Posterior-based Osteotomies for Deformity Correction

Evan F. Joiner, MD[a], Praveen V. Mummaneni, MD, MBA[b], Christopher I. Shaffrey, MD[c,d], Andrew K. Chan, MD[e,*]

KEYWORDS

• Adult spinal deformity • Lumbar lordosis • Posterior column osteotomy
• Pedicle subtraction osteotomy • Vertebral column resection

KEY POINTS

- Posterior-based osteotomies are a widely used technique to restore lordosis in adult spinal deformity.
- Posterior-column osteotomies are ideal for patients with an unfused anterior column and non-focal sagittal deformity requiring modest correction in lordosis; multilevel posterior-column osteotomies can provide significant harmonious correction in appropriate patients.
- Pedicle subtraction osteotomies and vertebral column resections, 3-column osteotomies, are appropriate for patients with a fused anterior column and more severe deformity, particularly focal and/or multiplanar deformity.
- Pedicle subtraction osteotomy and vertebral column resection have significantly higher rates of complication than posterior-column osteotomy.

INTRODUCTION

Restoration of physiologic lumbar lordosis is a key principle in adult spinal deformity surgery and an essential strategy in the restoration of sagittal alignment. Extensive literature has established that the restoration of lordosis to within 10° of pelvic incidence is associated with improved postoperative outcomes including lower rates of disability, increased quality of life, and lower incidence of proximal junctional kyphosis.[1–4] More recent studies have focused on the potential need for age-matched pelvic incidence-lumbar lordosis mismatch goals affording less aggressive correction targets in older patients.[5] Likewise, the development of the global alignment and proportion score has sought to capture nuanced impacts of the full pelvic incidence spectrum as well as the distribution of lordosis on overall alignment and surgical success.[6] Relatedly, there is increasing evidence that, throughout the population, proximal lordosis (L1-L4) is significantly influenced by pelvic incidence while distal lordosis (L4-S1) may be relatively fixed across a range pelvic incidence values (ie, less dependent on pelvic incidence).[7] Despite these nuances and ongoing work to optimize

[a] Department of Neurological Surgery, Columbia University-NewYork Presbyterian Hospital, 710 West 168th Street, 4th Floor, New York, NY 10032, USA; [b] Department of Neurological Surgery, University of California San Francisco, 505 Parnassus Avenue M779, San Francisco, CA 94143, USA; [c] Department of Neurosurgery, Duke University, 40 Duke Medicine Circle Clinic 1B/1C, Durham, NC 27710, USA; [d] Department of Orthopaedic Surgery, Duke University, 40 Duke Medicine Circle Clinic 1B/1C, Durham, NC 27710, USA; [e] Department of Neurological Surgery, Columbia University Vagelos College of Physicians and Surgeons, NewYork-Presbyterian Och Spine Hospital, 5141 Broadway, 3FW, New York, NY, USA
* Corresponding author. Department of Neurological Surgery, Columbia University Vagelos College of Physicians and Surgeons, NewYork-Presbyterian Och Spine Hospital, 5141 Broadway, 3FW, New York, NY, USA.
E-mail address: akc2136@columbia.edu
Twitter: @efjoiner (E.F.J.); @andrewchanMD (A.K.C.)

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sagittal correction in the individual patient, it is generally accepted that the amount of correction in lordosis required is influenced by the degree of preoperative pelvic incidence-lordosis mismatch.

Posterior-based osteotomies play an important role in the restoration of physiologic lordosis. They are particularly well-suited for patients with contraindications to an anterior or lateral approach to deformity correction (eg, multilevel ALIF, lateral interbody with the release of the anterior longitudinal ligament) and for patients who require direct posterior decompression at the time of deformity correction. This article addresses indications, techniques, and complications of posterior-based osteotomies including posterior-column osteotomy, pedicle subtraction osteotomy, and vertebral column resection.

PREOPERATIVE RADIOGRAPHIC EVALUATION

Candidates for posterior-based osteotomy require standing radiographs from the cranium to the feet. These allow for the assessment of key spinopelvic parameters including sagittal vertical axis, lordosis, pelvic incidence, pelvic tilt, T1 pelvic angle, and sacral slope as well as the visualization of compensatory knee flexion, pelvic obliquity, and leg length discrepancy. Accurate determination of spinopelvic parameters is vital as goals of spinal deformity surgery include the normalization of the sagittal vertical axis and pelvic tilt and restoration of lordosis; the extent of planned correction is thus determined by a patient's preoperative parameters. Flexion and extension radiographs and comparison of upright imaging with supine imaging are helpful for determining rigidity or flexibility of the deformity, which influences the osteotomies required to attain a given degree of correction.[3,8,9] Magnetic resonance imaging and computed tomography are recommended for the assessment of neural elements (eg, central and foraminal compression) and bony structures (eg, bone quality, ankylosis, haloing instrumentation).[10] Patients who have a fused anterior column on computed tomography will require a 3-column osteotomy (ie, pedicle subtraction osteotomy or vertebral column resection) if a gain in lordosis is desired through the anteriorly fused segments.

ANESTHESIA, POSITIONING, AND PERIOPERATIVE MANAGEMENT

Because of the risk of neurologic injury during osteotomy, neuromonitoring with somatosensory evoked potentials and motor evoked potentials is recommended. Electromyography is helpful as well. To optimize neuromonitoring, total intravenous anesthesia and short-acting paralytic should be used.[11] Tranexamic acid safely reduces blood loss by roughly 50% and should be strongly considered in patients without significant contraindications (history of stroke, recent percutaneous cardiac intervention, and so forth).[12,13] An open-bottom Jackson table may optimally induce lordosis, optimize venous return, and reduce blood loss; use of a lower extremity flat board rather than a sling is recommended to provide optimal restoration of lordosis. Alternatively, an open bottom surgical table with a hinged axis—permitting flexion and extension of the lumbar spine during surgery—may be utilized. All patients should receive intraoperative antibiotics.

POSTERIOR COLUMN OSTEOTOMY

Described by Smith-Petersen in 1945 and modified by Ponte in 1984, posterior-column osteotomy has been a mainstay of deformity correction for decades.[14,15] Posterior-column osteotomy, a Schwab grade II osteotomy, involves removal of the posterior elements, including superior and inferior facets and a portion of the spinous process, lamina, and ligamentum flavum at a given level. Smith-Petersen initially described posterior-column osteotomy as a lengthening procedure involving the removal of the posterior elements and disruption of the anterior longitudinal ligament through extension across the disc space. Ponte adapted this approach to characterize what is now considered a standard posterior-column osteotomy, a posterior shortening procedure that involves the removal of the posterior elements and allows for the induction of lordosis across a flexible, unfused disc space without necessarily disrupting the anterior longitudinal ligament. Posterior-column osteotomy provides 5° to 10° of lordotic correction per level. Primary advantages of posterior-column osteotomy include an excellent safety profile and a posterior approach that can readily be combined with pedicle screw placement and posterolateral fusion without the need for a second anterior surgery. The primary disadvantages of posterior-column osteotomy involve its limited correction and inability to address anteriorly fixed deformity.

Indications

Posterior-column osteotomy is ideal for patients with flexible, non-focal sagittal deformity requiring the restoration of lordosis. A single posterior-column osteotomy generates 5° to 10° of lordosis; however, multilevel posterior-column osteotomy affords correction in lordosis similar to that achieved by three-column osteotomy[16] and does

so harmoniously across several segments.[17] Patients with moderate to severe sagittal imbalance, global loss of lordosis on standing films, and evidence of some retained flexibility on flexion-extension films or supine radiographs/computed tomography may be good candidates for multilevel posterior-column osteotomies. Because posterior-column osteotomy requires an unfused disc space, it is not an option at levels with evidence of anterior fusion from ankylosis or prior interbody fusion. Multilevel posterior-column osteotomy is also generally less morbid than more aggressive osteotomies and may be suitable for older, frailer patients.[16–22] Posterior-column osteotomy can also be combined with anterior or lateral approaches to help induce lordosis while simultaneously stabilizing the anterior column.

Technique

Level selection

Level selection is influenced by the goals of sagittal correction and restoration of lordosis. As a general rule of thumb, the optimization of sagittal correction targets a postoperative sagittal vertical axis of less than 5 cm.[3,9] Sagittal correction is accomplished primarily through the restoration of lordosis; restoration of 10° allows for roughly 1 cm of sagittal correction.[23] Lordosis should be corrected to bring the pelvic incidence-lumbar lordosis mismatch within 10°. Given that approximately two-thirds of physiologic lordosis occurs between L4 and S1 and 40% at L5-S1, the distal lumbar spine is critical to the restoration of lordosis.[24,25] The level and number of posterior-column osteotomies to be performed should be determined to achieve the restoration of these physiologic parameters assuming that each posterior-column osteotomy will provide 5° to 10° of lordosis.

Surgical technique

Following meticulous midline subperiosteal dissection, pedicle screws are placed. Pedicle screw placement does not interfere with the performance of posterior-column osteotomy at a given level. Screw stimulation and/or intraoperative imaging (eg, x-ray or computed tomography) may be used to confirm screw placement. Next, posterior-column osteotomy—consisting of laminectomy (or extensive caudal and rostral laminotomy), flavectomy, and bilateral facetectomies—is performed using high-speed burr, osteotome, and/or rongeurs (Fig. 1).

Posterior-column osteotomy introduces flexibility at a given level that can be utilized to restore lordosis. Lordosis can be optimized through reverse table breaking, bolster manipulation, and compression across posterior instrumentation. The optimal number and arrangement of rods depends upon the extent of surgery. Harmonious rod shape and avoidance of excessive recontouring should be prioritized to optimize rod strength and durability.[26] Cobalt chrome reduces the risk of rod fracture; however, stiffer cobalt chrome may increase the risk of proximal junctional kyphosis.[27,28]

Following compression across the posterior-column osteotomy site(s) and rod placement, it is essential to evaluate for the impingement of the thecal sac and nerve roots, ensuring that compression across each posterior-column osteotomy has not introduced dural buckling or foraminal stenosis. Neuromonitoring and visual/manual inspection are critical in this evaluation. The formal intraoperative x-ray may be helpful to confirm adequate lordotic correction. Alternatively, pre-planned patient-specific rods may also serve as a template to ensure adequate lordotic correction has been achieved. After final tightening, remaining bony surfaces are decorticated;

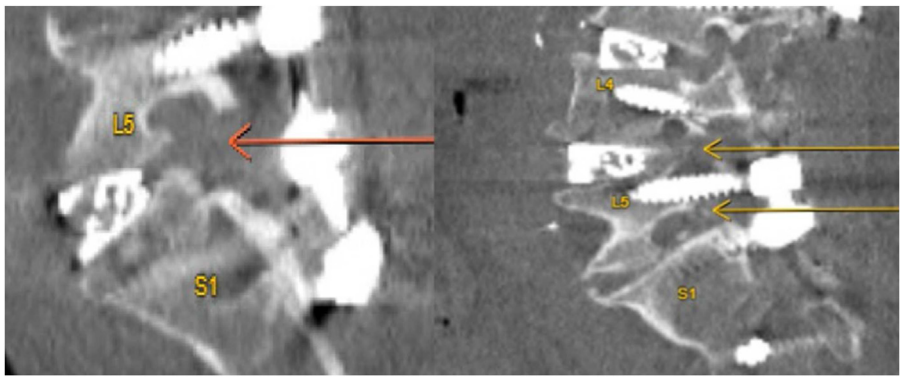

Fig. 1. Postoperative CT scan of a patient who received L4-5 and L5-S1 posterior column osteotomies in addition to L3-S1 ALIF and T2-pelvis posterior spinal instrumented fusion. This demonstrates the complete facetectomies involved in posterior column osteotomies. The arrows note the region where the facets have been removed.

posterolateral fusion may be optimized through the use of autograft, allograft, and demineralized bone matrix.[29,30] Some surgeons choose to supplement their fusion with bone morphogenic protein. Pre- and postoperative radiographic images for a patient who underwent posterior column osteotomies are shown below (Fig. 2).

Complications

Posterior-column osteotomies are less morbid than three-column osteotomies, although they are higher risk than inferior facetectomies alone. In a prospective study of 2210 patients undergoing deformity correction, rates of neuromonitoring alerts were higher among patients with posterior-column osteotomy (9.3%) than among those without (4.2%). However, rates of neurologic injury within the posterior-column osteotomy group were relatively low (0.37%) and not significantly higher than those in the non-posterior-column osteotomy group.[18] Posterior-column osteotomy involves greater blood loss than deformity surgery without posterior-column osteotomies.[19] Additional operative and perioperative complications include durotomy, pleural effusion, venous thromboembolic disease, wound dehiscence, wound infection, urinary tract infection, pneumonia, sepsis, and death. Long-term postoperative complications include hardware failure, pseudarthrosis, and proximal junctional kyphosis.

PEDICLE SUBTRACTION OSTEOTOMY

First described by Thomasen in 1985, pedicle subtraction osteotomy has become integral to the treatment of fixed sagittal deformity.[31] Pedicle subtraction osteotomy involves a wedge-shaped resection of bone from the posterior elements to the anterior cortex of the vertebral body. Pedicle subtraction osteotomy provides significant sagittal correction, obtained through a 25° to 40° correction in lordosis at the index level.[32,33] Advantages of pedicle subtraction osteotomy include the ability to address deformity in the setting of anterior column fusion. The main disadvantage of pedicle subtraction osteotomy is its high complication rate including blood loss, neurologic injury, rod fracture, and pseudoarthrosis.[32,34] Nonetheless, in appropriate patients, pedicle subtraction osteotomy provides durable improvements in radiographic parameters and a wide range of

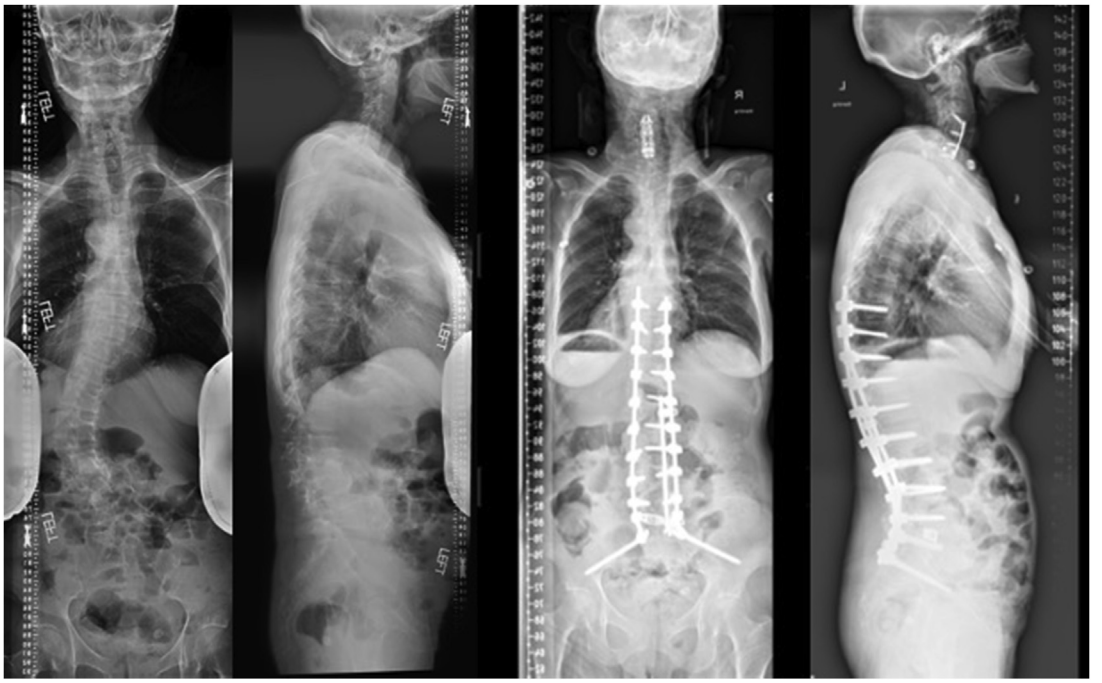

Fig. 2. This is a 66-year-old woman with scoliosis and severe back pain. She had preoperative coronal malalignment with lumbar hypolordosis. Preoperative AP and lateral radiographs (left) demonstrate coronal vertical axis 3.0 cm, sagittal vertical axis 4.2 cm, pelvic incidence-lumbar lordosis mismatch 40 to 5°, and pelvic tilt 20°. She underwent a T9 to pelvis posterior instrumented fusion with L1-S1 posterior column osteotomies, and L5-S1 TLIF. Three-year postoperative AP and lateral radiographs (right) show excellent correction of her coronal alignment while re-establishing her physiologic lumbar lordosis and maintaining her sagittal alignment (cervical vertical axis 0.8 cm, sagittal vertical axis 2.0 cm, pelvic incidence-lumbar lordosis mismatch 40–31°: 9, pelvic tilt 19°).

clinical outcomes including pain, patient satisfaction, disability, and Scoliosis Research Society scores.[35–38]

Indications

Pedicle subtraction osteotomy is indicated for patients with moderate to severe rigid sagittal deformity requiring a minimum of 30° of lordotic correction unlikely to be accomplished through posterior-column osteotomies alone. It is particularly valuable for patients with an anterior column fusion and those requiring focal lordotic correction at a single level as opposed to gradual correction over multiple levels. For patients with concurrent coronal imbalance, asymmetric pedicle subtraction osteotomy may allow for simultaneous coronal and sagittal corrections.[39,40] For patients requiring more aggressive correction, pedicle subtraction osteotomy may be extended to include the entirety of the cephalad disc (Schwab grade IV osteotomy, "extended pedicle subtraction osteotomy").

Technique

Level selection

In patients with focal angular deformity, pedicle subtraction osteotomy should be performed at the apex of deformity. When possible, more caudal levels (L3-S1) should be prioritized for pedicle subtraction osteotomy in order to avoid the conus medullaris and to replicate physiologic lordosis, two-thirds of which arises from L4-S1.[25,41] Furthermore, pedicle subtraction osteotomy performed at lower lumbar levels more effectively corrects pelvic tilt than it does at higher lumbar levels.[42,43]

Osteotomy planning

Pedicle subtraction osteotomy should be tailored to achieve the primary goals of restoration of sagittal balance and physiologic lordosis. While pedicle subtraction osteotomy generally provides between 25° and 40° of correction in lordosis, 30° is a reasonable focal correction goal. Though actual correction may vary between surgeons and may be difficult to determine reliably intraoperatively, the degree of correction, α_2 - α_1 (Fig. 3), should nonetheless be planned carefully prior to surgery to avoid inadequate or excessive correction. Dynamic interaction between various spinopelvic parameters and compensatory changes that occur in unfused portions of the spine following deformity surgery add to the complexity of osteotomy planning. Nonetheless, pedicle subtraction osteotomy follows the simple rule that a larger wedge resection achieves greater restoration of lordosis and in turn greater sagittal correction.

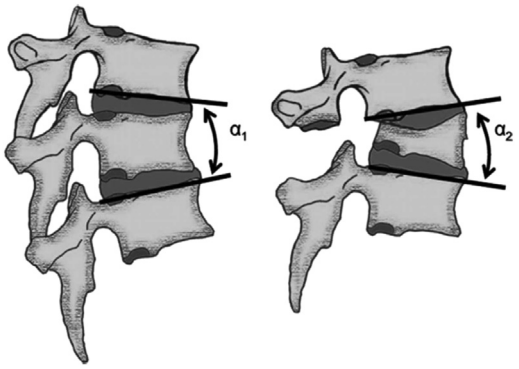

Fig. 3. The pedicle subtraction osteotomy degree of resection is defined as α_2 - α_1. (*From* Smith JS, Bess S, Shaffrey CI, et al. Dynamic changes of the pelvis and spine are key to predicting postoperative sagittal alignment after pedicle subtraction osteotomy: a critical analysis of preoperative planning techniques. *Spine* 2012;37(10):845–53 with permission.).

Surgical Technique

Following subperiosteal dissection, pedicle screws are placed at least 3 levels above and below the planned pedicle subtraction osteotomy, skipping the index level. Fixation should ideally be extended to the pelvis with iliac or S2-alar-iliac screws.

Pedicle-to-pedicle exposure is subsequently performed in the region of the pedicle subtraction osteotomy: removal of entire posterior elements at the index level, inferior facetectomy at the level above, superior facetectomy at the level below, and removal of the spinous processes, majority of laminae, and ligamentum flavum at the levels above and below. Wide laminectomy and flavectomy above and below the index level—as well as decompression of any scar in revision cases—helps prevent dural buckling and/or nerve impingement at time of osteotomy closure.

At this point, a temporary rod must be placed prior to proceeding because the resection of the anterior column is destabilizing and may result in subluxation or premature closure of the osteotomy. Pedicles of the index level are subsequently removed to the dorsal cortex of the vertebral body; attention must be paid to exiting nerve roots running medially and inferiorly to the pedicles (Fig. 4). Psoas is reflected away from the lateral vertebral body using a periosteal elevator or sponge stick. A retractor or temporary sponge may be placed anterior to the body for ventral protection and hemostasis.

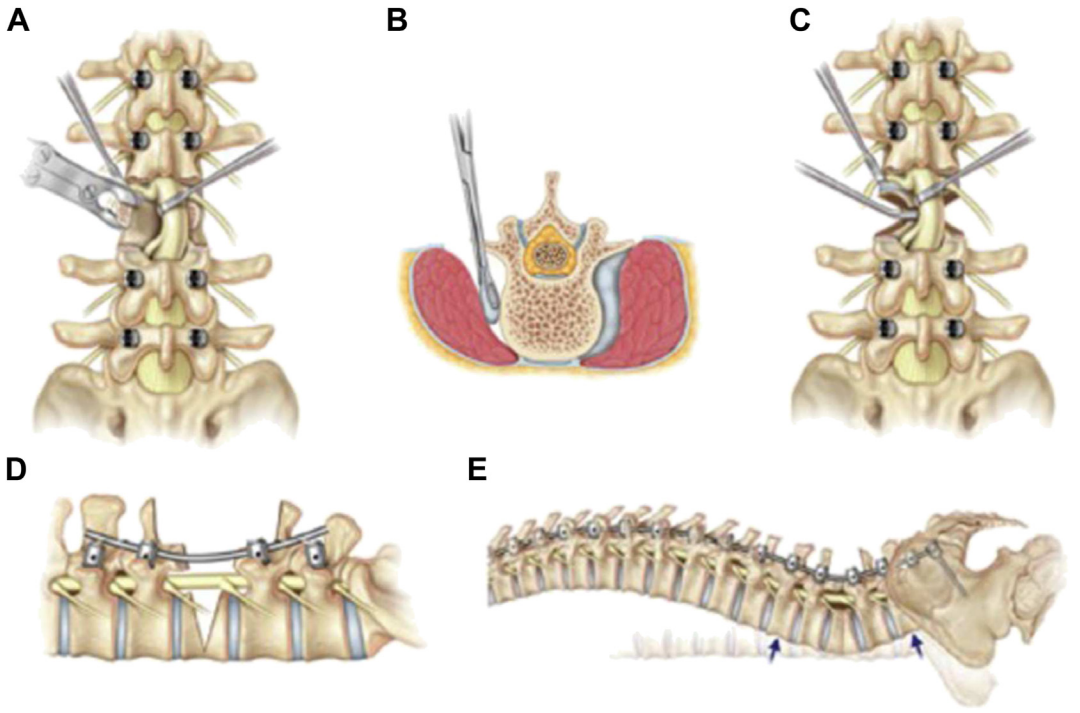

Fig. 4. Key steps of pedicle subtraction osteotomy. (*A*) "Pedicle-to-pedicle" exposure is performed in the region of the pedicle subtraction osteotomy. Pedicles of the index level are removed to the dorsal cortex of the vertebral body. (*B*) Psoas is reflected away from the lateral vertebral body. (*C*) The body is decancellated and the lateral vertebral cortex resected in a wedge-shaped fashion to the anterior cortex. (*D*). Temporary rod placement is necessary during pedicle subtraction osteotomy to stabilize the spinal column. (*E*) Once complete, the osteotomy is closed through extension across the index level. (*From* Mummaneni PV, Dhall SS, Ondra SI, Mummaneni VP, Berven SH. Pedicle Subtraction Osteotomy. *Neurosurgery.* 2008; 63(3 Suppl):171 to 176 with permission.)

The body is then decancellated and the lateral vertebral cortex resected in a wedge-shaped fashion to the anterior cortex using rongeurs and box cutter osteotomes. The anterior cortex should be left intact to serve as a hinge across which correction is performed and to protect anterior visceral and vascular structures. After using a freer-type dissector to establish a plane between ventral dura and posterior cortex, a down-pushing curette is used to mobilize the posterior cortex anteriorly, completing the osteotomy. Failure to establish this plane prior to this maneuver may result in a ventral cerebrospinal fluid leak.

Once complete, the osteotomy is closed through extension across the index level. Reverse table breaking, bolster manipulation, and compression across posterior instrumentation during rod placement may all facilitate closure. Closure of the osteotomy represents a period of heightened risk to neurologic structures. To reduce the risk of ischemia, neural perfusion should be optimized through the maintenance of mean arterial pressures above 90 mm Hg during closure. Following closure, the neural elements must be evaluated through both visual/manual inspection and neuromonitoring. Evidence of dural buckling, neural impingement, or decrement in signals should be addressed through additional removal of bone or soft-tissue structures and/or less aggressive extension.

Several considerations in rod construct selection and promotion of fusion are pertinent given the significant amount of stress across the pedicle subtraction osteotomy. It is important to prevent notching of the rod at the index level; excessive rod recontouring should be avoided. Use of pre-contoured or pre-planned, patient specific-rods and cobalt chrome may reduce rod strain.[27,28,44] Additionally, satellite rods and four-rod constructs reduce pseudarthrosis and rod fracture after pedicle subtraction osteotomy.[45,46] Supplementation of pedicle subtraction osteotomy with anterior column support (eg, ALIF, TLIF, or lateral interbody) may also reduce rod strain and risk of pseudarthrosis.[47,48] In addition to the use of autograft, allograft, bone matrix, and/or bone morphogenic protein,[29,30] fusion can be facilitated through thoracolumbar bracing for the first 3 to 6 month after

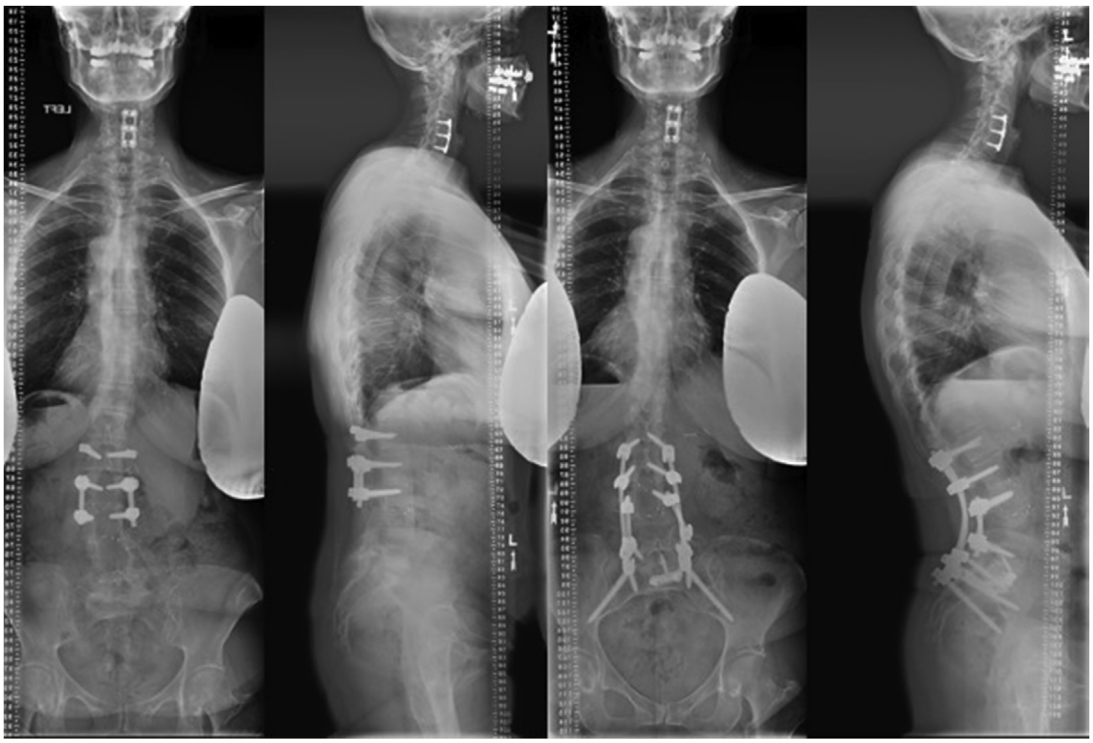

Fig. 5. This is a 66-year-old woman with a prior L1-3 fusion and L3-4 laminectomies who presented with flat back syndrome, sagittal plane imbalance, and inability to stand erect. Preoperative AP and lateral radiographs (left) demonstrate sagittal vertical axis 8.5 cm, pelvic incidence-lumbar lordosis mismatch 60 to 27°, and pelvic tilt 37°. She underwent an L4 pedicle subtraction osteotomy, L1 to pelvis posterior instrumented fusion, and L5-S1 ALIF. Three-month postoperative AP and lateral radiographs (right) show excellent correction in her lumbar lordosis and sagittal alignment (sagittal vertical axis 0 cm, pelvic incidence-lumbar lordosis mismatch 60–60°, and pelvic tilt 24°). Coronal vertical axis remained well aligned pre- and postoperatively.

surgery, which if tolerated, may reduce cyclic loading and rod stress.[43] Pre- and postoperative radiographic images for a patient who underwent pedicle subtraction osteotomy are shown below (Fig. 5).

Complications

Complication rates from pedicle subtraction osteotomy are high (~30% to 75%).[16,20,22,36,37,49–51] One prospective study of 71 patients demonstrated nearly twice the blood loss from pedicle subtraction osteotomy (2617 mL) than from multiple pedicle-column osteotomeis (1398 mL).[16] A prospective study with 2-year follow up on 82 patients who underwent three-column osteotomy reported major or minor complications in 78% of patients, including reoperation rate of 33% and neurologic injury rate of 30%. This risk of neurologic injury, reported by many studies to be ~10%,[16,21,22,35,50] should be juxtaposed with the relatively low risk of neurologic injury from posterior column osteotomy (~0.5%).[18]

Common complications of pedicle subtraction osteotomy include durotomy, pleural effusion, and wound infection. Less common short-term complications include nerve impingement, postoperative ileus, venous thromboembolic disease, urinary tract infection, pneumonia, sepsis, myocardial infarction, and death. Common long-term complications include suboptimal postoperative alignment, which occurs in roughly a third of patients and can cause persistent pain and disability.[33,52] Symptomatic pseudarthrosis after pedicle subtraction osteotomy is reported in roughly 10% of patients.[53] Additional long-term complications include hardware failure (rod fracture, screw fracture) and adjacent segment disease. Indeed, elevated rod stress at the site of the osteotomy and frequently high bending angles result in shorter fatigue life and increased risk of rod fracture after pedicle subtraction osteotomy.[54,55]

VERTEBRAL COLUMN RESECTION

The earliest descriptions of complete vertebrectomy date back to the 1920s; Bradford first reported the use of circumferential vertebral column resection for the treatment of rigid spinal deformities in the 1980s.[56,57] Suk and collaborators subsequently described the modern posterior-based approach to vertebral column resection, which has become one of the most powerful techniques for the treatment of severe fixed deformity.[58,59] Vertebral column resection (Schwab osteotomy grades V/VI), which involves removing an entire vertebra (or vertebrae) as well as adjacent discs, has potential to provide 45° or more of sagittal correction.[60,61] Because vertebral column resection allows for the complete translation of the spinal column, it is a powerful treatment for coronal deformity as well.[62] The power of vertebral column resection comes at the cost of relatively high rates of complication including neurologic injury, blood loss, and proximal junctional kyphosis. Nonetheless, vertebral column resection is a valuable technique for the treatment of severe fixed deformity and yields significant improvements in radiographic and clinical outcomes.[63,64]

Indications

Vertebral column resection is indicated for patients with severe fixed sagittal deformity requiring more correction than can be provided by posterior-column osteotomies and/or pedicle subtraction osteotomy alone. It is particularly valuable for patients with severe focal angular sagittal deformity and for patients with concurrent coronal deformity requiring multiplanar correction.

Technique

Level selection

Unlike pedicle subtraction osteotomy, where level selection may be influenced by a variety of factors, vertebral column resection should typically be performed at the apex of deformity in the sagittal and/or coronal planes.

Osteotomy planning

As with pedicle-column osteotomy and pedicle subtraction osteotomy, osteotomy should provide the angular correction required to achieve the primary goals of restoration of sagittal balance and physiologic lordosis as well as providing coronal correction as needed. The choice between single- and multilevel vertebral column resection should be guided by the principle of resecting the fewest levels required to provide adequate correction.[56]

Surgical technique

Pedicle screw placement at least 3 levels above and 3 levels below the level(s) of the vertebral column resection is recommended; for patients undergoing lumbar vertebral column resection, fixation should be carried through the ilium. Following pedicle screw placement, the entire posterior elements are removed as described for pedicle subtraction osteotomy. For vertebral column resection, it is necessary to remove the bilateral transverse processes at the index level(s) and, for vertebral column resection within the thoracic spine, to remove the articulating rib heads. Removing the posterior elements exposes the exiting nerve roots; in the thoracic spine, these roots may be tied off and ligated if necessary for exposure.

Prior to the resection of the anterior column, temporary rod placement is necessary to stabilize the spinal column. Index level pedicles are then resected to the dorsal cortex of the vertebral body, and psoas is mobilized from the lateral vertebral body as described above for pedicle subtraction osteotomy.

The body is subsequently decancellated and lateral vertebral cortex resected. In contrast to the wedge-shaped osteotomy performed for pedicle subtraction osteotomy, the entire vertebral body and cephalad/caudad discs are resected using high-speed burr, box cutter osteotomes, and/or rongeurs. Care must be taken during the resection of the anterior cortex not to injure the visceral and vascular structures anterior to the spinal column; a thin rim of anterior cortex may be left to promote fusion.[62] As with pedicle subtraction osteotomy, it is necessary to establish a plane between the ventral dural and the posterior cortex of the vertebral body prior to mobilizing the posterior cortex anteriorly.

Once osteotomy is complete, correction is performed. A second temporary rod must be placed at this point if it has not been placed earlier. The deformity is gradually corrected through sequential compression and shortening of the spinal column across temporary rods. Asymmetric compression (eg, convex compression) allows for correction within the coronal plane; distraction should not be performed until sufficient closure of the osteotomy has been performed and adequate slack has been afforded to the concave dura and spinal cord.[62,65] Following gross correction, temporary rods are sequentially replaced by permanent rods; additional correction may be provided by in situ bending, reverse table breaking, and bolster manipulation. Closure of the osteotomy represents a period of heightened risk to neurologic structures which should be mitigated

through the maintenance of mean arterial pressures above 90 mm Hg during closure as well as careful evaluation of the neural elements via visual/manual inspection and neuromonitoring.

Finally, interbody placement within the osteotomy site is advised to provide anterior column support and promote fusion.[62] Many of the same considerations regarding rod construct and promotion of fusion apply to both pedicle subtraction osteotomy and vertebral column resection: cobalt chrome, precontoured rods, four-rod constructs, and bone matrix and/or bone morphogenic protein may all help to reduce rates of rod fracture and pseudarthrosis.

Complications

Vertebral column resection is associated with high complication rates (roughly 20% to 75%).[38,59,63–66] As with pedicle subtraction osteotomy, risks include neurologic injury and major medical complications within the perioperative period as well as long-term complications such as pseudarthrosis, proximal junctional kyphosis, and the need for revision surgery.

A systematic review of seven studies with 390 patients who underwent posterior vertebral column resection noted an overall complication rate of 32%.[63] Neurologic injury, the most common complication, occurred in 8% of patients. Average blood loss was 2639 mL, which is comparable to that reported elsewhere for pedicle subtraction osteotomy.[16] Revision surgery was required in 6% of patients.

A retrospective study by Kelly *and colleagues* suggests vertebral column resection may carry higher risk of major medical complications than pedicle subtraction osteotomy.[21] Among a cohort of 132 patients who underwent pedicle subtraction osteotomy or vertebral column resection, vertebral column resection patients were more likely to experience major medical complications than pedicle subtraction osteotomy patients (73.7% vs 46.9%). However, there was no statistically significant difference in new neurologic deficits between these groups (15.8% vs 8.8%).

In a series of 54 adult and pediatric patients with 5-year follow up after posterior vertebral column resection, Lenke and colleagues have reported a 55.6% complication rate including 9.3% rate of neurologic deficit and 13% rate of revision surgery.[64] Notably, 34.8% of adult patients developed proximal junctional kyphosis; however, none required revision for symptomatic proximal junctional kyphosis. Among adults, common perioperative complications were excessive blood loss, pleural effusion, and postoperative anemia. Common longer-term complications included compression fracture, prominent instrumentation, and pseudarthrosis/rod fracture.

SUMMARY

Posterior-column osteotomy, pedicle subtraction osteotomy, and vertebral column resection represent powerful posterior-based techniques for the treatment of sagittal imbalance through the restoration of physiologic lordosis. While multilevel posterior-column osteotomy is best suited for patients with flexible sagittal deformity, pedicle subtraction osteotomy and vertebral column resection provide greater focal restoration of lordosis and allow for the treatment of both rigid and multiplanar deformity.

CLINICS CARE POINTS

- Posterior-based osteotomies should be considered for the restoration of lordosis in adult spinal deformity.
- Posterior-column osteotomy is well-suited for patients with flexible deformity requiring modest sagittal correction.
- Three column osteotomies, including pedicle subtration osteotomies and vertebral column resection, are powerful techniques for the correction of more severe deformity, particularly focal and multiplanar deformity; however, these techniques carry higher complication rates.
- Regardless of which type of posterior-based osteotomy is implemented, the risk of neurological injury should be mitigated through the use of neuromonitoring and diligent visual/manual inspection following osteotomy closure.
- Techniques to reduce intraoperative blood loss (meticulous subperiosteal dissection, the use of tranexamic acid, utilization of an open table, etc) and methods to optimize fusion (use of bone morphogenic protein, optimal correction of spinopelvic parameters, minimization of rod notching and/or overcontouring, use of satellite rods and four-rod constructs, etc) may help to mitigate key additional short-term complications (acute blood loss and associated medical sequelae) and long-term complications (pseudoarthrosis and adjacent segment disease) associated with posterior-based osteotomies.

DISCLOSURE

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