Pre-Operative Patient-Specific Factors Predict the Change in Adjacent Segment Range of Motion 3 Years after Anterior Cervical Discectomy and Fusion

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INTRODUCTION: Anterior cervical discectomy and fusion (ACDF) remains the most common surgical treatment for cervical radiculopathy and myelopathy, with over 150,000 procedures performed in the United States annually [1]. Although ACDF has good short-term outcomes, approximately 25% of patients develop symptomatic adjacent segment disease (ASD) and require reoperation within 10 years [2,3]. The etiology of ASD remains unclear. Previous studies have identified associations between ASD and genetics [4], age [5,6], BMI [7], psychiatric history [6], and preoperative disc degeneration [5,7-10]. These studies suggest that preoperative disc degeneration, characterized by disc bulge and loss of disc height, has the strongest association with development of ASD [5,7-10, 11]. However, few studies have attempted to correlate these patient factors with mechanical changes in the spine to explain the development of ASD [6-8, 12]. The purpose of this study was to identify patient factors that predict changes in adjacent segment kinematics three years after ACDF. Based upon our findings from one-year post-surgical data [17], we hypothesized that preoperative disc height and disc bulge would be the primary predictors of change in adjacent segment range of motion (ROM) three years after ACDF.

METHODS: Patients who were scheduled to receive either one-level (C56 or C67) or two-level (C456 or C567) ACDF provided written informed consent prior to participating in this prospective IRB-approved study. Pregnant women and patients with any injury or disease interfering with spine function were excluded. Participants performed three trials each of full ROM flexion-extension and axial rotation while synchronized biplane radiographs were collected at 30 images/sec. Tests were completed before (PRE) and 3 years after (3YR-POST) one-level or two-level ACDF. CT scans of the cervical spine (C1-C7) were acquired PRE for each participant and used to create subject-specific 3D bone models. Digitally reconstructed radiographs were generated from the 3D bone models [13] and matched to the biplane radiographs using a validated volumetric model-based tracking technique with an *in-vivo* accuracy of 0.19 mm for tracking individual bone motion, 0.2 mm to 0.4 mm for measuring anterior and posterior disc height, respectively, and 1.1° or better for measuring rotation [14]. Six degrees of freedom (DOF) joint kinematics were calculated and filtered with a 4^{th} order Butterworth filter [15]. Total ROM at each motion segment and disc height were calculated using anatomic coordinate systems centered on each vertebral body with the vertical axis parallel to the posterior vertebral body [16]. Change in ROM was calculated as the difference between 3YR-POST and PRE ROM. Preoperative MRIs were evaluated to identify disc bulge [17]. Patient factors including age, sex, BMI, smoking status, diabetes, psychiatric history, presence of an inciting event, and length of symptoms were collected from medical records. Multiple linear regression was performed using the backward method to identify patient factors that predicted changes in adjacent segment kinematics with $p > 0.05$ set as the threshold for variables to be removed (SPSS 28.0). The relative importance of each predictor in the model was represented by the size of the standardized regression coefficient (β).

RESULTS: Data processing is complete for 33 of 65 participants that completed testing PRE and 3YR-POST (19F, 14M, mean age: 47.6±8.2 years, BMI: 32.7±6.4kg/m^2, 8 smokers, 5 diabetics, 12 history of psychiatric medication, 13 with an inciting event, and symptoms lasted 22.2±31.1 months before surgery). At 3YR-POST, flexion/extension ROM increased from PRE by 1.8±3.0° (range -4.3° to 9.1°) at the superior adjacent motion segment and by 2.0±4.4° (range -6.2° to 10.6°) at the inferior adjacent motion segment (Figure 1), while axial rotation ROM increased from PRE by 1.3±2.5° (range -4.2° to 6.6°) at the superior adjacent motion segment and by 1.9±2.7° (range -0.4° to 8.4°) at the inferior adjacent motion segment (Figure 1). Younger age (β=-0.596; p<0.001) and greater superior adjacent disc height (β=0.320; p=0.039) were predictors of increased superior adjacent segment flexion/extension ROM at 3YR-POST. Lack of superior adjacent disc bulge (β=-0.504; p=0.01), being a woman (β=-0.490; p=0.027), larger superior adjacent disc height (β=0.443; p=0.024), lower BMI (β=-0.424; p=0.042), and not having diabetes (β=-0.363; p=0.045) were predictors of increased superior adjacent segment axial rotation ROM at 3YR-POST. Use of psychiatric medications (β=0.697; p=0.011) and younger age (β=-0.594; p=0.023) were predictors of increased inferior adjacent segment flexion/extension ROM at 3YR-POST. Smoking (β=0.716; p= 0.009) was the only predictor of increased inferior adjacent segment axial rotation ROM at 3YR-POST.

DISCUSSION: This study found that, in general, increased adjacent segment motion 3 years after ACDF is predicted in younger, healthier individuals with healthier adjacent discs (no bulge, greater disc height), while decreased adjacent segment motion is predicted in older individuals with less healthy adjacent discs. The only exception being smoking predicted increased ROM at the inferior adjacent segment during axial rotation. These midterm results reflect the progression of disc degeneration proposed by Kirkaldy-Willis and Farfan, where disc degeneration progresses from the healthy state to an early instability (*i.e.*, more ROM), followed by late stabilization (less ROM) as degeneration progresses [18]. The results support our hypothesis that greater adjacent segment disc height and lack of disc bulge predict increased adjacent segment ROM three years after ACDF. However, in contrast to the one-year post-surgical data, this interim analysis of 3YR-POST data identified additional factors that predict changes in post-surgical adjacent segment ROM. These results are limited to the 3-year post-operative follow up time and the subset of data that has been analyzed. Continued follow-up data are needed to confirm these results persist long-term and pre-surgical pain should be considered when assessing the generalizability of results.

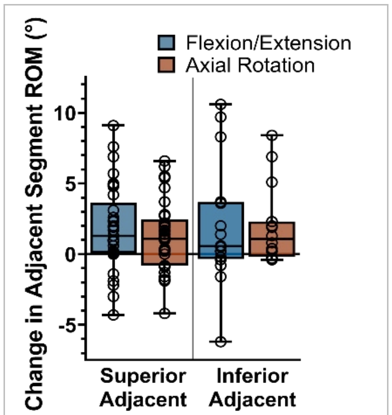

Figure 1: *Change in adjacent segment ROM from PRE to 3YR-POST. Box and whiskers indicate median and interquartile ranges, Circles represent data from each patient.*

SIGNIFICANCE: Surgeons may be able to use this patient-specific information to develop a more accurate prognosis for patients who require ACDF surgery.

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