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# Derotation of the Spine

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With the application of modern techniques of instrumentation for idiopathic scoliosis, it is now possible to address correction of the deformity in three dimensions. Historically, Harrington instrumentation addressed the coronal plane with distraction forces applied along the concavity of the curve but was observed to create iatrogenic flatback by decreasing thoracic kyphosis or lumbar lordosis. Segmental instrumentation with hooks, wires, or hybrid instrumentation addressed these sagittal plane concerns to some extent but was insufficient to correct the axial plane rotational deformity present in idiopathic scoliosis. Proponents of the Cotrel-Dubousset procedure [1] believed that rotational correction of the scoliosis would occur with the rod derotation maneuver, but this was later disproved with pre- and postoperative CT scans of instrumented patients. Labelle and colleagues [2] used three-dimensional digitizers during surgery; they showed that the Cotrel-Dubousset rod derotation maneuver did exert coronal and sagittal plane correction and relocated the instrumented portion of the spine but that little axial plane rotation had occurred. Hook and wire fixation lacks the ability to derotate the spine, because force is applied posterior to the instantaneous axis of rotation (IAR) and the moment arm is inadequate to apply sufficient torque. True correction of axial plane vertebral rotation, and consequent elimination of the convex thoracic or thoracolumbar prominence, is difficult to achieve without anterior diskectomy and chest wall violation with thoracoplasty.

## Pedicle screws and derotation of the spine

The challenges of three-dimensional correction of scoliosis with posterior-only surgery are well addressed with the use of segmental pedicle screw fixation and, specifically, the application of direct vertebral rotation, as first described by Lee and colleagues [3]. Pedicle screws extend into the vertebral body anterior to the IAR and can be manipulated with the use of long derotator instruments attached to the screw heads to achieve true three-dimensional correction of the scoliotic deformity. Segmental fixation with pedicle screws addresses the most rigid rotated portion of the spine, spreads the corrective force over multiple implants, can pull the concavity out of the chest, and results in little loss of correction over time.

## Assessment of axial rotation

The clinical examination of a typical patient with thoracic scoliosis can reveal the nature of the coronal plane deviation along the curve(s), the hypokyphosis or apical lordosis in the sagittal plane, and the axial plane rotation present along the apex of the curve, as seen by an elevation of the ribs along the convexity and a relative depression of the ribs along the concavity (Fig. 1). The Adams forward bend test gives a more apparent picture of rotation and posterior topography; when combined with an inclinometer, it can attempt to quantify the rib prominence in degrees of axial trunk rotation.

CT is the "gold standard" for accurate assessment of vertebral rotation but is limited in its

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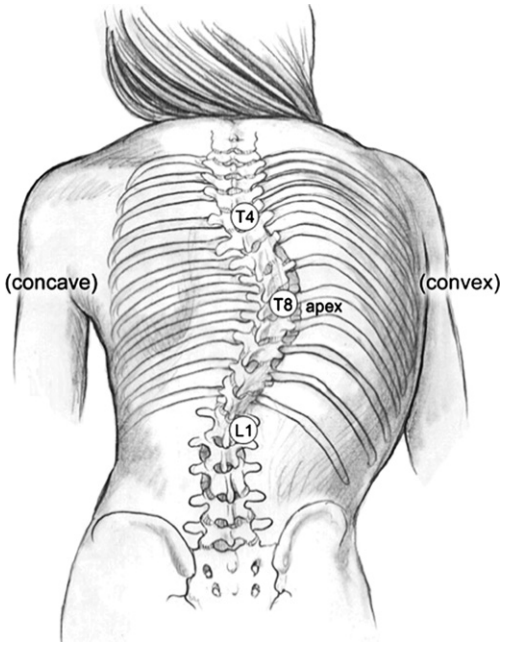


Fig. 1. Posterior view of a patient with Lenke type I right thoracic scoliosis shows the typical trunk shift, rib asymmetry, and convex rib prominence. (*Courtesy of* DePuy Spine, Inc., Raynham, MA; with permission.)

clinical utility because of cost, radiation exposure, and the effects of changes in position and posture during acquisition of the CT scan. Radiographic techniques from two-dimensional erect radiographs to assess vertebral rotation are available, and the Perdriolle [4] and Nash-Moe [5] methods are commonly used and simple to apply. These methods have considerable intra- and extraobserver reliability problems, however, and the use of pedicle screws obscures some of the landmarks necessary to quantify rotation after surgery. Recently, Kuklo and colleagues [6] have described radiographic correlates for thoracic torsion, such as apical rib hump prominence, apical rib/vertebral body ratio, and apical rib spread difference. These measures for thoracic torsion were shown to have good correlation with pre- and postoperative CT scans and can be useful clinical measures for assessing three-dimensional correction and restoration of chest wall symmetry.

## Goals of vertebral derotation

The goals of vertebral derotation are to achieve true three-dimensional correction of the spinal deformity and reverse the torsional asymmetry

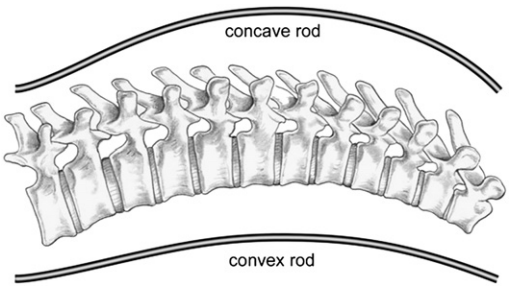


Fig. 2. Differential rod contouring: the concave rod pulls the apical vertebrae dorsally out of the chest, and the convex rod is relatively underbent to reduce the convex rib prominence. (*Courtesy of* DePuy Spine, Inc., Raynham, MA; with permission.)

induced by scoliosis. Intuitively, in typical thoracic adolescent idiopathic scoliosis (AIS), this would mean optimal coronal correction, restoration of thoracic kyphosis, and realignment of the thoracic torsion by lifting the concavity out of the chest and reducing the convex rib deformity. The upper and lower instrumented vertebrae would be level and, along with the apex, brought into the stable zone, as defined by the center-

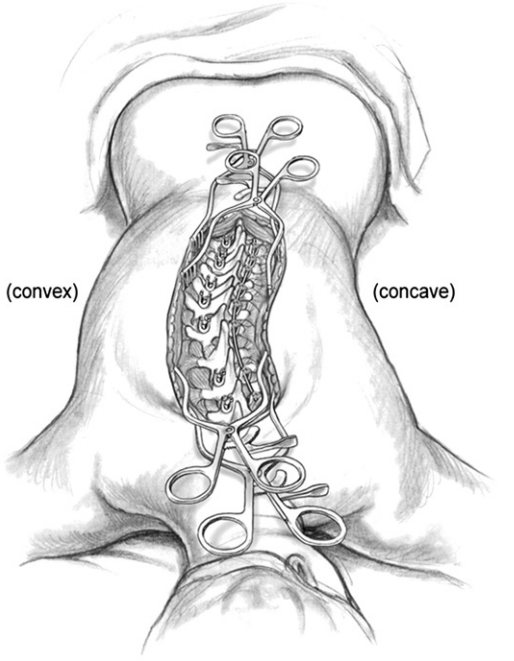


Fig. 3. Concave rod inserted with the set screws left loose before translation or derotation. (*Courtesy of* DePuy Spine, Inc., Raynham, MA; with permission.)

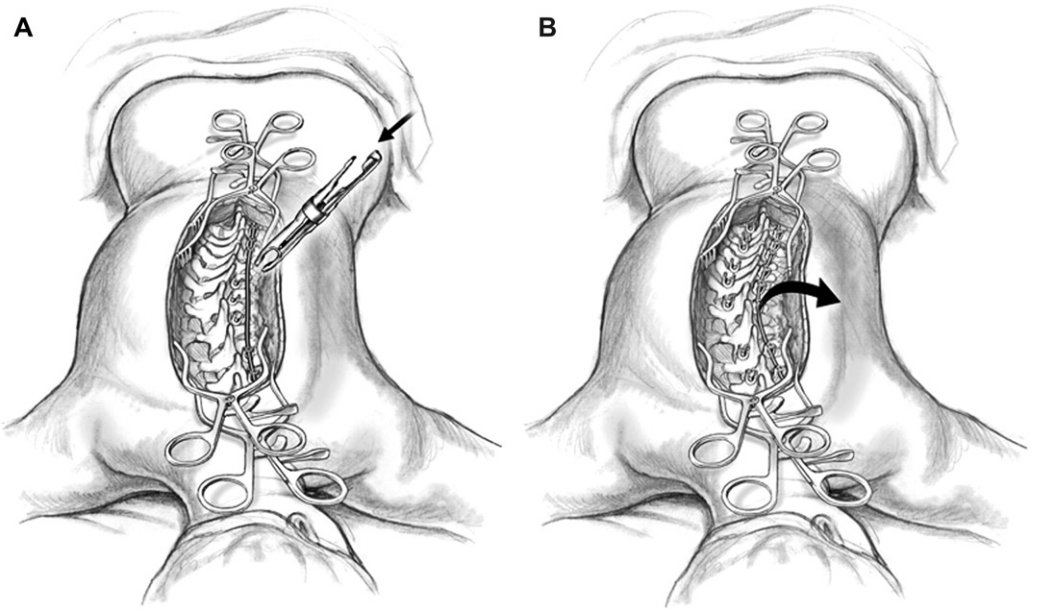


Fig. 4. (*A*) Translational correction of the scoliosis with a rod reduction device. (*B*) Rod derotation maneuver with arrow pointing direction of 90° rotation to correct scoliosis in the coronal plane and set rod in the proper sagittal plane (alternate method of correction). (*Courtesy of* DePuy Spine, Inc., Raynham, MA; with permission.)

sacral vertical line. The rib prominence would be virtually eliminated without thoracoplasty.

### Technical considerations and pitfalls in vertebral derotation

Fixed-angle pedicle screws offer better axial plane control of the vertebral segment than polyaxial screws [7], and an attempt should be made to use them in the strategic areas (ie, apex of the deformity). Recently, uniplanar screw technology that allows the cephalad/caudad movement of a polyaxial screw but permits the screw to remain fixed in the coronal and axial planes for vertebral body derotation maneuvers has become available. Application of force to the screws should be slow, deliberate, and controlled and depends on the bone mineral density and integrity of the bone-screw interface. More force can be applied to the convex screws, because these pedicles are typically larger than the concave pedicles in the apex of the scoliosis [8] and the medial wall of the pedicle is thicker than the lateral wall of the pedicle [9]. When rotated to failure, however, the convex screws do fracture the medial wall and enter the spinal canal; the concave screws can fracture the lateral pedicle wall, rib-pedicle


Fig. 5. En bloc derotation of the thoracic apex with derotators attached to pedicle screws; only the concave rod is implanted at this point and serves as the axis of rotation. (*Courtesy of* DePuy Spine, Inc., Raynham, MA; with permission.)

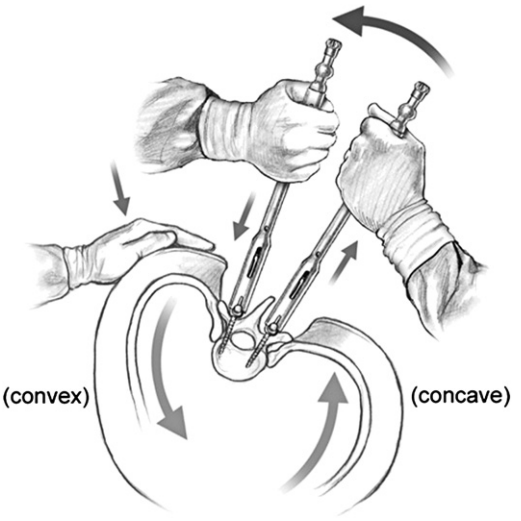


Fig. 6. Axial view of the spinal derotation concept: the screws on the concavity are pulled up and over, the screws on the convexity are pushed down and laterally from midline, and an assistant pushes down on the convex rib prominence to distribute forces. (*Courtesy of* DePuy Spine, Inc., Raynham, MA; with permission.)

unit, and transverse process and could injure the aorta [10]. Finally, care must be taken not to transfer torsional forces outside the instrumented segments to compensatory curves or neutrally rotated vertebral levels and create iatrogenic torsion; the neutral end vertebrae must be locked before derotation of the apical levels.

**Author's preferred technique of direct vertebral rotation in adolescent idiopathic scoliosis**

- On the concave side: insert monoaxial or uniplanar screws at every level. Also consider using polyaxial reduction screws at the apex of the concavity, particularly for severe curves.
- On the convex side: insert monoaxial or uniplanar screws into at least three to four convex pedicles at the apex as well as at the proximal and distal foundations.
- Confirm placement of screws, and check screw length with fluoroscopy or plain radiographs before rod insertion.
- Contour the concave rod with extra kyphosis (anticipating that the rod is going to become flatter during the translation/reduction of the scoliosis) to pull the apical vertebrae dorsally out of the chest, and correct apical lordosis (Fig. 2).
- Contour the convex rod with less thoracic kyphosis to push down on the convex side of the vertebral bodies, thus displacing them

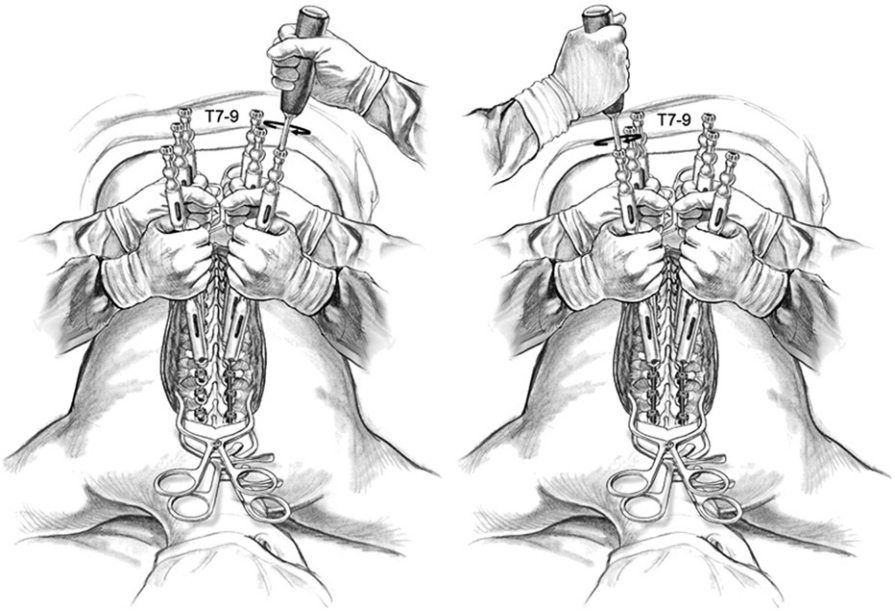


Fig. 7. En bloc derotation with concave rod implanted and set screws tightened (*left*); the convex rod is then implanted with rotation held corrected while set screws are tightened (*right*). (*Courtesy of* DePuy Spine, Inc., Raynham, MA; with permission.)


Fig. 8. Segmental spinal derotation: starting at the lowest instrumented vertebra in neutral alignment and securing its position with both rods implanted. (*Courtesy of* DePuy Spine, Inc., Raynham, MA; with permission.)

anteriorly and decreasing the rib prominence (see Fig. 2).

- Insert the concave rod into the pedicle screw anchors, leaving the set screws loose (Fig. 3).
- The rod can engage the anchors by means of one or both of the following:
  1. Translation maneuver: insert the rod proximally and distally, and tighten the set screws proximally and distally, leaving the rod in the correct sagittal plane. After proximal and distal foundations are connected and locked, apical screws are translated to the rod segmentally by using reduction devices or reduction screws (Fig. 4A).
  2. Rod rotation maneuver: insert the rod, and perform a rod rotation maneuver as in the classic Cotrel-Dubousset technique [2]. In this case, the rod rotates from the midline scoliotic position laterally to the left approximately 90° (Fig. 4B). During the 90° rotation, one must have control by pushing down over the convex ribs to avoid aggravating the rib prominence. This accomplishes translocation of the spine dorsally and medially but rarely results in true axial plane derotation.

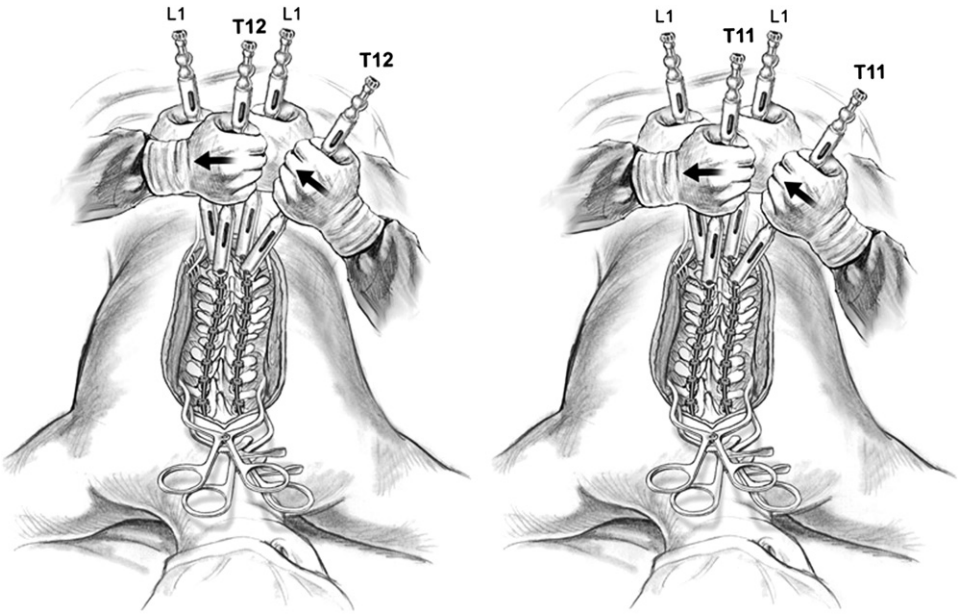


Fig. 9. Segmental spinal derotation: with the lowest instrumented vertebra held in countertorsion, derotators are used sequentially proceeding cephalad, adjusting the axial plane rotation relative to neutral at each segment. (*Courtesy of* DePuy Spine, Inc., Raynham, MA; with permission.)

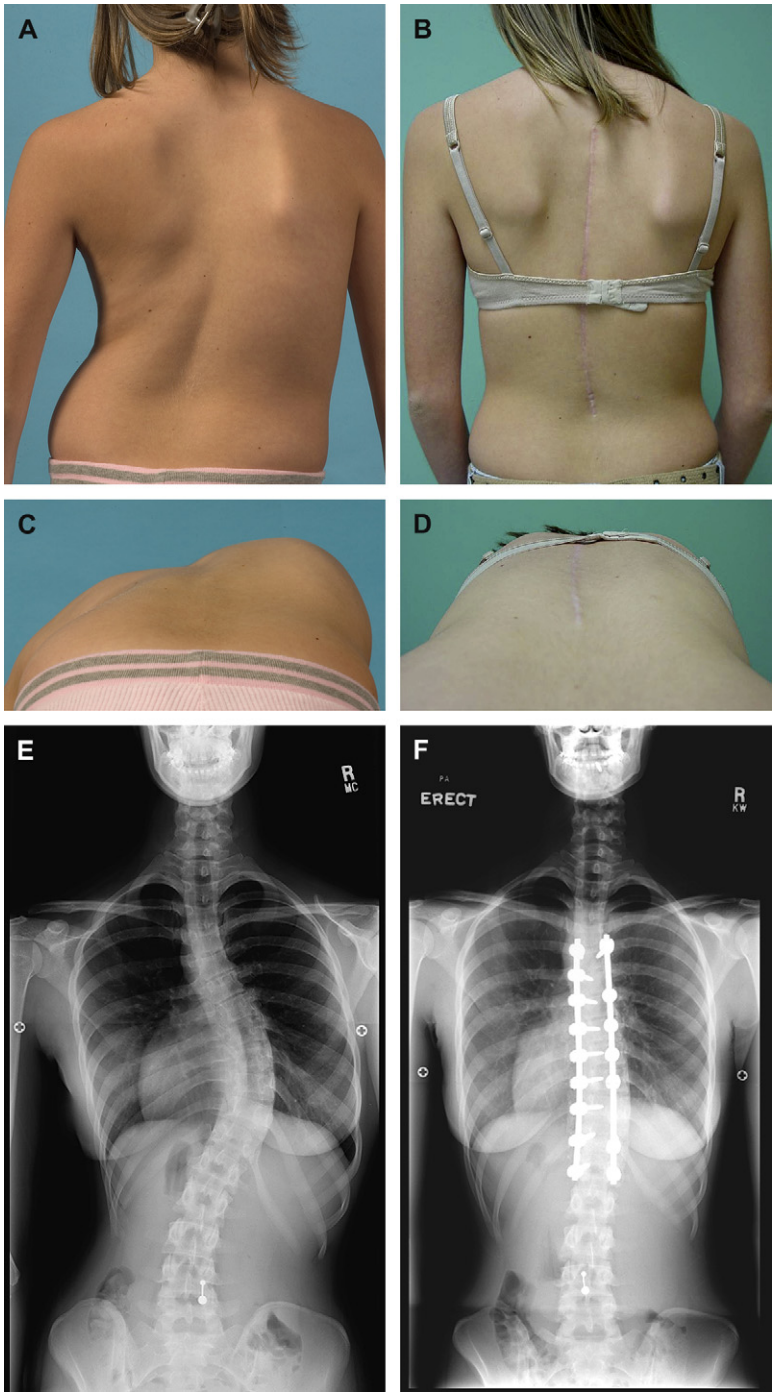


Fig. 10. Clinical photographs and radiographs before and after surgery (2-year follow-up) of a 13-year-old girl with AIS. Note correction of truncal shift, thoracic torsion, rib asymmetry, and rib prominence on forward bending after surgery with segmental pedicle screw fixation and vertebral derotation without thoracoplasty. (*A*) Preoperative clinical photograph. (*B*) Two-year postoperative clinical photograph. (*C*) Preoperative forward bend photograph. (*D*) Two-year postoperative forward bend photograph. (*E*) Preoperative posteroanterior radiograph. (*F*) Two-year postoperative posteroanterior radiograph.

- Finally, proceed with one or both of the vertebral body derotation techniques explained next.

*En bloc spinal derotation*

- After the concave rod is engaged in all anchors, attach derotation instruments to the apical screw heads on the concave and convex sides (Fig. 5).
- An assistant pushes down on the convex ribs, and the convex screws and the concave and convex screws are rotated in the direction that reduces the rib prominence (counterclockwise; see Fig. 5; Fig. 6). This should be done simultaneously to distribute strain and to limit loading of the bone-screw interface. The rotation of the concave screws helps to decrease the torsion and lifts the concavity out of the chest (see Figs. 5 and 6). A rehearsal of this maneuver before rod insertion can be helpful to gain a sense of how much force can be applied safely.
- Tighten the set screws on the concave rod holding this position (Fig. 7A).
- Implant the convex rod, and tighten the set screws on the convex side (Fig. 7B).

*Segmental spinal derotation (individual vertebral level)*

Segmental vertebral body derotation can be done as the sole derotation maneuver or in addition to the en bloc maneuver described previously.

- Implant both rods, and capture them with set screws. Most set screws should be left loose, because lengthening of the spine is expected at each level that is to be segmentally derotated. Only the set screws in the distal neutral vertebra should be tightened (eg, L1 in Fig. 8), because derotation is based on this neutral level and no torsional forces are transmitted distally.
- Attach two derotators in the distal segment to lock the bottom neutral vertebra. Then, attach the derotators in the next proximal one to two vertebrae. The derotators on the distal vertebra must be held by an assistant to provide counterrotation force.
- Derotate each proximal vertebral body sequentially to achieve a neutral position in reference to the neutral distal vertebra (Fig. 9). After derotation of each segment, the set screws are tightened. Repeat this process, moving along toward the apex.
- Complete neutral derotation might not be achieved at the apex relative to its torsion to the axial plane. Revisiting the apical levels after a few minutes may allow additional correction because of viscoelastic relaxation of the spine. Care must be taken not to loosen the bone-screw interface while performing the maneuver.
- Repeat the derotation for each segment until all vertebral levels nearly match the neutrally rotated distal vertebra. During segmental spinal derotation, segmental compression (convexity) or distraction (concavity) may be simultaneously applied to effect maximal correction just before the set screws are finally tightened. Pre- and postoperative photographs and radiographs are presented in Fig. 10.

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