

Pedicle Subtraction Osteotomy for Cervical-Thoracic Kyphosis: A New Approach

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ABSTRACT

STUDY DESIGN: A description of pedicle subtraction osteotomy for correction of kyphotic deformity of the cervical-thoracic spine and a prospective evaluation of the surgical outcomes.

OBJECTIVES: To describe the surgical technique and the postoperative results of pedicle subtraction osteotomy in the upper thoracic spine and the cervical-thoracic junction.

SUMMARY OF BACKGROUND DATA: Pedicle subtraction osteotomy (PSO) is used in reconstructive spine surgery to facilitate correction of spinal deformities in the sagittal plane. Interlaminar “Smith-Peterson” osteotomies allow for correction over several spinal segments and have been utilized to correct sagittal plane deformities at spinal cord levels (i.e. cervical and thoracic levels). This technique requires an intact anterior motion segment or an anterior osteotomy if there is a preexisting anterior column fusion. PSO allows for significant correction through a single vertebral level and is a well-described technique for restoration of sagittal balance below cord level. PSO is a “shortening” osteotomy and may be safely used in the cervical-thoracic spine.

METHODS: Three patients (2 male, 1 female; mean age 50 years) underwent pedicle subtraction osteotomy for kyphotic deformities of the upper thoracic spine or cervical-thoracic junction. Surgical indications included post laminectomy kyphosis, following spinal cord tumor resection, post-traumatic kyphosis and cervical-thoracic junctional kyphosis due to degenerative cervical spondylosis. Prospectively collected data was reviewed to document early postoperative results for this procedure.

RESULTS: Mean follow up is 15.3 months (range 12 to 20 months). Average preoperative kyphosis was -55.6 degrees (range -38 to -70 degrees) at the cervical thoracic junction. Clinically satisfactory correction of deformity was accomplished in all patients. Mean correction was 23 degrees (range 15 to 30 degrees) after PSO.

CONCLUSIONS: Kyphotic deformities of the cervical-thoracic junction, causing chin-on-chest deformity, are difficult problems to correct and require complex spinal reconstructive techniques to restore sagittal balance and allow forward gaze. PSO allows for significant correction through one spinal segment and may be used safely to achieve sagittal balance. PSO may be used alone or in combination with other

techniques as some patients may require multi-stage procedures with both anterior and posterior spinal reconstruction to obtain stable sagittal correction.

KEY WORDS: Kyphosis; Cervical thoracic junction; osteotomy

KEY POINTS: 1. Cervical thoracic junction (CTJ) deformity is a difficult management problem.

2. Several treatment options exist to treat CTJ deformity.

3. Major correction at a single level with PSO is a useful correcting CTJ deformity.

Mini-Abstract:

This paper is a description of the techniques and outcomes of pedicle subtraction osteotomy (PSO) for correction of kyphotic deformity in the cervical-thoracic spine. Clinically satisfactory correction of deformity was accomplished in all patients with a mean correction of 23 degrees (range 15 to 30 degrees) after PSO. Kyphotic deformities of the cervical-thoracic junction, causing chin-on-chest deformity, are difficult problems to correct and require complex spinal reconstructive techniques to restore sagittal balance and forward gaze.

INTRODUCTION

Severe kyphotic deformity of the thoracic and cervical spine distorts the sagittal balance of the upper spine and results in significant morbidity. This chin-on-chest deformity not only causes cosmetic defect and loss of forward gaze but also disrupts the normal biomechanics of the spine causing progression and pain.

There are several well-documented causes of kyphosis in the upper thoracic and cervical spine including cervical laminectomy, spinal trauma, spinal tumor, degenerative spondylosis and ankylosing spondylitis.^{1, 8-11} Although some of these deformities may be flexible, the majority have some fixed deformity, with or without neurological symptoms.

Kyphotic deformity, regardless of the cause, requires experience with complex spinal reconstructive techniques if surgical correction is to be performed. Surgical intervention may require single or multilevel vertebral osteotomies.²⁻¹¹ Smith-Peterson et al.¹⁰ were the first to describe multilevel posterior osteotomies of the spine in 1945, and several modifications of this “extension” osteotomy have subsequently evolved. This approach requires an intact anterior motion segment at the osteotomy level or an anterior osteotomy, if there is a pre-existing anterior column fusion. This method creates extension and has a risk of lengthening the spinal column.

Recent articles have reported successful results for a single level dorsal “decancellation osteotomy” otherwise known as the “eggshell” procedure or pedicle subtraction osteotomy (PSO).²⁻⁴ Reports to date have only described the PSO procedure for deformities below the thoracolumbar junction or below the level of the spinal cord. This approach does not require an intact anterior motion segment or an anterior motion segment. This method has its fulcrum through the anterior spinal column and ultimately “shortens” the spinal canal. It also results in bone on bone contact, facilitating fusion. We report here

the surgical technique and the early postoperative results following pedicle subtraction osteotomy in the upper thoracic and cervical spine in our first 3 patients.

MATERIALS AND METHODS

Cervical-thoracic junction and upper thoracic spine pedicle subtraction osteotomy procedures were performed on 3 patients between April 2001 to December 2002. Outcome data was collected prospectively to determine the early postoperative results.

The study group consisted of 2 males and 1 female. Mean age was 50 years (range 20 to 72). Indications for surgery were upper thoracic or cervical kyphosis, resulting in symptomatic sagittal plane deformity. One patient underwent surgery for progressive post-laminectomy kyphosis of the cervical-thoracic junction following spinal cord astrocytoma resection 20 years prior. The second patient had cervical-thoracic junction kyphosis due to progressive unstable degenerative cervical spondylosis resulting in a chin-on-chest deformity. The third patient developed a post-traumatic junctional kyphosis following failed fusion surgery for a T6-7 fracture dislocation. All patients were unable to maintain an erect posture due to their spinal deformity. Patient history, physical examination and radiographic studies, computed tomography (CT) and magnetic resonance imaging (MRI), showed no acute neurological compression in these patients. Cervical-thoracic kyphosis was measured using the Cobb angles on plain lateral radiographs obtained preoperatively and postoperatively. All patients underwent radiographic evaluation with 36 x 14 inch films as well as standard cervical and thoracic spine radiographs.

SURGICAL TECHNIQUE

Following the induction of general anesthesia, the patient is placed in either halo or Mayfield cranial fixation. Halo orthoses are used when the patients' age, bone quality or deformity required rigid postoperative spinal support. The patient is then turned into the prone position on the Jackson table and the cranial fixation device is secured. Spinal cord monitoring with somatosensory evoked potentials and cell saver auto-transfusion are routinely used.

A midline skin incision is made and the spine is exposed by subperiosteal dissection of the paraspinal muscles thereby exposing the spinous process, laminae, facet joints and transverse processes. Exposure is extended five levels above and below C7 for the cervical-thoracic junction osteotomy or the intended osteotomy level in the upper thoracic spine. Radiographic confirmation of the osteotomy level is then made.

Prior to performing the osteotomy, pedicle screws and lateral mass screws are placed in their appropriate adjacent levels, excluding the level of the osteotomy. We place pedicle screws at C2 and thoracic levels, and use lateral mass screws in the remaining cervical segments. A complete laminectomy is performed at the designated osteotomy level. Partial resection of the spinous processes and laminotomies of adjacent levels are performed to allow adequate room for the redundant dura once the osteotomy is closed. Laminar decompression extends from the pedicle above the wedge osteotomy to the pedicle below thus creating a “super foramen” containing the two nerve roots. The ligamentum flavum is completely removed exposing the dura and the two exiting nerve roots bilaterally. A high-speed drill is then used to burr out the pedicles to their “cortical shell,” and a rongeur is then used to resect the remaining pedicle shell completely. Curettes and various rongeurs are then used to remove the cancellous bone from the vertebral body (i.e. decancellization) in a tapered wedge shape. **Fig. 1a,b** Reverse angle curettes and rongeurs are used to remove the posterior and lateral cortex of the vertebral body without disturbing or retracting the spinal cord. The cancellous bone is then removed with a pituitary rongeur.

The wedge osteotomy is then closed by gentle elevation of the patient’s head held in the Jackson table cranial fixation frame **Fig. 1c**. This can be accomplished manually by the assistant holding the head or using the mechanical portion of the Jackson head frame.

During the closing procedure, the dura and nerve roots were carefully observed to prevent entrapment in the anterior wedge or posterior elements. The cranial fixation frame is then locked into position in the

corrected position and intraoperative radiographs are obtained. Rods are then attached to the previously placed screws and locked into place. Further reduction is obtained as needed using gentle compression across the osteotomy prior to screw tightening. Autograft bone is then harvested and placed across the closed osteotomy defect and over the length of the posterior instrumented levels. A drain is placed, and the wound is closed in multiple anatomic layers. Postoperatively, the patients are maintained in either a halo vest or a Minerva type cervical-thoracic orthosis for 12 weeks.

RESULTS

Correction of Kyphosis

In this preliminary series, 3 patients underwent pedicle subtraction osteotomy procedures at the cervical-thoracic junction and upper thoracic levels for severe sagittal plane kyphosis and symptomatic deformity. Two patients underwent osteotomy through C7 for cervical-thoracic junction kyphosis with “chin-on-chest” deformity, and the third patient underwent osteotomy through T7 for severe post-traumatic kyphosis measuring -60 degrees and causing a significant gibbus at this level.

Posterior spinal instrumentation was performed at the C2-T8 and C2-T6 levels in the two respective patients who underwent osteotomy at C7. The upper thoracic (T7) PSO patient underwent T2-L1 posterior instrumentation. There were no complications related to the placement of hardware. The mean preoperative sagittal deformity measured in our patient group was -55.6 degrees (range -38 to -70 degrees). At most recent follow-up, measurements of the same vertebral segments showed a mean correction of 23 degrees (range 15 to 30 degrees). Forward gaze was restored in all patients. **Fig.2a, b.** Mean preoperative VAS scores were 7.1 preoperatively and improved to 3.4 postoperatively.

Procedure-related Complications

No patient experienced a new neurologic deficit. One patient experienced a wound infection, which resulted in wound dehiscence and required re-operation for irrigation, debridement and closure. This patient required a prolonged hospitalization of 29 days due to intravenous antibiotics, re-operation and rehabilitation. Mean hospital stay was 15 days (range 7 to 29 days). There were no postoperative deaths. One patient in this series suffered a brainstem stroke 4 months postoperative from a dissecting vertebral aneurysm and subsequently died. The remaining patients all went on to fusion with no loss of correction.

DISCUSSION

Etiologies and Background

The most common etiologies for cervical-thoracic-junction and upper thoracic kyphotic deformities are ankylosing spondylitis, prior laminectomy, traumatic injury, degenerative spondylosis, and spinal cord tumors. Scheurman's kyphosis is another cause of kyphotic deformity that may cause loss of forward gaze but is distinctly different from the types of deformity we are presenting and treating in this series. Kyphosis occurring in the cervical spine or upper thoracic spine may cause significant cosmetic and functional deformity due to sagittal plane imbalance primarily involving the cervical segments. This problem differs from sagittal plane imbalance caused by kyphotic deformities of the lower thoracic and lumbar spine. Standard 36 x 14 inch lateral radiographs may show a *normal* C7 "plumb line" centered over the sacrum as the deformity is caused by kyphosis at or above the cervical-thoracic-junction. Not only does this result in lack of forward gaze, but it also alters the biomechanics of the entire spine and may result in progressive forward decompensation with deformity and pain. Although these deformities may be flexible, most have some component of fixed deformity that may exist with or without neurological symptoms.

History of Sagittal Plane Deformity Correction

The Smith-Peterson extension osteotomy technique, described in 1945, has been used extensively and previously considered the prototype procedure for reconstruction of sagittal imbalance in patients with deformity above the thoracolumbar junction. This procedure creates multiple interlaminar osteotomies to produce correction over several spinal segments. Corrections ranging from 20 degrees to 40 degrees are achievable. Early reports of this procedure had unacceptably high complication rates with mortality rates approaching 10% and neurologic injury in 30%.^{9,10} Improved surgical techniques, spinal cord electrophysiological monitoring and autologous cell-saver technology have reduced surgical morbidity.

Limitations of the Smith-Peterson technique are that the osteotomies must be performed at multiple levels to achieve acceptable correction and an intact anterior motion segment or anterior osteotomy is required to allow closure of the posterior interlaminar osteotomies. This may require both anterior and

posterior approaches to the spine to allow correction. Additionally, this approach lengthens the spinal column and has the potential for neurologic injury from stretch of the spinal cord. There is also a higher risk of psuedoarthrosis due to multiple osteotomies that must fuse.

Simmons described the concept of a single posterior wedge cervical osteotomy for the treatment of ankylosing spondylitis.¹⁰ He performed laminectomy and bilateral facetectomies at C7 and extended his osteotomy to include the spinous processes of C6 and T1. C7 was the preferred level of osteotomy as the vertebral artery enters the transverse foramen at C6 and is thus avoided at this level. Also, the spinal canal at C7/T1 is significantly larger than in the mid-cervical spine and if neurologic injury were to occur during osteotomy, upper extremity function would be spared. This type of osteotomy has its fulcrum of rotation located in the middle column. When closed, this ultimately shortens the spinal column and theoretically avoids spinal cord injury. This technique has many similarities to the modern pedicle subtraction osteotomy.

Current Techniques of Pedicle Subtraction Osteotomy

Several authors have reported successful results for a single level dorsal decancellation osteotomy also known as the “eggshell” procedure or pedicle subtraction osteotomy (PSO).²⁻⁴ Most current literature describes the PSO only for deformities below cord levels. Reports show corrections of 35 to 40 degrees in the lumbar spine, which is comparable with Smith-Peterson osteotomies at multiple levels. This technique creates lordosis through removal of the posterior aspect of a single vertebral body creating a closing wedge with the hinge located at the anterior column instead of the middle column. Once closed, there is bone contact in all three columns and the spinal canal is effectively shortened. Thus the PSO procedure can provide excellent sagittal correction while simultaneously forming a stable construct and minimizing neural compression.

Significant undercutting of the adjacent lamina must be performed, above and below the osteotomy level, to allow space for the spinal cord and dura when the osteotomy is closed. Five cervical segments are included in the fusion when a C7 osteotomy is performed. At least three levels should be included above the osteotomy site when addressing levels below the cervical thoracic junction and instrumentation should not end at the cervical thoracic junction.

Our results show that a pedicle subtraction osteotomy can be performed safely at spinal cord levels. Smaller correction is obtainable in the cervical and upper thoracic spine than in the lumbar spine, using the PSO technique. We obtained a mean correction of 23 degrees. This is a result of the osteotomy size allowable in the cervical and upper thoracic spine compared with the lumbar spine.

CONCLUSION

Kyphotic deformities of the cervical-thoracic junction, causing chin-on-chest deformity, are difficult problems to correct and require major spinal reconstructive techniques to restore sagittal balance and allow forward gaze. Pedicle subtraction osteotomy allows for significant correction through one spinal segment. This technique creates lordosis through removal of the posterior aspect of a single vertebral body creating a closing wedge with the fulcrum located at the anterior column. Once closed, there is bone contact in all three columns and the spinal canal is effectively shortened. The PSO procedure can

provide excellent sagittal correction while simultaneously forming a stable construct and minimizing neural compression. This preliminary report shows that PSO may be performed successfully to correct cervical thoracic kyphosis.

FIGURES

Figure 1: a) Illustration of kyphotic deformity and planned pedicle subtraction osteotomy resection. (PSO)

b) Area of “wedge” resection in completed PSO procedure.

c) Closed osteotomy and deformity correction completed.

Figure 2: a) Pre-operative “chin-on-chest” cervical thoracic junction kyphosis causing deformity.

b) Post-operative correction of Sagittal balance after C7 PSO with C2 to T5 instrumented fusion.

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