

Master's Surgical Technique: Operative Treatment of Scheuermann's Kyphosis

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Abstract: Severe Scheuermann's kyphosis can be associated with pain and a lifetime of progression. Operative treatment in carefully selected patients has been shown to improve radiographic outcomes, pain, and satisfaction compared to nonoperative treatment. Historically, combined anterior disc releases and fusion with posterior instrumentation and fusion was the preferred method of treatment. However, more recently, with improvements in spinal instrumentation and use of posterior osteotomies, anterior surgery is rarely indicated. This paper outlines the process of a posterior spinal fusion with posterior column osteotomies for Scheuermann's kyphosis.

Key Concepts:

- Anterior releases are rarely needed with modern surgical techniques, including pedicle screws and spinal osteotomies over many vertebral levels.
- The stable sagittal vertebra is generally the lower instrumented vertebrae that should be included in the construct to minimize junctional issues distally. Contouring the upper end of the rod into a little extra kyphosis minimizes the risk of proximal junctional kyphosis.
- The use of multiple serial reducers allows for load-sharing of the large forces generated during correction and minimizes the risk of screw pull-out.

Introduction

Scheuermann's kyphosis is defined as a structural kyphosis of the thoracic and/or thoracolumbar spine with three adjacent vertebrae with anterior wedging of at least 5 degrees (Sorensen criteria).¹ It is commonly seen in otherwise healthy teens and preteens, and it is reported in an estimated 2.8% of the population.² Reports of gender distribution vary from male-dominated to gender equal.^{3,4}

Treatment plans vary depending on the severity of the deformity, the presence of pain or neurological

symptoms, and patient age. Most patients with less severe deformities are treated using nonoperative methods, such as stretching and bracing.^{3,13} Scheuermann's may be associated with back pain, usually near the apex of the deformity, particularly with prolonged periods of sitting or exercise.⁵ Pain frequently subsides with skeletal maturity, and curves that remain under 70 degrees should present with few long-term difficulties. However, patients with more severe kyphosis may experience progressive deformity,⁶ chronic pain,⁷⁻⁹ and, at times, neurologic complications.^{5,10-12}

There is currently no consensus on an absolute indication for surgery. The literature supports considering surgical management for patients with: thoracic kyphosis >70 degrees, progression of kyphosis despite bracing and stretching, or significant pain.^{3,5,13,14} Surgical intervention aims to correct the underlying structural abnormality and alleviate symptoms. Patients who receive operative treatment for Scheuermann's have been shown to have improvements in radiographic outcomes, less pain, and greater satisfaction compared to nonoperative patients.¹⁵

While controversial, magnetic resonance imaging (MRI) is probably not routinely indicated on all patients as part of the preoperative assessment if pain is at the apex of the curve or in a hyper-lordotic lumbar spine below a hyper-kyphotic thoracic spine. Tight hamstrings, such as a popliteal angle of 60 degrees or less is common, especially in adolescent males and is not by itself a sign of neurologic pathology. Radicular pain, night pain, pain out of proportion to the disease, or focal neurologic signs or symptoms are indications for an MRI study whether surgery is planned or not. The wise surgeon pays attention to the slightly increased risk of low lumbar spondylolysis which may impact treatment.

Description of the Method

Determining Fusion Levels

The selection of the correct fusion levels is critical for avoiding junctional issues postoperatively. The lowest instrumented vertebra (LIV) should include the stable sagittal vertebra (SSV) to help minimize the risk of distal junctional kyphosis (DJK).¹⁶ Historically, surgeons have looked to include the first lordotic disc space which may be a consideration as well. Less is written about choosing the upper instrumented vertebrae (UIV). For a curve with a high thoracic apex around T6 or T7, the UIV is usually chosen to be T2. For a thoracolumbar apex, a UIV of T4 is usually sufficient. The chance of proximal junctional kyphosis (PJK) can be minimized by bending extra kyphosis into the upper portion of the rods intraoperatively and avoiding overcorrection of the Scheuermann's kyphosis (Figure 1). To illustrate this

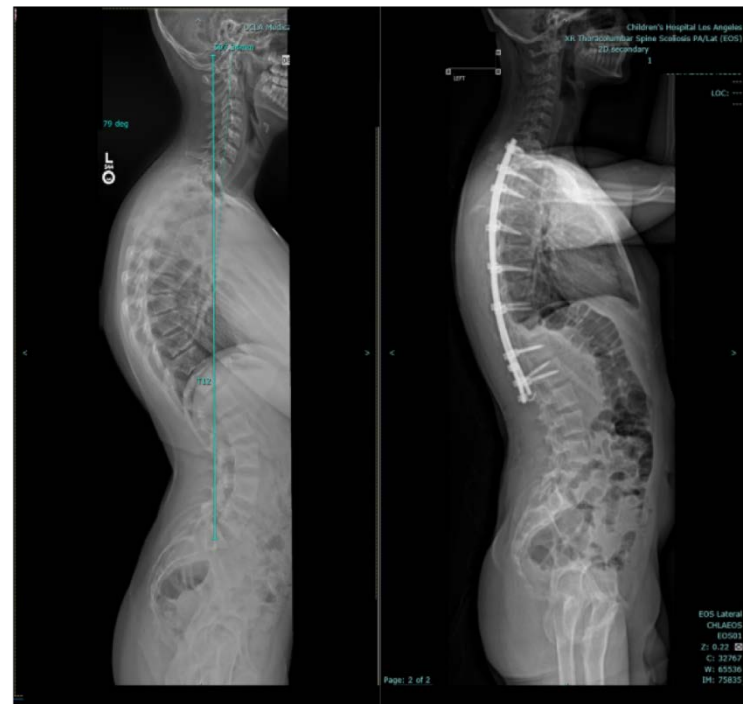


Figure 1. Preoperative radiograph and postoperative radiograph. The LIV was chosen and the stable sagittal vertebra, as can be seen in the preoperative image. (Used with permission from the Children's Orthopaedic Center, Los Angeles)

point, imagine the top half of the rod is perfectly straight: the patient's head leans forward to center over the pelvis which pulls the spine away from the rods and/or causes PJK. Now imagine the opposite: if the rod has extra kyphosis at the top the patient's head seeks to center over the pelvis by shifting posteriorly, protecting against PJK (Figure 2).

Patient Positioning

The patient is placed in the prone position, resting on a transverse chest pad and on bilateral hip pads that support the center of each iliac crest. A gap is left between the chest pad and hip pads, as this positioning allows gravity to help correct the kyphosis. Prior to prepping and draping, the patient's head is positioned such that it will not block the surgeon's hands or impede placement of upper instrumentation. This may involve some combination of lowering the head relative to the body and slightly flexing the neck. When prepping, the authors find it helpful to remember, "You can't prep too high,"



Figure 2. This is an example of a patient in which the surgeon did not bend the rods into enough kyphosis during the first surgery or provide enough rigid fixation. Clinically, when the patient stands with her head over the pelvis, the spine pulls forward away from the rods (images a and b). Revising this problem often requires additional proximal levels of instrumentation, osteotomies, and more kyphosis bent into the top part of the rod (images c and d). (Used with permission from the Children's Orthopaedic Center, Los Angeles)

as failing to prep sufficiently cephalad is a common pitfall. Unlike in scoliosis, the upper vertebrae in Scheuermann's kyphosis are tilted toward the head in the sagittal plane, so prepping must account for the incision to be made adequately cephalad in order to accommodate the surgeon's hands and instruments, especially if pedicle screws are placed to be at the highest level.

Dissection

During dissection, mean arterial pressures are maintained in the 50-60s mmHg in order to minimize blood loss. Prior to making the incision, both the UIV and LIV are identified using fluoroscopy. A shallow, longitudinal, midline incision is made with a 15-blade. The dissection is continued using cautery on "cut" function through the dermis/remainder of the skin in order to improve cosmesis. Our team prefers to use a needle-tip cautery electrode, as it allows for increased precision during dissection. The cautery is then switched to its

"coagulation" function, and dissection is continued in a layer-by-layer fashion down toward the center of the spinous processes. One should aim to split the cartilaginous apophysis in order to enter an avascular plane along which the muscle can be separated from bone without significant bleeding and dissection can proceed subperiosteally. Beware that particularly at the apex of a significant kyphosis there is a larger amount of space between spinous processes and even facet joints than the normal spine; surgeons should be careful not to inadvertently plunge into the unprotected canal in this region. As important exceptions to this process, the spinous processes and their cartilaginous apophyses should be left intact at the UIV, at one level below the UIV, at the LIV, and at one level above the LIV, as preserving these structures and the associated interspinous ligaments provide a strong foundation for fusion and helps minimize the risk of junctional issues. During dissection, self-retaining retractors are used to aid with exposure of the spinous

processes as well as to provide laterally directed tension that helps pull muscle away from the spinous processes. If concerned about bleeding, one may consider dissecting the LIV and UIV first, as these levels are gravitationally dependent relative to the curve apex when the patient is in the prone position, meaning that blood may pool in these areas and limit visualization.

Spinous processes may be removed on a case-by-case basis to allow for easier access into the spinal canal for osteotomies. For thin children with palpable spinous processes, only the inferior half of the spinous processes should be removed, as leaving the superior half of the spinous processes in place helps minimize implant prominence while still allowing for osteotomies. However, most adolescents with Scheuermann's kyphosis are on the larger side, in which case spinous processes may be removed and subsequently used as bone graft. After spinous processes are removed, bone wax is placed over any areas of bleeding bone.

Facetectomies & Osteotomies

The authors prefer to use an ultrasonic bone-cutting tool for facetectomies and osteotomies, as this tool requires little force, allows for precise control, and automatically coagulates bleeding bone as it cuts, thus eliminating the need for bone wax. The ultrasonic bone-cutting tool is used to remove the inferior facets from the level above the LIV up to the UIV. In the lumbar region, each inferior facet may be removed using one straight cut parallel to the joint. In the thoracic region, two perpendicular cuts are utilized to remove each facet.

When performing facetectomies and osteotomies at the apex of a severe Scheuermann's kyphosis, there may be areas where there is no overlap between the superior and inferior facets of adjacent vertebrae. Therefore, when cutting out an inferior facet, one must not assume that the superior facet of the level below will be present as a barrier against cutting too deeply, and care should be taken to avoid inadvertently entering the spinal canal. Despite this risk, there is typically significant room between the posterior aspect of the spinal cord and the

posterior vertebral elements as the spinal cord rests against the posterior vertebral body, leaving room for safe posterior based osteotomies (Figure 3).

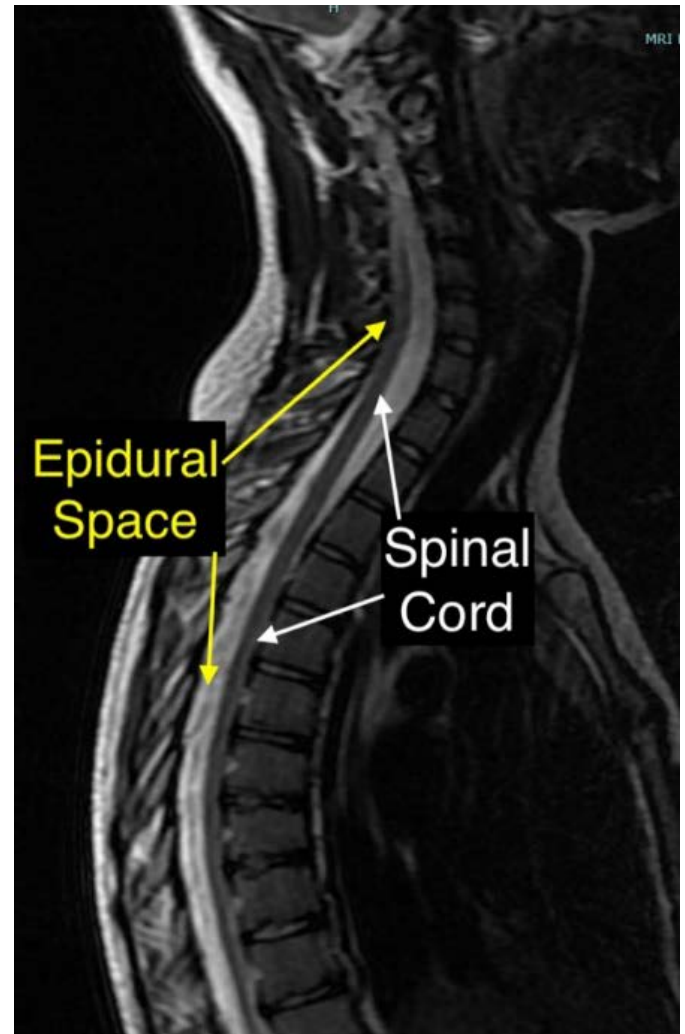


Figure 3. In Scheuermann's kyphosis, note the spinal cord is against the vertebral bodies at the apex which creates epidural space posterior to the cord, where osteotomies can be performed safely. Conversely, in the lordotic cervical spine and lumbar spine the neural elements may be touching the lamina, and this space should be entered with great care. (Used with permission from the Children's Orthopaedic Center, Los Angeles)

Next, the interspinous ligament and the majority of the ligamentum flavum are removed. A wide rongeur is preferred as a safer option here, as it is less likely to plunge into the spinal canal compared to a narrow rongeur. Removal of the entire ligamentum flavum is not necessary

for correction of kyphosis and leaving some ligamentum flavum intact is protective of the spinal canal. The authors generally remove just enough of the ligamentum flavum such that a 1-3mm-wide opening into the spinal canal is present at midline (as evidenced by the visualization of epidural fat).

Next, Ponte osteotomies are performed surrounding the apex of the deformity. Exactly how many osteotomies to perform is largely a subjective decision based on the flexibility of the spine encountered intraoperatively. Following removal of the inferior facets, the underlying superior facets can be visualized well. A horizontal cut is made through the superior facet well proximal to the pedicle with an ultrasonic bone-cutting tool. The superior portion of the facet that is now free of bony attachment can be left in place, as it causes no harm. Once a cut is made, motion is demonstrated between the vertebral segments by gently rotating the ultrasonic bone-cutting tool while its blade is still in the groove of the cut. If clear motion between the vertebral segments is not observed, the osteotomy is not complete. If additional motion is needed, a Kerrison rongeur can be used to aid in complete resection of the superior facet and surrounding lamina.

Anchor Placement

Pedicle screws are placed using standard anatomic technique with power pedicle preparation and screw placement as described previously in *JPOSNA (JPOSNA Volume 1, No. 1)*. The starting point is prepared by burring through the cortex with a 3mm ball-shaped rotary burr. Then, a flexible 2mm drill bit is used to prepare the pedicle tract about 20-25mm deep. This is followed by a 3mm dull threaded reamer which not only expands and dilates the pedicle tract but also helps determine the appropriate length of the screw.

The authors have found the use of down-going transverse process hooks on the UIV to be clinically equivalent to the use of pedicle screws at this level, and hooks may also have the advantage of being easier to place at the UIV. When placing transverse process hooks,

significant force may be required to advance the hook into the space between the transverse process and rib. This force is directed caudad for down-going hooks and must never be directed towards the canal.

It is not necessary to place screws at every level. However, with heavier patients, patients with poor bone quality, or in cases of severe deformity, a higher screw density may provide additional stability and help better distribute the mechanical load during correction. Conversely, in thin patients, pedicle screws should be avoided at the apical one-to-two levels of the curve to minimize prominence of the construct.

Once all screws are placed, triggered electromyographic is performed by sequentially stimulating all pedicle screws located at T6 and below. All screws with stimulation thresholds >6.0 mA are generally considered “safe.”¹⁷ While 6.0 mA is used by the senior author, each local team should decide what stimulation threshold to use. Intraoperative fluoroscopy is used to verify that all pedicle screws are in appropriate position. Care is taken to be certain that the upper screws do not violate the disk above the UIV.

Rod Placement & Correction of Deformity

In scoliosis correction, it is wise to err on the side of cutting the rods longer than one thinks they need to be, as the spine lengthens with correction in that context. In kyphosis, however, it's the opposite: rods should be cut 5-10mm shorter than one thinks they should. As the kyphosis is corrected, the posterior distance decreases, and a shorter rod is needed.

When the rods are cut to size, anesthesia is informed that the spinal correction is about to happen, so the mean arterial pressure can be brought above 75 mmHg.

There are three principles to remember when shaping a rod. First, the spine will move to the rods, and the rods will also move (or bend) to the spine. Therefore, less kyphosis should be bent into the rods than what is desired in the final configuration, keeping in mind that as one corrects the spine, a little bit more kyphosis will

automatically occur in the rods. Second, when doing a long fusion involving the thoracic spine, extra kyphosis should be bent into the top of the rods. This helps minimize the chances of proximal junctional kyphosis. Third, remember that in a normal spine, T12 to L1 should be perfectly straight. Below these levels, the spine is lordotic and above it is kyphotic. If the apex of deformity is at the thoracolumbar junction, however, some residual kyphosis should be anticipated and will be well tolerated.

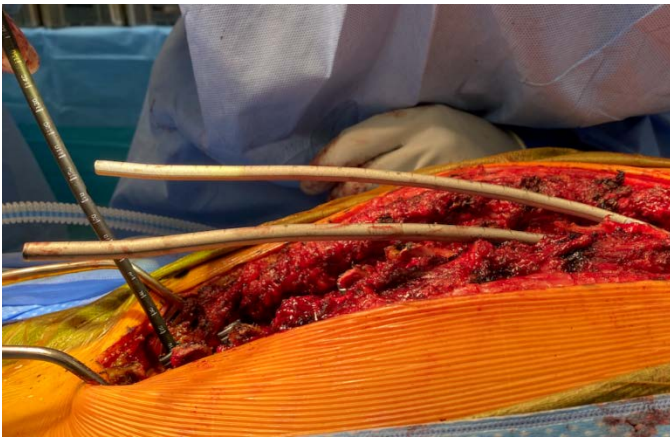


Figure 4. The rods have been seated in the cephalad half of the anchors. In this case, the caudad end of the rods are 10cm from the LIV pedicle screws. (Used with permission from the Children's Orthopaedic Center, Los Angeles)

With Scheuermann's kyphosis, the sagittal profiles of both rods should be identical. This is different from a differential rod bend for correcting rotational deformity in scoliosis.

As the most robust fixation is typically distally, there is wisdom in first seating the rods proximally and then bringing them down to the distal anchors. If hooks are used at the UIV, then as soon as the rod is seated in the upper levels, the two down-going transverse process hooks should be compressed just enough to ensure that the hooks are fully engaged around the transverse processes and do not become displaced while one is seating the remainder of the rod. Note that after both rods are seated in the upper thoracic anchors, the caudad portion of each rod rests significantly (around 10cm) higher than (i.e., dorsal to) the lower instrumented vertebra pedicle

screws (Figure 4). This is the amount of correction that will ultimately be achieved.

The primary correction maneuver is performed by applying a downward, bending force upon the free, cantilevered, caudad ends of the rods, thus pushing the rod ends towards the LIV pedicle screws. The greatest forces are generated on the spine and on the instrumentation during the reduction as both cantilevered rods are forced down into the lower pedicle screws. This time is also when the greatest force is being placed on the screws, threatening to pull out the screws. To mitigate this risk, the authors use many serial reducers, slowly tightening each reducer one at a time. This avoids putting too much stress on any one screw, or the entire system, all at once; the iterative, incremental tightening of different serial reducers limits the amount of force exerted on one point in space or time (Figure 5). This is the time to move slowly and cautiously; moving slowly will maximize safety and decrease the chances of pedicle screws pulling out. Breaks are taken between rounds of tightening the serial reducers to allow the body to adjust to its new position. A secondary correction maneuver that is used for the stiffest and largest deformities is compression of the posterior portion of the spine across the apex of the kyphosis. This shortens the posterior column and corrects kyphosis.

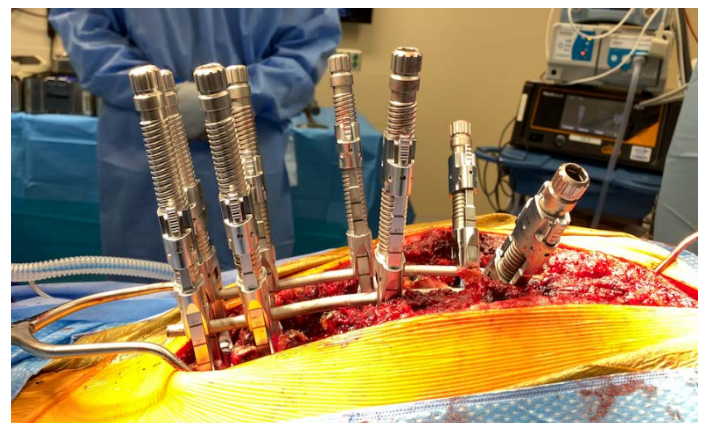


Figure 5. The use of many serial reducers share the load of correction over many screws, minimizing the risk of screw pull-out. Once the rods are completely seated within the tulips, set screws are then placed, and the serial reducers are removed. (Used with permission from the Children's Orthopaedic Center, Los Angeles)

Bone Grafting & Closure

Irrigation is performed with a dilute povidone-iodine solution followed by sterile saline. Decortication is performed of all exposed bone in the fusion area, paying special attention to the facet joints near the LIV. Crushed cortical cancellous allograft and autograft from removed facet joints and spinous processes are placed along the decorticated posterior elements. The authors prefer to utilize the autograft near the LIV and UIV which are at highest risk for a nonunion. Vancomycin powder is combined with the bone graft for infection prophylaxis.

Closure is performed with running knotless, barbed, absorbable suture, in multiple layers, starting with #1 in muscle and then fascia. The subcutaneous layer is closed with 0 suture and the subcuticular layer with 3-0. A clear plastic adhesive closure is placed over the wound that allows visualization of the incision and reduces tension on the incision.

Comparison to Other Methods

Historically, anterior disc releases with posterior spinal fusion was the preferred method for kyphosis treatment.^{18,19} The basis of this treatment stemmed from a high incidence of loss of correction following a posterior-only treatment of Scheuermann's kyphosis²⁰ with instrumentation used in the past. However, with the use of pedicle-screw-based constructs and posterior osteotomies, more recent studies have demonstrated that anterior release is not necessary.^{21,22}

Summary

Historically, anterior disc releases with posterior spinal fusion were the preferred method for kyphosis treatment. In the era of pedicle screws, anterior release is not necessary. Successful treatment of Scheuermann's kyphosis may be obtained with liberal use of posterior osteotomies, using many serial reducers simultaneously to load-share over many screws, contouring the upper portion of the rod into a bit of extra kyphosis to prevent PJK, and including the stable sagittal vertebra in the lower instrumented vertebrae to prevent DJK.

Additional Links

<https://www.jposna.org/ojs/index.php/jposna/article/view/13>.

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