Coronal Realignment and Reduction Techniques and Complication Avoidance

Kai-Ming G. Fu, MD, PhD[a,*], Justin S. Smith, MD, PhD[b], Christopher I. Shaffrey, MD[b], Christopher P. Ames, MD[c], Shay Bess, MD[d]

KEYWORDS

• Scoliosis • Congenital deformity • Idiopathic scoliosis • Severe degenerative scoliosis

KEY POINTS

- Multiple reduction/realignment techniques have been described for treating coronal plane deformity.
- Rigid deformities may require anterior release or osteotomies before correction.
- Each deformity is unique and requires a tailored approach, often combining several techniques.
- Minimizing complications from spinal reconstructions requires adequate preoperative planning and attention to detail in the perioperative period.

Advances in technology, such as segmental pedicle screw instrumentation, have dramatically increased the number and effectiveness of realignment and reduction techniques for the treatment of coronal spinal deformity. Historically, distraction–compression was the primary technique used to correct coronal curvature.[1,2] However, employing this technique has deleterious effects on sagittal alignment, and it is rarely used as the sole maneuver to correct spinal deformity today. Other techniques, including cantilever bending, in situ bending, translation, derotation, direct vertebral rotation, and vertebral column resection have been described and are more commonly employed today.[3–5] Each patient's spinal deformity is unique; therefore spinal realignment must be individualized and employ a combination of techniques. The treatment of coronal deformity often requires substantial spinal reconstruction and involves significant risk of complications. Minimizing complications requires attention to detail in planning, positioning, and in perioperative management.

CORONAL CORRECTION CONCEPTS

The correction of spinal malalignment requires the application of appropriate forces counter to the direction of the deformity. All reduction strategies

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[a] Department of Neurosurgery, Weill Cornell Medical center, 525 East 68th Street, New York, NY 10065, USA; [b] Department of Neurosurgery, University of Virginia, PO Box 800212, Charlottesville, VA 22908, USA; [c] Department of Neurological Surgery, University of California, 505 Parnassus Avenue, Room 779 M, San Francisco, CA 94143-0112, USA; [d] Rocky Mountain Hospital for Children, 1719 E. 19th Avenue, Denver, CO 80218, USA
* Corresponding author.
E-mail address: kaimingfu@gmail.com

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employ one or more of the following forces. Distraction of the vertebrae may be employed to address the concavity of the curve but also results in kyphosis in the sagittal plane. Compression is best applied over the convexity of the curve and results in increased lordosis in the sagittal plane. Other forces that can be applied in correction include the application of cantilever forces, translation or reducing the vertebra to a straight construct, tilting, and derotation or applying force in the axial plane to correct rotational deformity.[6–8]

The use of these forces requires a spine with some degree of flexibility. In certain cases, applying these forces will not result in adequate reduction due to the rigidity of the deformity. In other cases, previous operations may have led to arthrodesis of the spine in the deformed state. In these cases, the principles of rigid and revision surgery are applied. These include anterior releases designed to increase flexibility of a rigid curve, or osteotomies, including smith-petersen, pedicle subtraction, or vertebral column resection, which offer varying degrees of sagittal and coronal plane correction.[9,10]

PROCEDURES AND TECHNIQUES

Historically, scoliosis was treated with the principles of correction pioneered by Harrington.[2] **Fig. 1** demonstrates this technique. Distraction is applied to the concave side, and compression is applied over the convex side. Reduction is not segmental, but the technique can correct lateral and angular displacement. The technique does not correct rotational deformity and places high stress on the spine and instrumentation. Furthermore, the application of a straight rod reduced thoracic kyphosis and reduced lumbar lordosis, resulting in flat back deformity and sagittal spinopelvic malalignment. Subsequently, many patients required revision surgeries, which entailed complex osteotomy procedures to correct the iatrogenic sagittal plane deformity.[11] **Fig. 2** demonstrates such a case in which attempted coronal realignment resulted in thoracolumbar junction kyphosis, necessitating revision. Attention to detail in all planes is required to avoid long-term complications.

With the advent of segmental instrumentation, other techniques have been described to affect coronal reduction with less deleterious effects in the sagittal plane. First described by Luque,[12] translational reduction involves the placement of a contoured rod, during which each segment is brought toward the rod. **Fig. 3** demonstrates this technique. In general, the proximal and distal ends of the rod are provisionally placed. After this, each vertebral segment is reduced to the

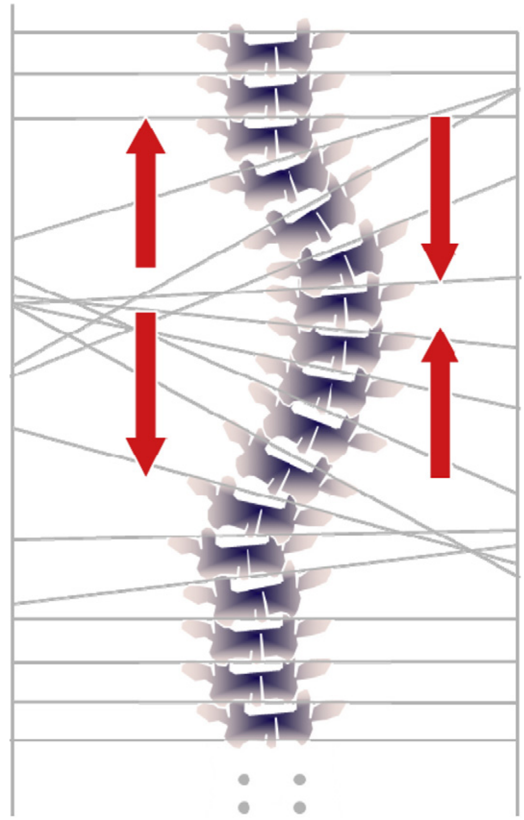

Fig. 1. Graphical demonstration of regional distraction compression technique as described by Harrington. Distraction is applied on the concave side, while compression is applied on the convex side. *Arrows* represent direction of correctional forces.

construct. This technique is useful in correcting lateral and rotational deformity. Proper contouring of the rod allows for the maintenance of physiologic lumbar lordosis and thoracic kyphosis. Translation, however, places high stress on the bone/implant interface, and there are limits to reduction before implants fail, either by loss of fixation (loosened screw), failure (instrumentation fracture), or failure to maintain correction.

In situ bending is another method for obtaining coronal correction. **Fig. 4** demonstrates this technique. In this method, the rod is shaped and fixed to the spine. The deformity is then corrected by bending the rod to the desired shape with in situ bending tools. This method provides for correction of lateral deformity. Again, this technique results in high stress on the instrumentation and bone. With titanium rods, multiple bends can lead to increased rod notching and structural weakening of the rod with associated risk of rod fracture.[13]

Segmental rod translation applies the techniques of translation in a segmental fashion. Again, the rod is contoured to the appropriate shape with

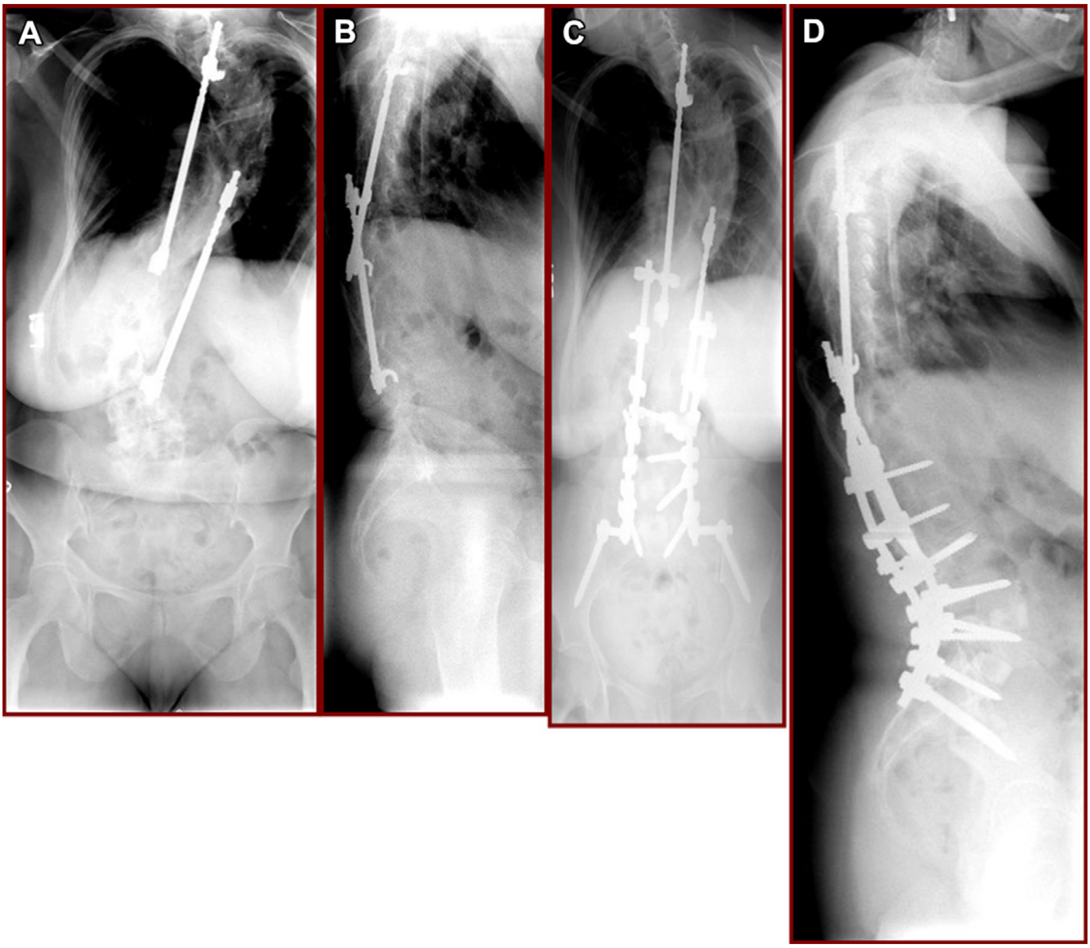

Fig. 2. Patient with Harrington rod instrumentation (*A*, *B*) demonstrating loss of lumbar lordosis. Revision with extension to pelvis was required (*C*, *D*) to restore sagittal alignment.

care taken to address the physiologic contours of the sagittal plane. As opposed to the translation techniques describe previously, the rod is secured at 1 end only. Each segment is brought to the rod, and the deformity is reduced at each segment, leading to a realigned spine (**Fig. 5**). A benefit of this approach is that less stress is applied to the instrumentation and bone, as the reduction is gradual and controlled. In addition, lateral and rotational components of deformity can be readily addressed.

Derotation has been advocated as another method for correcting deformity. Rod derotation was introduced theoretically to produce a 3-dimensional correction of deformity. **Fig. 6** demonstrates this technique. The rod is properly contoured to reflect the desired physiologic sagittal profile. including restoration of thoracic kyphosis and lumbar lordosis. According to derotation theory, this contour approximates the spinal deformity rotated 90°. The rod is applied with the spine translated to the rod. The rod is then rotated in the axial plane to correct the coronal deformity while preserving or promoting a proper sagittal alignment. The benefit of this technique is that the procedure is simple and quick. One drawback is the high level of stress placed on the construct and bone interface. In addition, the amount of reported rotational correction varies, with some reports as low as 11°.[4,14] However, derotation has been demonstrated to be superior to Harrington techniques in curve correction and maintenance of correction.[15] A comparison of derotation with translation techniques among 70 adolescent idiopathic scoliosis patients demonstrated no significant difference between the procedures, with the exception of improved coronal thoracic curve reduction with the translation technique.[4] Direct vertebral derotation (DVD) has also been advocated as a method for potentially addressing thoracic rib hump and

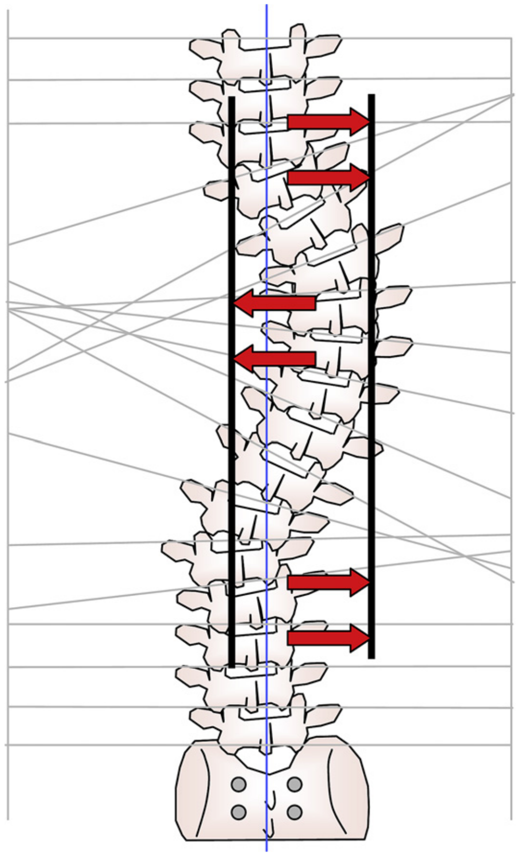

Fig. 3. Translational technique. Contoured rod is secured proximally and distally. The spine is then brought to the rod (*arrows*).

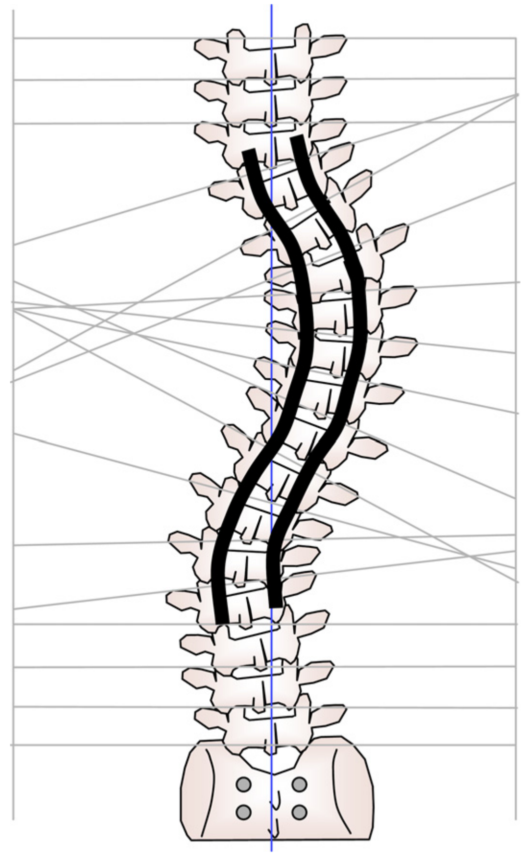

Fig. 4. In situ bending technique. Rods are contoured to the deformity and applied. Rods are then bent to reduce coronal deformity.

avoiding the need for a thoracoplasty. A recent report suggests that thoracic rib humps are addressed equally with and without DVD, but that DVD provides less correction in the thoracolumbar region.[16] DVD has been reported to have a deleterious effect on lumbar lordosis also. In patients undergoing DVD for adolescent idiopathic scoliosis, those treated with DVD demonstrated about a 12° loss of lumbar lordosis and an 8° loss of thoracic kyphosis.[17] Therefore, when employing this technique, care must be taken to avoid further flattening maneuvers.

A comparison of all these techniques demonstrates some benefits and drawbacks with each type of procedure. Segmental instrumentation has led to great improvements in techniques affording proper alignment in multiple planes. Each patient's deformity has individual characteristics, and the approach to each patient requires a customized plan for coronal realignment and reduction. **Fig. 7** demonstrates a combination technique for addressing coronal plane deformity. The technique requires distraction, compression, and/or translation applied segment by segment. Reduction screws used at the apex may facilitate a controlled sequential reduction. A combination technique provides a comprehensive approach to the deformity addressing each segment in turn while building a construct with appropriate coronal and sagittal plane contours. In addition, individual segments may be derotated to address axial deformity. The combination technique places the bone and instrumentation under less stress, allowing for smaller rods and lower profile connectors.

The application of all of the previously described techniques is requisite on the flexibility of the spine. Rigid deformities may require additional procedures before attempted reduction. Osteotomies, including Smith-Petersen (facet osteotomies) or pedicle subtraction osteotomies, may used posteriorly to facilitate manipulation. Vertebral column resection provides the largest amount of correction in the sagittal and coronal planes. Anterior release can be performed before posterior coronal reduction procedures. Anterior release procedures reduce the stiffness of a curve and are usually

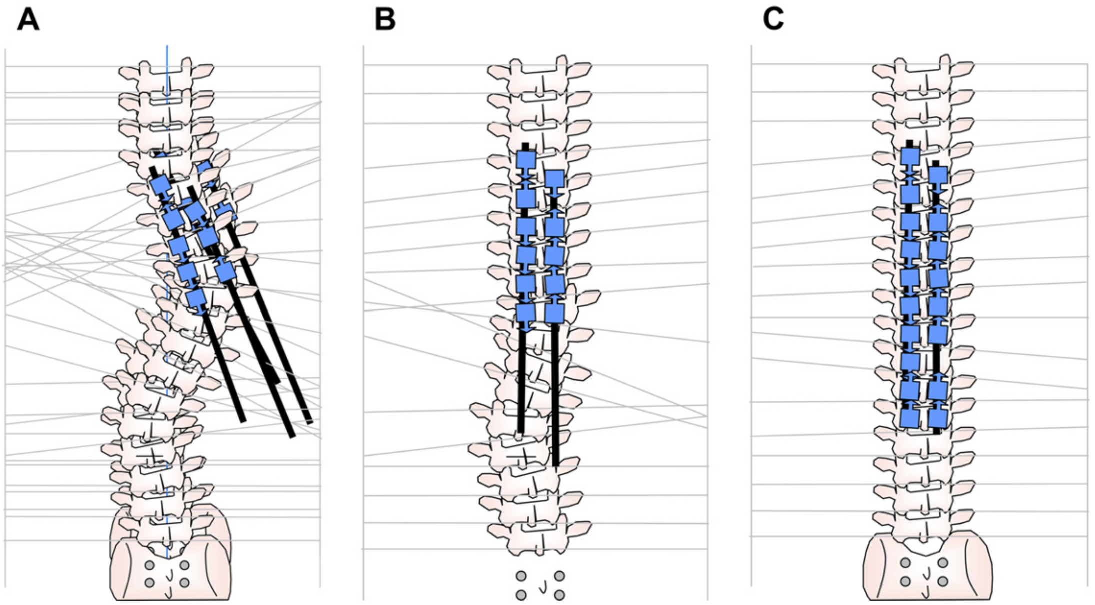

Fig. 5. Segmental rod translation. Contoured rods are applied (here proximally), and the spine is sequentially transferred to the rod segment by segment as shown progressively from panels *A*–*C*.

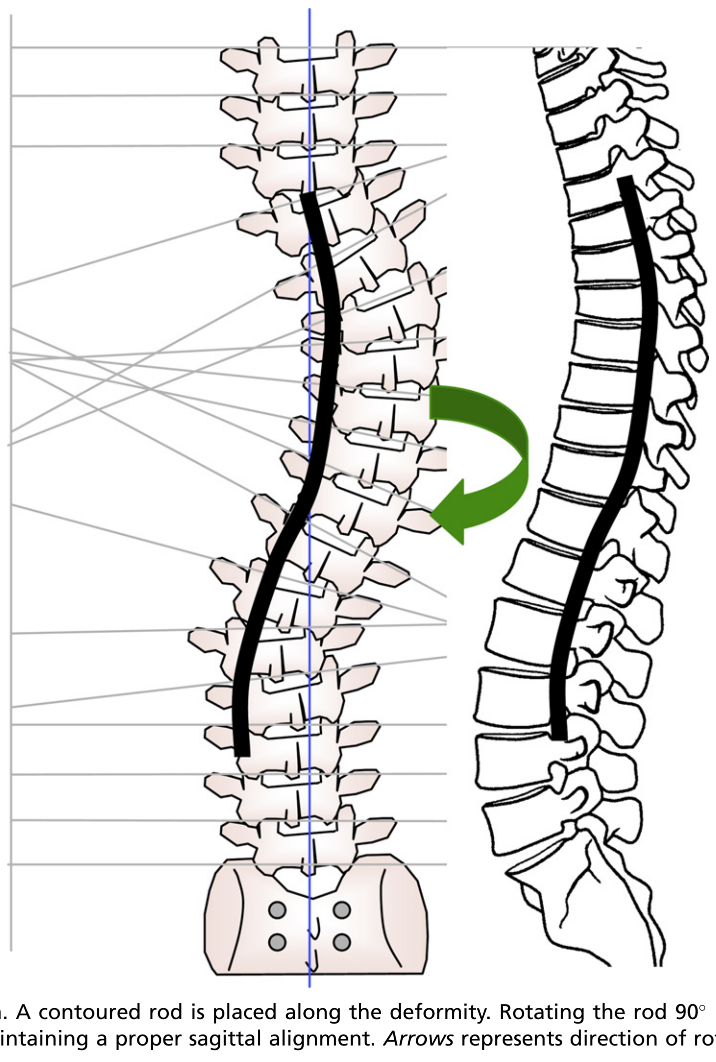

Fig. 6. Rod rotation. A contoured rod is placed along the deformity. Rotating the rod 90° reduces the coronal deformity while maintaining a proper sagittal alignment. *Arrows* represents direction of rotational correction.

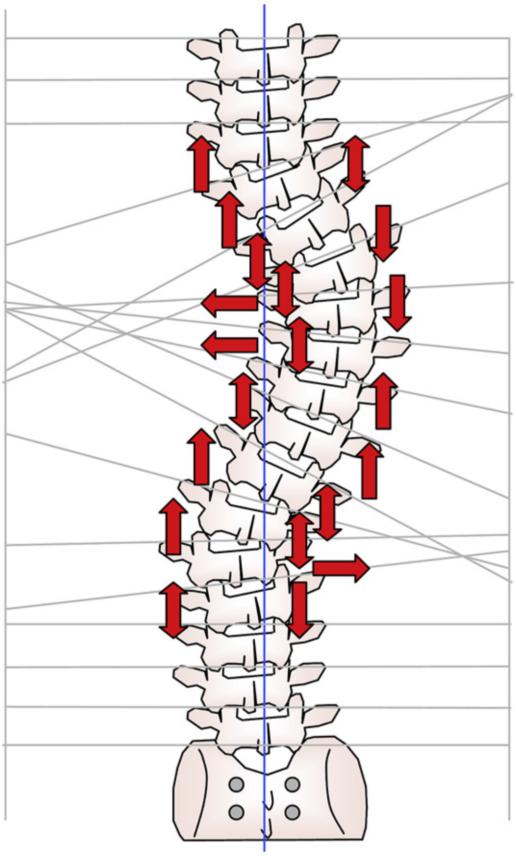

Fig. 7. Segmental correction. Each segment is translated, compressed, and distracted as indicated. *Arrows* represent segmental corrective maneuvers to be applied for correction.

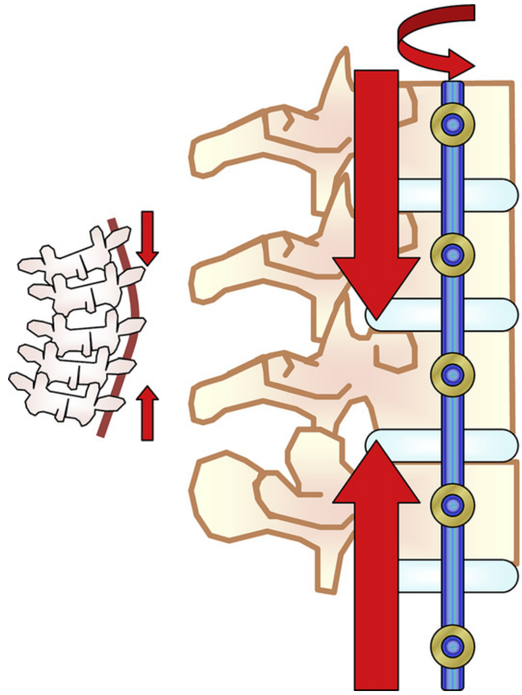

Fig. 8. Anterior correction. Compression along the convexity of the curve results in coronal plane reduction. *Arrows* represent direction of anterior reduction.

performed at areas of rigidity as determined by preoperative radiographs (lateral bending, bolster). The technique includes an anterior or anterolateral approach. For each segment, the disk is incised and removed. Structural interbody grafts may be placed. Such grafts may be contoured to aid in correction in both the sagittal and coronal planes. Anterior osteotomies can be performed for extremely rigid deformities.

Some deformities may be best approached with an anterior correction as demonstrated in **Fig. 8**. Anterior correction is effected with segmental distraction and compression, addressing lateral displacement. Derotation can be performed for correction of sagittal displacement. In situ bending is also used. However, effective translation is difficult to perform anteriorly.

DIAGNOSTIC CRITERIA

Coronal plane deformity encompasses a multitude of pathologies, ranging from neuromuscular to idiopathic to degenerative scoliosis. Affected patients range from infants to the elderly. Indications for intervention vary for each pathology; therefore, a complete discussion on the indications for treatment is beyond the context of this article. In general, adolescent idiopathic patients are considered for treatment if the major curve is greater than 45°. Imaging required for these patients includes long cassette scoliosis radiographs as well as others as needed to assess rigidity (bending, bolster). Older patients may require surgery for the sagittal plane deformity as much as a coronal deformity. Imaging generally includes advanced imaging studies (magnetic resonance imaging or computed tomography myelogram) to assess for spinal stenosis with resultant neurogenic claudication and or/radiculopathy. Patients often proceed with operative intervention for radicular pain or neurologic deficit.

COMPLICATIONS

Correction of thoracic and thoracolumbar deformity is not without potential complications. Depending on the size of the procedure, degree of correction, and age and comorbidities of the patients, the complication rates can be as high as 71% in the elderly.[18] Pediatric and younger adult patients have been reported to have complication rates much lower, in the 10% to 20% range.[18–20] Longer-term alignment complications can be minimized with proper preoperative planning.

Evaluating and addressing pelvic obliquity and leg length discrepancy are important in planning the extent of coronal correction. Fractional lumbral curves may need to be addressed to maintain coronal balance.

Other common complications are infections, dural tears, implant complications, and new neurologic deficits. Vancomycin powder and pulse irrigation have been used in longer cases.[21] Introperative guidance can be used to assess placement of instrumentation. Neurologic monitoring, including both motor-evoked potentials and somatosensory-evoked potentials should used intraoperatively and be monitored frequently during reduction techniques.[22–24] In the event of a new neurologic postoperative deficit, with appropriate intervention most deficits have been demonstrated to improve, most back to near baseline.[25]

Other common potential perioperative complications include postoperative anemia, deep vein thrombosis (DVT), and pulmonary embolus. Proper resuscitation should be performed to correct intraoperative blood loss. Care should be taken to perform mechanical DVT prophylaxis before induction through mobilization and discharge. Antibiotics can be given prophylactically while closed drainage systems are maintained in place. Immediate postoperative management in an intensive care unit setting may be indicated based upon duration and operative blood loss, or for frequent neurologic monitoring. Postoperative anemia is treated with transfusions as necessary. Long-term complications include adjacent level disease, proximal junction kyphosis, and pseudoarthrosis rates approaching 20%, necessitating longer-term postoperative patient follow-up.[26,27]

SUMMARY

Realignment of scoliosis in the coronal plane requires extensive spinal reconstruction. Various reduction techniques have been described. Each deformity is unique and requires a tailored approach to correction. Often, a combination of techniques must be employed. Preoperative planning is essential. Attention to detail is required in all aspects of the procedure, from positioning to postoperative mobilization. Despite these precautions, complications can occur, and a thorough discussion of risks and benefits should be held with the patient and family.

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