO, a complete laminectomy extending through the bilateral pars interarticularis is performed in addition to bilateral facetectomies. However, superior and inferior to the level of the PSO, a partial laminectomy is performed through the bilateral pars interarticularis. Centrally, decompression is achieved with resection of the ligamentum flavum. In the case of revision laminectomies, one should take care removing the scar tissue above the thecal sac. Removing the scar allows the dura to have multiple buckles rather than one stiff area producing a single buckle which can cause cauda equina compression. At the level of the PSO, the bone surrounding the pedicle is completely removed, including the transverse process. This should provide exposure of the four nerve roots bilaterally (Figure 1). At the level of the pedicle, the cobb elevator is used to expose the vertebral body on both sides. If the segmental vessels are

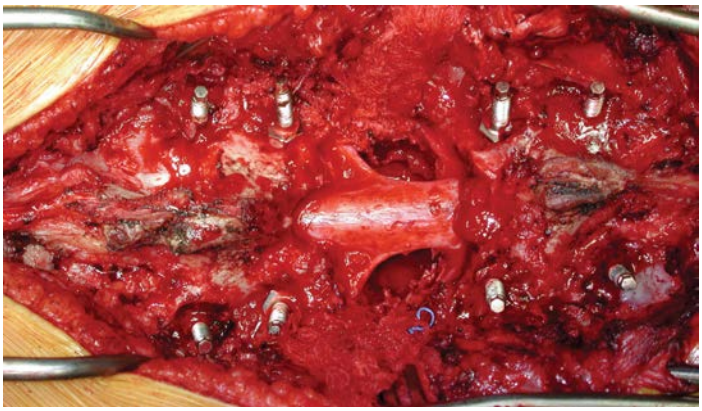

Figure 1. Exposure of the four nerve roots and six pedicles is essential prior to performing the pedicle subtraction osteotomy.

encountered, bipolar cautery is used to control the bleeding. The plane between the lateral aspect of the vertebral body and the adjacent soft tissue is then developed and maintained with the use of sponges or retractors. This allows for adequate visualization of the bony anatomy including the vertebral body.At this point, the posterior retractors are placed. Utilizing nerve root retractors to protect each individual nerve root, the pedicle is decancellated and the vertebral body is hollowed out using a curette. The wall of the pedicle is then resected using a rongeur.

Wedge Osteotomy

Using an osteotome, a pre-planned wedge is made with wider resection posteriorly, allowing for creation of the proper wedge. If necessary, fluoroscopic guidance can be utilized to maintain orientation when creating such a wedge. If a wedge is not created, this will not improve the lordosis or sagittal alignment, but instead will result in shortening of the entire column. One must also take care to resect laterally from the walls of the vertebral body, to prevent impingement upon closure. The spoon retractors should be placed with care to separate the psoas from the vertebra body side walls and not left in place for a long time.

In this manner, the anterior cortex remains preserved, which allows for decreased risk of injury to the anterior vessels and viscera. During the osteotomy, one must take care to continuously protect the nerve roots and thecal sac with the appropriate nerve root retractors in addition to providing hemostasis control with the use of hemostatic agents and sponges. When performing an osteotomy on one side, a rod should be placed above and below the osteotomy site and the process should be repeated on the other side. When decancellating the vertebral body, one must take care to begin with creating a thin posterior cortical wall.Then a Woodson or a curved freer can be used to remove any dural adhesions to the posterior wall, to prevent injury to the anterior portion of the dura. Once the resection of the lateral walls is complete, a Woodson or a posterior body wall impactor can be used to fracture the posterior wall into the cavity created and these elements can be resected using a Leksell or pituitary rongeur. In addition, asymmetric PSOs can be performed in the cases of kyphoscoliotic deformities, allowing for correction in the coronal plane upon wedge closure.

Osteotomy Closure

Before obtaining closure of the osteotomy, care must be taken to remove any remaining bony fragments than might compress the exiting nerves, since the two adjacent exiting nerves will now share a newly created "super" foramen on each side. A table that may bend the torso in extension can be very useful in closing the osteotomy. This can be more useful then closing the osteotomy by compression across the screws above and below the osteotomy. During closure, with the help of neuromonitoring, the neural elements are carefully accounted for. If no neuromonitoring changes are recorded and the nerve roots are free of any impingement from bone or soft tissue, the surgeon can then place the final rods and perform final tightening.

In this manner, the wedge osteotomy can be successfully closed and the correction is maintained by the short rods connecting the immediate adjacent levels. (Figure 2). The long rods are then placed along the entire length of the

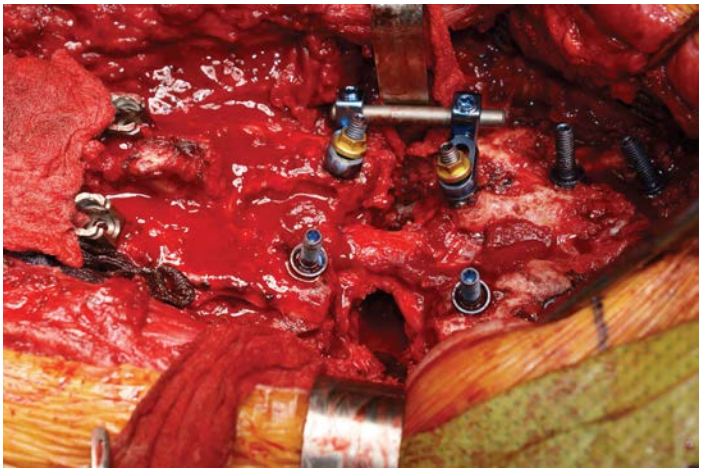

Figure 2. The short rods control the osteotomy closure as well as prevent translation while finishing the osteotomy.

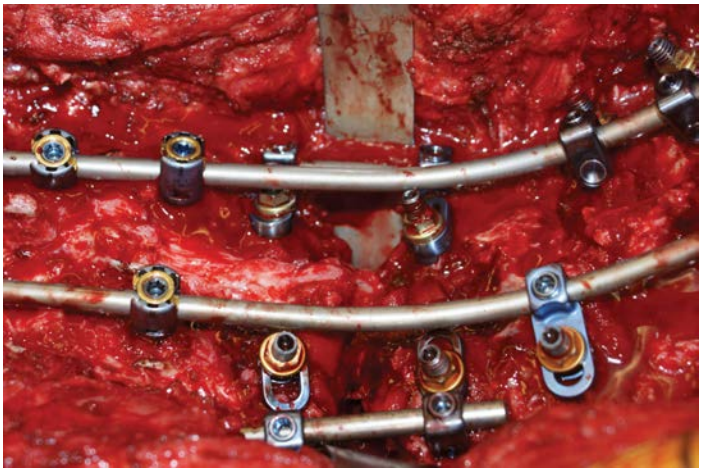

Figure 3. The short rods hold the osteotomy correction during placement of the long rods and are independent of the long rods.

Figure 4. These are the pre-operative x-rays of a 65 year old male with 4 prior spine surgeries in 1998, 2008, 2015, and 2016. He had a fusion at L4-L5 and developed footdrop on the right side. The fusion was extended to L3 and then extended again to L1. The fusion was revised from L1 to L3 because of screw cut out. He presented in clinic with junctional failure above L1.

instrumented fusion and are not connected to the screws attached to the short rods (Figure 3). This avoids the need for severe angular bending of the long rods, which can weaken the rods, make them vulnerable to rod fractures, and predispose the patient to pseudarthrosis. If there is any concerning change in the neurophysiological monitoring, the closure should be stopped and reversed to protect the neural elements and further decompression and resection of the bony elements may be necessary.

Finishing Steps

The procedure is then completed with decortication with a high-speed drill followed by placement of harvested bone graft or the off-label use of rh-BMP2, bone morphogenetic protein. Drains are then placed and closure of the wound is then performed. A case example is presented in Figures 4-6.

Conclusions

Pedicle subtraction osteotomies are an outstanding tool in the treatment of adult spinal deformity. They are useful in revision surgery as well as in the treatment of severe, rigid curves. However, surgeons must be aware of the higher complication rates associated with osteotomies and should carefully review the lessons and newly-derived technique modifications illustrated in the recent literature.

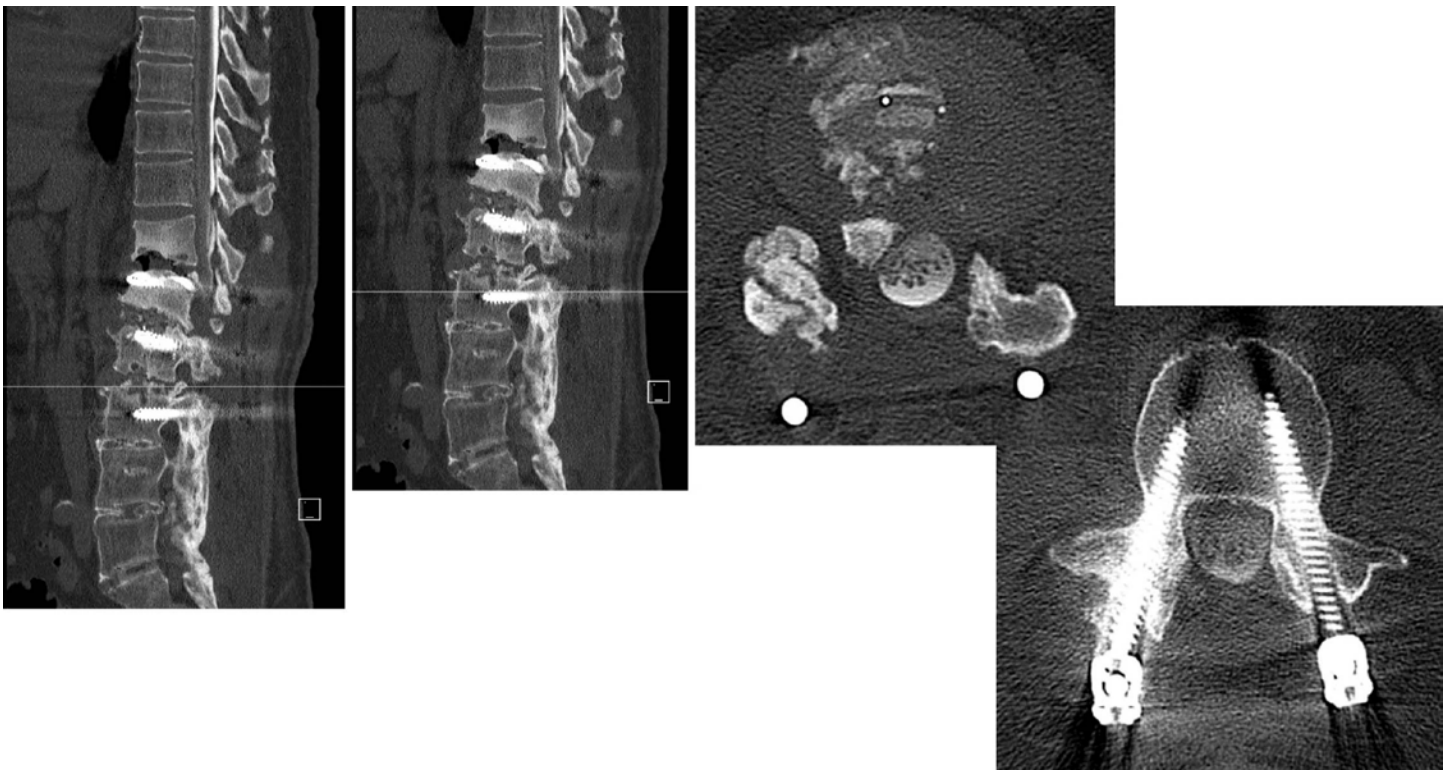

Figure 5. The CT scan shows bone fragments in the canal as well as pseudarthroses at multiple levels.

Figure 6. Pre-operative and Post-operative x-rays demonstrating the amount of correction achieved with the four-rod technique. PSO allows for correction of the flatback as well as extension of the fusion into the thoracic spine.

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