

# One- and two-level ACDF are not associated with adjacent-level bony foraminal narrowing three-years after surgery when compared to age-matched healthy controls

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**Disclosures:** None.

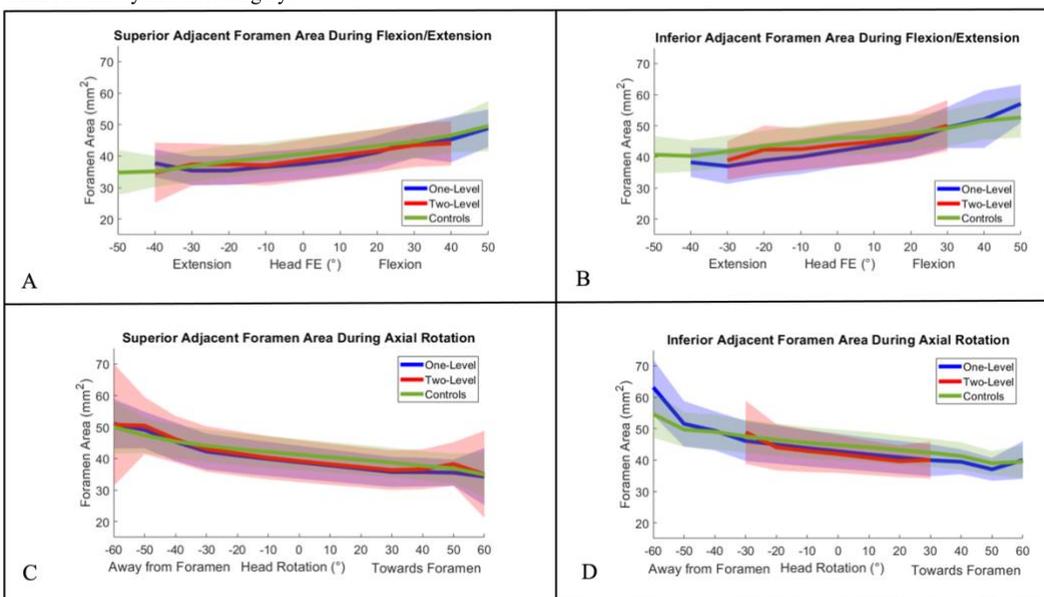
**INTRODUCTION:** Adjacent segment disease (ASD) is a common complication after anterior cervical discectomy and fusion (ACDF) involving degeneration of the spinal segments directly adjacent to the fused site<sup>1</sup>. One possible sequelae of ASD is neural foraminal narrowing that may result in radiculopathy<sup>2</sup>. Prior study has shown an association between smaller inferior adjacent segment foramen width and worsening long-term patient-reported outcomes after one-level ACDF<sup>3</sup> during head extension and rotation. However, it is unclear whether the adjacent-level foramen area of the surgical cohort differ compared to those of asymptomatic, age-matched controls throughout dynamic motion, which may provide further insight on changes attributed to altered biomechanics at the adjacent segment due to fusion. Furthermore, the effects of multi-level fusion on the adjacent-level foramen area remain unknown. This study aimed to compare the adjacent-level bony foramen area at three-years after one-level and two-level ACDF with those of asymptomatic, age-matched controls during dynamic flexion-extension (FE) and axial rotation (AR). We hypothesized that inferior adjacent-level foramen area of both surgical cohorts would be significantly smaller than those of controls throughout FE and AR three-years after surgery.

**METHODS:** All participants provided informed written consent to participate in this IRB-approved study. Surgical participants received a C456, C56, or C567 ACDF for progressive symptoms refractory to conservative treatment for myelopathy, radiculopathy, or myeloradiculopathy resulting from degenerative spondylosis, symptomatic cervical disc herniation, or symptomatic disc degeneration. All surgical participants completed pre-surgery and 3-years post-surgery testing. All control participants were healthy, asymptomatic individuals with no history of neck surgery, chronic neck pain or diagnosis of osteoporosis. Controls were age, sex, and BMI matched to at least one of the participants. During testing, all participants sat upright with their head in neutral position for a single static image, then performed 3 trials of full range of motion (ROM) FE of their head, followed by 3 trials of full ROM AR while synchronized biplane radiographs of the cervical spine were collected at 30 images/s for 3 seconds each trial. Three-dimensional vertebral motion was calculated using a previously validated model-based tracking technique that matched digitally reconstructed radiographs from subject-specific bone models (obtained from CT) to the radiographs. This model-based tracking technique has been validated *in vivo* to have a precision of 0.19mm or better for tracking individual bone position<sup>4</sup>. Head motion was synchronously recorded with the biplane radiography using optical motion capture using 4 markers placed on the head and 4 markers placed on the thorax. A previously developed algorithm for measuring neural foramen cross-sectional area was modified for this analysis by establishing a best-fit plane through four landmarks: superior-medial, middle, and superior-lateral edge of the inferior bone, and middle inferior pedicle surface of the superior bone<sup>5</sup>. The intersection of the best-fit plane with the 3D bone surface models defined the boundary of the neural foramen on each bone, and the boundary of the neural foramen was then used to calculate the cross-sectional area as the spine moved through the full ROM. Foramen area was interpolated to every 10° of head FE and AR and averaged across the three trials. Left and right-side regions were averaged at corresponding FE and AR angles. Linear mixed-effects analysis was used to assess differences in average foramen area between controls, one-level ACDF, and two-level ACDF at each 10° increment of FE or AR with significance set at  $p < 0.05$ .

**RESULTS:** 47 ACDF patients (20F, average age 48.4 years, average BMI: 31.8kg/m<sup>2</sup>) and 22 controls (10F, average age 47.6 years, BMI: 31.0 kg/m<sup>2</sup>) completed testing. The analysis included 7 C456, 21 C56, and 19 C567 arthrodesis patients. The superior and inferior adjacent foramen area of neither surgical cohorts differed significantly compared to those of asymptomatic controls throughout head FE (Figures 1A-B). Similarly, the superior and inferior adjacent foramen area of neither surgical cohorts differed significantly compared to those of controls throughout axial rotation three-years post-surgery (Figures 1C-D). The foramen area of neither adjacent-level differed significantly between groups pre-surgery throughout FE and AR.

**DISCUSSION:** The main findings were that the adjacent level bony foramen area after single- or two-level ACDF did not differ significantly pre- or post-surgery compared to those of age-matched controls throughout dynamic motion, consistent with our prior study showing similar non-significant differences one-year post-surgery<sup>6</sup>. These results suggest that ACDF may not be associated with adjacent-level bony foramen narrowing after surgery. The true cervical foramen area, however, may be reduced by additional soft tissue structures (e.g. disc) that were not captured in our bony foramen area measurements. Adjacent-level soft tissue alterations, such as ligament and facet joint hypertrophy, and disc degeneration as a result of altered adjacent-level biomechanics<sup>7</sup> may be more critical for symptomatic foraminal stenosis than bony foraminal changes.

**CLINICAL RELEVANCE:** One- and two-level ACDF are not associated with adjacent-level bony foraminal narrowing compared to age-matched healthy controls three-years after surgery.



**Figure 1.** A.) Superior and B.) inferior adjacent bony foramen three-years after surgery throughout FE. C.) Superior and D.) inferior adjacent bony foramen after surgery throughout AR.

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**ACKNOWLEDGEMENTS:** This work was supported by NIH Grant R01 AR069543 and NIH Grant UL1 TR001857.