INTRODUCTION:
Abnormal cervical spine motion may occur following anterior cervical disectomy and fusion (ACDF) surgery and result in excessive loading of the intervertebral discs, leading to disc degeneration. Intervertebral range of motion is a standard metric used to evaluate spine loading of the intervertebral discs, leading to disc degeneration. Intervertebral range of motion only describes the amount of motion, not the quality of motion. The instant center of rotation (ICR) has been proposed as a reliable, stable measurement of the quality of vertebral motion through which abnormalities could be explored. Characterizing the quality of motion may be important for analyzing changes in function due to pathology or surgical intervention.

Previous studies have determined a single, stationary ICR location at each level of the cervical spine using static radiographs collected at full flexion and extension, and by averaging ICR location from sagittal radiographs collected during slow movement. These analyses have been limited, however, in that a single point representing the average location of the ICR does not account for motion of the ICR during the dynamic flexion-extension cycle. Furthermore, there is currently no data describing the ICR in ACDF patients. This study aims to determine the ICR at C4-C7 during continuous flexion-extension movement in single-level ACDF patients and asymptomatic controls. It was hypothesized that there would be no difference in ICR following fusion.

METHODS:
Nine C5/C6 ACDF patients (47±8 yrs; 1M, 8 F; 7.0±1.2 mo. postsurgery) and eight asymptomatic subjects (45±7 yrs; 4 M, 4 F) performed continuous flexion-extension movements within a biplane x-ray system. Biplane x-rays were collected for 3 seconds at 30 frames per second during a full flexion-extension cycle. Subject-specific bone models derived from CT were input to a computerized tracking program that reproduced bone location and orientation in 3D space for each x-ray frame with sub-millimeter accuracy. The ICR of each vertebra relative to the immediately inferior vertebra was calculated for intervertebral rotations greater than 1.0° using the finite helical axis method for C4 through C7. Thus, the ICR was calculated approximately 40-50 times during each continuous flexion-extension cycle and interpolated at one degree increments of intervertebral rotation. ICR location was then averaged across all control subjects and ACDF patients, separately, and compared using t-tests. This protocol has been IRB approved, and all subjects underwent informed consent prior to participation.

RESULTS:
The ICR moves anterior as the subjects flex (moving from blue to red, in Figures 1 and 2), and posterior as they extend (moving from red to blue, in Figures 1 and 2). In all subjects, the ICR moved more cranial relative to the inferior vertebral body center when progressing from the C4 to C7 vertebral level.

In control subjects, the C4-C5 segment had a larger ICR anterior-posterior (AP) range than seen at lower levels (Figure 1). This ICR AP range was significantly larger in control subjects when compared to fusion patients (Table 1).

DISCUSSION:
Results agree with previous reports showing the ICR is located more cranial relative to the inferior vertebra as level progresses from C4 to C7.

Differences in adjacent segment ICR motion in ACDF subjects when compared to controls may imply altered mechanical loading during dynamic motion following fusion. This modified loading pattern may be detrimental to disc homeostasis. The results shown here provide the first in vivo evidence of altered quality of motion following fusion.


ACKNOWLEDGEMENT: This research was funded by grants from the CSRS and grant R03AR056265 from the NIH.

Table 1: ICR anterior-posterior range and superior-inferior location in control and fusion patients above and below the fused segment.