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Concepts of Surgical Correction-Segmental Derotation and Translation Techniques

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Spinal deformity surgery once aimed only at stopping progressive disfigurement. With modern techniques, spinal deformity surgery now attempts not only to stop the structural imbalance but to reduce it back to as normal an alignment as possible. New surgical tools, advanced instrumentation, and innovative operative techniques allow the spine surgeon to reduce and reconstruct previously inoperable or uncorrectable deformities.

In idiopathic scoliosis, the spine can be imbalanced in all three of its planes: sagittal, coronal, and axial. Sagittal deformity in scoliosis can be seen as hypokyphosis, hyperkyphosis, or lordosis of the thoracic spine. Coronal deformity appears as lateral deviations resulting in major and minor curves in the thoracic and lumbar spine. These cause trunk imbalance over the pelvis and shoulder imbalance over the trunk. Axial deformity attributable to rotation, typically at the apical vertebrae, can induce the disfiguring rib hump of scoliosis. Consequently, deformity in any one plane does not develop in isolation and seems to be coupled to curvature, rotation, and translation in the other planes [1,2]. Thus, complete correction of spinal deformities requires attention to all three planes, which is the basis of the recent Lenke classification system.

Segmental correction

Early techniques of deformity correction comprised nonsegmental anchoring instrumentation at the adjacent normal structural level, with no fixation at the levels between. Nonsegmental correction with Harrington distraction or compression rods, which are anchored by hooks at the upper and lower stable vertebrae, relied on single-vector forces for reduction of deformity and achieved acceptable coronal correction. These methods resulted in significant sagittal plane complications, namely, iatrogenic flatback syndrome, however [3].

Segmental correction is simply defined as the application of corrective forces at each required segment of the deformed spine. The earliest versions of segmental correction used sublaminar wiring to Luque rods at individual segments of the spine to achieve reduction and stabilization [4]. Sublaminar wiring would typically begin on the concave side, reducing the scoliotic spine by translating it toward the rod as the wires were sequentially shortened. Newer wiring techniques using specialized rod frames have reported excellent results with greater than 50% correction of the major curve, 31% apical derotation, and greater than 95% shoulder and trunk imbalance [2,5].

The development of hook instrumentation (Cotrel-Dubousset instrumentation) allowed rigid polysegmental fixation for the first time [6]. Hook pullout and rostral-caudal end failure were constant problems, however [7,8]. Wiring and hook constructs allowed for correction of scoliosis and translational deformity [9] but were reported to be inadequate for rotational correction because of the lack of torque necessary for triplanar correction [8,10–12]. Modern pedicle screw instrumentation now provides rigid segmental fixation far surpassing that of previous techniques and

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tools. Additionally, because the pedicle screw traverses all three columns of the spine (anterior, middle, and posterior), it provides the strongest possible segmental fixation, thus allowing for segmental manipulation in three dimensions, including rotation, for three-dimensional correction [11,13]. The strength of the pedicle screw allows for enough torque to be applied to the spine in all three planes as it is realigned.

Retrospective data support the superiority of segmental pedicle screw instrumentation versus (1) hook constructs and (2) pedicle screws inserted in a hook pattern [8,14,15]. Major curve correction was 55% with hooks, 66% with hook-pattern screws, and 65% to 72% with segmental screws, with loss of correction of 6%, 2%, and 1% to 3%, respectively [8,16]. Compensatory curve correction was 57% with hooks, 67% with hook-pattern screws, and 70% with segmental pedicle screws [8]. In patients with hypokyphosis, all showed significant improvement, with best restoration achieved using segmental screws [8].

Supplementing segmental instrumentation are segmental release techniques that allow for increased mobility of the spine at a particular segment to aid in reduction of deformity [17,18]. Such techniques include facetectomy (Smith-Peterson osteotomy), pedicle subtraction osteotomy, and spondylectomy. Interbody release (discectomy) by means of anterior or posterolateral approaches are also used. Such mobilization maneuvers allow for untethered and unrestricted correction of spinal deformities and are addressed in other articles in this issue.

Rod rotation versus rod translation

The intraoperative correction of scoliosis using pedicle screw systems is achieved by applying (1) rod rotation or (2) rod translation maneuvers. Rod rotation was initially described with Cotrel-Dubousset instrumentation using hooks or pedicle screws [6,19,20]. The rod rotation maneuver consists of the following:

1. Placing a preshaped rod into the hooks or screws on the concave side of a curve (see Figs. 1–3 in the article on derotation of the spine by Shah elsewhere in this issue)
2. Locking the rod only at the proximal and distal ends as points of fixation
3. Rotating the rod apex in the direction of correction by up to 90° (anteromedial for lordosis or posteromedial for kyphosis; see Figs. 5 and 6 in the article on derotation of the spine by Shah elsewhere in this issue)
4. Locking the remaining segmental hooks or screws to the rod while holding it in its new "derotated" position (see Figs. 3 and 7–9 in the article on derotation of the spine by Shah elsewhere in this issue)

In theory, the instrumented spine follows the rod through the pull of the intermediate hooks or screws and is derotated, such that scoliosis is converted to "normal" thoracic kyphosis or lumbar lordosis Fig. 1 [6,21,22]. Modifications to rod rotation include direct vertebral rotation [3], which uses the pedicle screws themselves, as opposed to the rod, to derotate the spine by directly manipulating the instrumented segments in the same direction as rod rotation.

Rod translation was popularized in the 1990s [19]. The rod translation maneuver obtains scoliosis reduction by means of the following:

1. Fixing a rod in normal alignment at the rostral and caudal ends to prevent dislodgment but allow sliding
2. Gradual alignment of the intermediate instrumented vertebrae toward the rod using various instruments, such as the "persuader"
3. Fixing and locking individual segments to the rod as they are translated or "persuaded" as the final correction is obtained

The instrumented spine is sequentially aligned with the rod through the torque and pull applied by the persuader or translating device, achieving incremental triplanar correction at each segment [19,21]. It is important to recognize that these techniques are primarily indicated for flexible curves and that fixed curves may not reduce unless release procedures are performed. Determination of flexible and inflexible structural curves requires specialized radiographic studies with specific comparative measurements, as discussed in elsewhere in this issue.

With both techniques, further correction is obtained by using compression, distraction, and in situ bending maneuvers for final adjustment before locking of the construct [23]. Compression between adjacent screws reduces residual convex curves, whereas distraction between adjacent screws further opens residual concave curves. In situ bending aids in further hypnotic or lord tic correction as needed.

Which of these two techniques is optimal for scoliosis correction is debated in the current

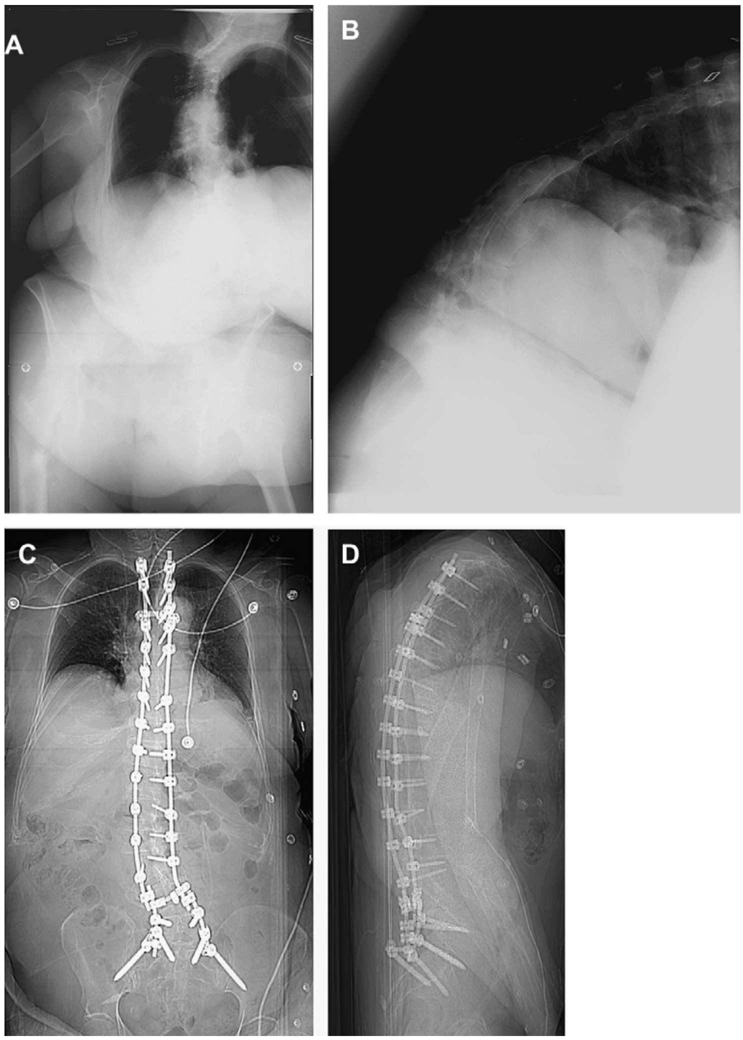

Fig. 1. Radiographs of a 63-year-old woman with severe kyphoscoliosis. Radiographs before surgery: anteroposterior (AP) view (*A*) and lateral view (*B*). Radiographs after surgery with correction using the rod rotation maneuver: AP view (*C*) and lateral view (*D*).

literature. Some experts believe that simple rod derotation confers significant coronal and sagittal correction but little effect on rotational correction [3,7,9]. Others have demonstrated the opposite, with 20% to 40% derotation correction [20,24]. Conversely, the benefit of rod translation [25] over rod rotation has not clearly been demonstrated in radiographic and clinical studies, and some even show that correction of major thoracic curves is less with translation than with rotation [12]. Recent comparative studies have concluded that both techniques produce significant three-dimensional correction of scoliotic deformities and are equivalent [1,21]. The decision to use rod rotation, translation, or a combination of both should be made by the surgeon according to personal preference, experience, and comfort [21,26].

Summary

Modern deformity correction depends on segmental instrumentation with pedicle screws. Rotation and translation maneuvers allow for triplanar correction with debatable advantages and disadvantages over each other. Additional tools and techniques should be applied to help achieve the most balanced results in the safest possible way.

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