The biomechanics of cervical spine deformity correction

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ABSTRACT
This article addresses basic concepts in the biomechanics of cervical deformity correction. We highlight the principles of deformity correction, followed by a discussion of surgical strategies, including ventral, dorsal and combined approaches. We emphasize the ventral approach to the correction of postsurgical cervical kyphosis.

KEYWORDS: cervical vertebrae, kyphosis, biomechanics

INTRODUCTION
The development of cervical deformity, such as kyphosis, may be secondary to advanced degenerative disease, trauma, neoplastic disease, or postsurgical changes. Cervical kyphosis may develop after either ventral or dorsal approaches. After ventral cervical surgery, kyphosis may result from pseudarthrosis or the failure to restore adequate lordosis. Following dorsal surgery, kyphosis may develop and progress in response to disruption of the natural stabilizing structures, such as the tension band of the dorsal cervical spine.

PRINCIPLES OF DEFORMITY CORRECTION
Applying the basic deformation correction component forces (distraction; three point bending; tension-band fixation; and fixed, non-fixed, and applied moment arm cantilever beam fixation) to the spine, either alone or in combination,

provides a variety of mechanisms for simple and complex deformity correction. Five additional factors, however, must also be considered:

1. Spine deformations are frequently multisegmental. Therefore, the correction strategies must be applied to multiple spinal segments.

2. The coupling phenomenon, which results in off-axis complex deformities, often complicates the situation. It consists of a motion that occurs along or about an axis of the Cartesian coordinate system obligating another motion (or deformation) along or about another axis. Thus, correction of the deformity should ideally include the consideration of such complex three-dimensional factors.

3. The manner in which the spine bears loads, particularly axial loads, is of significant relevance. The surgeon should consider the load-bearing axis (neutral axis) in this regard (Figure 1). In the normal cervical spine, the load-bearing axis is located in the dorsal region of the vertebral bodies. This is exaggerated if the spine contour is exaggerated. For example, in extension, the load-bearing axis passes even further dorsally in the cervical region, thus explaining why axial loads applied while the spine is extended result in significant dorsal element (facet joint) loading.

4. Attention must be paid to the concept of spinal (sagittal) balance. The spine indeed seeks a balanced posture, with the maintenance of a generous, but not excessive cervical lordosis. The maintenance or achievement of spinal balance should be a high priority in the decision making process.

5. Implant length must be sufficient to apply the necessary bending moment to the spine. However, it must not be so long that it creates excessive spinal stiffness, immobility or excessive stress on adjacent segments.

**CORRECTION STRATEGIES**

Cervical spine deformity correction strategies are different than those used in other regions, mainly due to the ease of surgical access of the ventral and dorsal aspects of the cervical spine and the presence of relatively poor fixation points, among other factors.

**CORONAL PLANE CERVICAL SPINE DEFORMITIES**

Coronal plane cervical spine deformity is uncommon. Hence, concave distraction and convex compression or the use of derotation are uncommonly required in the cervical spine. Both can be applied from a ventral or dorsal approach. The employment of rod-screw constructs to cervical spine surgery has facilitated the use of these strategies.

**SAGITTAL PLANE CERVICAL SPINE DEFORMITIES**

Sagittal plane cervical spine deformities usually consist of either kyphosis, subsidence, or translational deformities (spondylolisthesis). They conversely are relatively common.
CERVICAL SPINE KYPHOSIS AND SUBSIDENCE

Kyphotic cervical spine deformities are a common manifestation of the spondylotic process. They often accompany and contribute to cervical spondylotic myelopathy. This aging process of the cervical spine first involves the loss of ventral disc interspace height, followed by vertebral body height loss (subidence). This process is self-propagating because of the increasing length of the ventrally applied moment arm resulting from the repetitive application of axial loads. This creates an increasingly large bending moment that tends to exert increasingly greater adverse effects on spine contour (i.e., progressive kyphosis; Figure 2).

SURGICAL STRATEGIES

Cervical spine kyphosis can be approached ventrally, dorsally, or via a combined approach. Ventr...