Is Cervical Sagittal Imbalance an Independent Risk Factor for Adjacent Segment Disease After Multilevel Fusion?

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Introduction: Adjacent segment disease (ASD) in the cervical spine refers to the development of new radiculopathy or myelopathy of a spinal segment superior or inferior to a previous fusion. The etiology of ASD remains controversial, although clinical and basic science studies suggest it may be multifactorial. A recent review found low-grade (level III) evidence that postsurgical sagittal imbalance may increase the risk for ASD. Forward position of the head relative to the shoulders, assessed radiographically using the horizontal offset distance between C2 and C7 (C2-C7 SVA), is a measure of global cervical balance (Figure 1a). Kyphotic alignment of cervical segments, caused by malaligned fusion, as well as high sagittal inclination of the T1 vertebra secondary to thoracic hyperkyphosis or lumbopelvic malalignment can cause non-physiologic values of C2-C7 SVA exceeding normative values (> 2cm). Figure 1(a) shows the postoperative radiograph of a 75 year-old female with spondylotic myelopathy who underwent anterior decompression and C3-C7 fusion in poor sagittal alignment (excessive C2-C7 SVA). Figure 1(b) shows the development of ASD at C7-T1, 6 years following the surgery.

In this controlled laboratory study, we measured the effects of increasing C2-C7 SVA values on disc loading in the segment adjacent to 2- and 3-level cervical fusions using a previously reported laboratory model of cervical sagittal imbalance [1]. We assessed whether the presence of cervical sagittal imbalance is an independent risk factor for increasing the mechanical burden on the disc adjacent to cervical multilevel fusions during activities of daily living and may therefore contribute to the risk of adjacent segment degeneration.

Methods: Five human cadaveric cervical spines (Occiput-T1; age: 59.0±4.6) were tested first in the native intact state and then after laminectomy and posterior instrumentation across C4-C6 and C3-C6 to simulate 2-level and 3-level fusions, respectively. The T1 vertebra was anchored to a translating base. The occiput was free to move vertically but its angular orientation was constrained to ensure horizontal gaze, regardless of simulated imbalance [1]. A 5kg mass was attached to the occiput to mimic head weight. The magnitude of C2-C7 SVA was increased and motions of C1-C7 vertebrae were measured to
document postural consequences of sagittal imbalance. Intradoscal pressures (IDP) at the C6-C7 disc space below the fusion were analyzed to calculate the post-fusion to pre-fusion IDP ratio as a function of increasing C2-C7 SVA.

**Results:** In this model, as C2-C7 SVA was increased while maintaining horizontal gaze, the C4-C7 segments flexed while C0-C2 segments extended. Consistent with increasing segmental flexion, the IDP in the intact C6-C7 segment increased with increasing SVA (Figure 2, dashed line). After 2- or 3-level fusion of the mid-cervical segments, the C6-C7 segment had to flex even more in order to accommodate a given value of C2-C7 SVA, thereby resulting in increased IDP in the segment below the fusion for the same SVA value (Figure 2, solid line). The ratio of post-fusion to pre-fusion IDP at the C6-C7 disc was greater than 1.0, indicating increased disc pressure at the adjacent disc following fusion for a given value of C2-C7 SVA (Figure 2). Notably, the IDP ratio increased with increasing SVA magnitude ($R^2=0.47$, $p<0.01$) (Figure 3), suggesting an independent role of C2-C7 SVA in increasing intradiscal pressure below a fusion.

**Discussion:** This is the first study establishing a causative relationship between sagittal imbalance and increased disc loading below a multilevel cervical fusion. The study demonstrated that the compensatory increased flexion below a fusion, which develops in the presence of an increased SVA, leads to higher disc loading. While a direct link between such increased disc loading and radiographic or clinical degeneration has not been established, it would seem likely that sagittal imbalance plays an independent role in exacerbating adjacent disc pathomechanics after multilevel fusion, such as that seen in the clinical case shown in Figure 1.

**References:**
1. ORS annual meeting, New Orleans, LA 2014.

**Significance:** Cervical sagittal imbalance arising from regional and/or global spinal sagittal malalignment plays an independent role in exacerbating adjacent disc pathomechanics after multilevel fusion and should be addressed during surgical planning.
Figure 1 (a) 75-year-old female with spondylotic myelopathy. Underwent anterior decompression and C3-C7 360° fusion in 2001. Note: excessive C2-C7 SVA.
(b) C7/T1 severe ASD 6-years later

Figure 2

Graph showing the relationship between change in C2-C7 SVA (mm) and C6-C7 disc pressure (MPa). The graph compares intact and C4-C6 fusion conditions.
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Figure 3

2- & 3-level Decompression & fusion

Disc Pressure Ratio vs. Change in SVA (mm)