ARTIGO DE ATUALIZAÇÃO

Surgical decision making in adolescent idiopathic scoliosis: double curve patterns

Decisão cirúrgica na escoliose idiopática do adolescente: dupla curva

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ABSTRACT

The principle curve pattern that remains the most controversial in terms of selection of fusion levels and confusing in the potential for post-operative decompensation is the double curve patterns, despite the significant progress of the implants. The determination of fusion levels and instrumentation of adolescent idiopathic scoliosis correction are discussed, emphasizing the double curve patterns, along with the implant development for the surgical treatment of this vertebral deformity.

KEY WORDS: scoliosis, spinal fusion, orthopedic fixation devices, arthrodesis

Despite advances in scoliosis surgical treatment, the principle curve pattern which remains the most controversial in terms of selection of fusion levels and confusing in the potential for post-operative decompensation remains the double curve patterns (King-Moe II, Lenke 1 C); structurally significant thoracic curves along with similarly significant albeit typically more flexible lower lumbar curves. In the era of Harrington rod instrumentation, lower lumbar curves felt to be significant were commonly fused down to as low as the fourth lumbar vertebral body. Coronal plane decompensation was rarely an issue, however, anchoring the instrumentation as low as L4 left few mobile disc spaces unfused: the subsequent risk of degenerative spondylosis and flat back phenomena are well documented.

In 1983 the King Classification (King et al.) was introduced as a means of determining which aspects of the adolescent scoliotic spine required fusion and instrumentation. This proved to be the first such attempt at such an inclusive classification and has been widely used to this day. It must be remembered, however, that the King classification was one primarily suited for thoracic curves being treated with Harrington type instrumentation; single rods with distraction hooks superiorly and inferiorly (Figure 1).

Figure 1
A King-Moe Type I scoliosis treated with 2 Harrington rods with hooks set in distraction
In 1984, Cotrel and Dubousset (C-D) introduced their instrumentation system based on multiple points of fixation for hooks and dual rods and revolutionized the treatments of idiopathic scoliosis (Figure 2). Over the next two decades comparable systems based on similar principles of multiple sites of fixation of rigid instrumentation, evolved (Isola® Depuy - Acromed Rayham, MA, USS® Synthes Inc. Paoli, Pa, Synergy® Cross Medical Irving, CA). With this newer technology, the rules and guidelines for treatment, including levels of instrumentation, came to change from those used previously with Harrington instrumentation. Shorter fusions were attainable now, but unfortunately with this came previously unseen problems especially those seen with decompensation (Figure 3).

### Figure 2
Thoracolumbar curvature treated with Cotrel-Dubosset posterior instrumentation

In 1988, with the introduction of the Isola system, as well as in 1991, with the introduction of the USS scoliosis technique by Aebi et al. (USS) the derotation maneuver of CD was abandoned and replaced with what was felt to be a more biomechanically efficient means of correction, that of coronal plane translation. Since then, the incidence of post-operative coronal plane decompensation has diminished somewhat, but remains a serious risk, nonetheless. Muschik et al. compared rod rotation maneuvers with translation techniques and found substantially less coronal plane decompensation postoperatively using translation correction.

During the 1990s, the use of pedicle screws increased dramatically and has been found by many authors to provide not only better correction than similar constructs using hooks, but as well may actually save even more levels in the distal lumbar spine. However, despite these advances, issues with decompensation may still persist. Pedicle screws do provide more rigid fixation than hooks, however, the same biomechanical principles of curve correction persist and must be acknowledged. Large lumbar curves with significant lateral apical displacement, and those with significant fractional lumbosacral curves seem to be the most difficult cases.

It is also important to understand a lumbar curve’s natural history, i.e. its potential for worsening if left untreated. Lenke et al. evaluated their experience with C-D and concluded that if the rotation of the lumbar curve magnitude or deviation of the apical vertebra to that of the thoracic spine was greater than 1.0, then both curves should be fused. If less then 1.0, then selective fusion if only the thoracic curve is possible.

Another key to the lumbar curve’s ability to spontaneously correct and maintain balance can be found in the fractional lumbosacral hemicurve from L4 to the sacrum. Richards reviewed 24 patients with King III curves treated with selective thoracic fusion, all with large lumbar curves greater than 40°. The obliquity of L4 to the sacrum averaged 14° pre-operatively and remained so post-surgical with only 41% correction of the lumbar curve. Their conclusion was that some lumbar curves inability to correct could be found in the rigidity inflexible lumbosacral portion of the spine. Schwender and Denis reviewed 50 similar patients and similarly found many patients decompensated post-operatively because of rigid lumbosacral curves (Figure 4). Thus, the lumbosacral segment must always be assessed pre-operatively: If rigid and unable to correct on side bending, then careful correction (less correction) of the thoracic curve must take place so as to allow the lumbar curve to maintain overall coronal balance (Figure 5).
Figure 4
(A) AP and lateral views demonstrating a King-Moe Type I curvature with significant deviation of the lumbar apical segment laterally and an oblique take-off at the lumbosacral junction. (B) Left and right side-bending films demonstrating the correct ability of two curvatures. Note that even on right side bending the stiff lumbosacral and curve fails to correct completely. (C) Post-operative AP and lateral views showing correction of the scoliotic curvature. However, due to the stiff lumbosacral fractional curve, the post-operative PA film demonstrates imbalance and post-operative decompensation.

Figure 5
(A) AP and lateral radiographs of a 15 year old boy with a 50° right thoracic curvature. (B) Left and right side bending radiographs demonstrate the relative stiffness of the thoracic curvature correcting only to 29°. Over correction of this curve could thus result in potential coronal plane imbalance. (C) Relative under correction of the thoracic curve maintains overall sagittal balance.
Thus, while newer techniques may allow greater correction of the thoracic curve, it still remains an intellectual exercise to determine how or how not to include the more caudal lumbar curve.

The Lenke Classification\(^6\) (Table 1A, 1B, 1C) was introduced in 2000 in an attempt to provide a more sophisticated all inclusive classification system taking into account the influence of these modern surgical techniques. It is a comprehensive, albeit complex guide to the characterization of all of (or all of) scoliotic curves. It is made up of three principle subparts: A. the curve type, B. a lumbar modifier which is designed to describe the degree of lateral translation of the apex of a lower lumbar curve from the mid-sacral line, and C. a thoracic or sagittal modifier which reflects the degree of thoracic kyphosis or hypo-kyphosis.

Table 1A - Description of Curve Types

<table>
<thead>
<tr>
<th>CURVE TYPE</th>
<th>PROXIMAL THORACIC</th>
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<tbody>
<tr>
<td>1</td>
<td>Nostructural</td>
</tr>
<tr>
<td>2</td>
<td>Structural</td>
</tr>
<tr>
<td>3</td>
<td>Nostructural</td>
</tr>
<tr>
<td>4</td>
<td>Structural</td>
</tr>
<tr>
<td>5</td>
<td>Nostructural</td>
</tr>
<tr>
<td>6</td>
<td>Nostructural</td>
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</tbody>
</table>

Table 1B - Description of Curve Types

<table>
<thead>
<tr>
<th>LUMBAR SPINE MODIFIER</th>
<th>CSVL TO LUMBAR APEX</th>
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<tbody>
<tr>
<td>A</td>
<td>CSVL between pedicles</td>
</tr>
<tr>
<td>B</td>
<td>CSVL touches apical body(ies)</td>
</tr>
<tr>
<td>C</td>
<td>CSVL completely medial</td>
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</tbody>
</table>

Table 1C - Description of Curve Types

<table>
<thead>
<tr>
<th>THORACIC SAGITTAL PROFILE T5-T12</th>
<th></th>
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<tbody>
<tr>
<td>(hypo)</td>
<td>&lt; 10°</td>
</tr>
<tr>
<td>N (normal)</td>
<td>10° - 40°</td>
</tr>
<tr>
<td>+ (hyper)</td>
<td>&gt; 40°</td>
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Synopsis of three necessary criteria for curve classification, CSVL = center sacral vertical line

Eule et al.\(^7\) presented their work at the most recent gathering of the Scoliosis Research Society, from a multicenter study of idiopathic double curves wherein the lumbar curves were larger than 40°. They included 38 patients, all fused solely in the thoracic spine, 31 of that were treated by an anterior approach and seven whose spines were selectively fused posteriorly. The concept of this study was to see whether selective thoracic fusion\(^7\) still applies with large lumbar curves. The anterior fusion was a single rod and the posterior instrumentation were dual rods using hooks with or without screws as a distal foundation. Two of the seven patients (28%) treated posteriorly had a Lenke C lumbar modifier wherein the apical vertebral body was completely translated lateral to the mid-sacral line and nine of the 31 (29%) treated anteriorly had a similar lumbar pattern. Their findings were similar: Primary thoracic curve corrections, regardless of the surgical approach and the degree of spontaneous lumbar curve correction, were similar. They did, however, find that those treated posteriorly showed significantly greater degrees of coronal plane imbalance postoperatively, (p=0.05) than did those treated with an anterior surgical approach.

With our present knowledge and experience, our recommendations for treating the lumbar curve with a primary thoracic curve superiorly will be as follows: With lumbar A modifiers to the curve -such as the old King 3 right thoracic curve, or Lenke 1A -either an anterior or posterior spine fusion would appear to be adequate (Figure 6). Evidence would suggest that an anterior approach may carry with it the possibility of saving distal fusion levels when compared with posterior spine fusions\(^14\). In addition, evidence would suggest that the natural history of the unfused lumbar curve i.e. degree of spontaneous correction and maintenance of that correction, following an anterior approach may also be somewhat more favorable than those whose thoracic curves were treated with posterior hook rod instrumentation\(^8\). The natural history of the unfused lumbar curve following posterior thoracic spine fusion instrumented with pedicle screws has not yet been documented, yet anecdotal evidence may also suggest it to be more favorable than that seen with primarily hook and rod systems.

With most lumbar B and some C modifier type curves it would appear that the following seems to be true: If the patient presents in overall coronal balance (i.e. the C7 vertical plumb line bisects or nearly bisects the sacrum), careful thoracic fusion is probably warranted. This would apply to most B and some C modifier curves. One must always need to take into account however, the degree of flexibility of the lumbar spine and especially the
lumbosacral hemicurve i.e. overzealous correction of a thoracic curve in a setting of a rigid lumbar scoliosis which fails to spontaneously correct on its own may leave the patient seriously decompensated to the left. Finally, those with lumbar C modifiers wherein the patient begins out of balance in the coronal plane, extension of the fusion down to such a level that the lumbar curve is controlled and corrected seems to be the advised (Figure 7). The actual caudal endpoint is frequently dictated by the degree and rigidity of the lumbosacral hemicurve; i.e., the more rigid the hemicurve, or the more severe the obliquity of L4 or L5, the further caudal the fixation should extend so as to control the coronal plane balance. Pedicle screws may enable one to save levels when compared with hook rod systems due to its ability in three dimensions to control the last instrumented vertebral body and horizonalize it as best possible relative to the sacrum. However, despite the mechanical advantages of pedicle screw fixation, no data as yet exists that would suggest that even this will allow us to selectively fuse the thoracic spine of a coronally out of balance spine with a structurally significant lumbar curve.

**Figure 7**
A double curve pattern with a Lenke C modifier within the lumbar curve wherein the patient begins out of balance in the coronal plane. With this in mind the fusion is extended distally to include the lumbar curve with overall correction of the coronal plane imbalance.

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**REFERENCES**