Longitudinal Changes in Midrange Cervical Spine Kinematics After Anterior Cervical Arthrodesis

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INTRODUCTION: The etiology of adjacent segment pathology following anterior cervical arthrodesis remains controversial. In vitro studies consistently report that adjacent segment maximal range of motion (ROM) increases superior and inferior to cervical arthrodesis[1-3]. Previous in vivo results have been conflicting, indicating that maximal ROM may or may not increase superior and/or inferior to the arthrodesis[4-7]. These previous studies fail to evaluate midrange motion, which makes of the majority of activities of daily living[8,9]. Further, all previous reports focus exclusively on the planar flexion/extension motion and therefore no data exist to characterize adjacent segment motion during multi-planar head rotation. The objective of this study was **t**o compare maximal and midrange intervertebral ROM in asymptomatic control subjects and single-level arthrodesis patients longitudinally. It was hypothesized that maximal and midrange adjacent segment ROM would increase with time after surgery and that maximal and midrange adjacent segment ROM would be greater than ROM at the corresponding motion segments in similar-aged asymptomatic controls.

METHODS: Following Institutional Review Board (IRB) approval, informed consent was obtained from 8 single-level (C5/C6) anterior arthrodesis patients (1 M, 7 F; average age: 45±9 yrs.; age range: 37-56 yrs.; tested 7±1 months and 28±6 months post-surgery) and 6 asymptomatic controls of similar age (0 M, 6 F; average age: 47±6 yrs.; age range: 39-57 yrs.; 2 tests occurred 58±6 months apart). Participants performed dynamic full ROM flexion/extension and axial rotation while biplane radiographs were collected at 30 images/s. Three-dimensional vertebral positions were determined with sub-millimeter accuracy using a previously validated volumetric model-based tracking process that matched subject-specific bone models obtained from CT to the biplane radiographs[10]. Reflective markers were placed on the head and torso to determine global head ROM during each movement trial using an optical motion analysis system. The intervertebral ROM that occurred during the midrange of head motion (defined as ± 20° of head flexion/extension or head rotation from the neutral orientation) was determined for each dynamic movement trial. Previous research indicates that the vast majority of activities of daily living occur within this limited ROM[8,11,12]. The outcome variables were global head ROM and intervertebral maximal and midrange ROM during the flexion/extension and rotation movements. In cases of normally distributed data, paired t-tests were used to identify changes within subjects over time and independent-samples t-tests were used to identify differences between groups (control vs. arthrodesis) at the first and second test dates. In cases of non-normally distributed data, the Wilcoxon Signed Rank and the Mann-Whitney tests were used to test for differences within subjects and between groups.

RESULTS: On the first test date, global head ROM was significantly less in the arthrodesis group than in the control group during flexion/extension ($p = .041$) and rotation ($p = .018$). By the second test date, no significant differences in global head ROM were identified. Maximal flexion/extension and rotation ROM in adjacent segments were not significantly different between groups on either the first or second test date. On the first test date, no significant differences between groups were identified in terms of adjacent segment midrange ROM. On the second test date, midrange ROM was significantly greater in the superior adjacent segment of arthrodesis patients than in the C4/C5 motion segment of controls during flexion/extension ($p = .03$) (Figure 1) and rotation ($p = .05$) (Figure 2). Adjacent segment maximal ROM did not increase over time during flexion/extension or rotation movements.

DISCUSSION: This is believed to be the first in vivo study to assess adjacent segment effects during the midrange of motion. This longitudinal data indicates that C5/C6 arthrodesis appears to significantly affect midrange, but not end-range, adjacent segment motions. Information from midrange motion may provide more clinically and functionally relevant information than full ROM measurements due to the fact that the majority of daily activities do not require full ROM movements of the cervical spine[8,11,12]. Data from the present study suggests that if intervertebral adjacent segment motion in C5/C6 arthrodesis patients is compared to corresponding motion segments in asymptomatic controls over identical ranges of head motion, the adjacent segment motion is greater in arthrodesis patients. The topic of adjacent segment kinematics during midrange functional motions has not received nearly as much attention as end-range ROM, and is clearly worthy of future investigation given the high functional relevance of midrange motions. The results of this in vivo study contradict previous in vitro studies that indicated maximal adjacent segment rotational ROM increases after arthrodesis[1-3,13]. This discrepancy may be due to the inability of in vitro testing to replicate in vivo kinematics and due to incorrect assumptions made by in vitro test protocols[14].

SIGNIFICANCE: The effects of arthrodesis on adjacent segment motion may be best evaluated by in vivo studies that compare maximal and midrange adjacent segment motion to corresponding motion segments of similar-aged controls to determine if the adjacent segment motion is truly excessive.

REFERENCES: 1. Fuller, et al., 1998; 2. Cunningham, et al. 2010; 3. Eck, et al. 2002; 4. Park, et al, 2011; 5. Sasso, et al. 2008; 6. Kelly, et al., 2011; 7. Reitman, et al. 2004; 8. Cobian, et al. 2009; 9. Sterling, et al. 2008; 10. Anderst, et al., 2011; 11. Bible, et al., 2010; 12. Cobian, et al., 2013; 13. Schwab, et al., 2006; 14. Volkheimer, et al., 2015.

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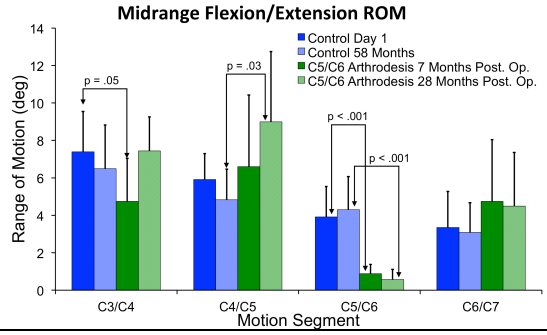

Figure 1: *Midrange intervertebral flexion/extension motion during ±20° head flexion/extension from neutral in controls (blue) and arthrodesis patients (green) on the first and second test dates. Error bars indicate ±1 SD. P-values are provided where significant differences were identified between groups and/or between test dates within a group.*

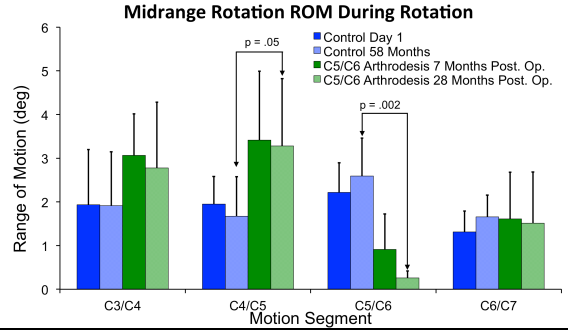

Figure 2: *Midrange intervertebral rotation during ±20° head rotation from neutral in control subjects (blue) and arthrodesis patients (green) on the first and second test dates. Error bars indicate ±1 SD. P-values are provided where significant differences were identified between groups and/or between test dates within a group.*