Interpreting Intervertebral Motion in the Cervical Spine During Flexion and Extension
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INTRODUCTION: One of the primary functions of the cervical spine is to facilitate and control motion of the head and neck. Abnormalities in this motion provide important diagnostic information. Flexion-extension x-rays are commonly used in clinical practice to help identify abnormalities in motion in patients with suspected cervical spine disorders. Interpreting these x-rays requires an understanding of both normal and abnormal motion. To help with this interpretation, many investigators have measured motion within the cervical spine of asymptomatic individuals and in patients with cervical spine disorders. The main focus of most studies has been rotation and shear between vertebrae. These data were recently summarized and provide clinicians with basic data on normal intervertebral motion. Intervertebral motion between vertebra may be more complicated than can be represented by intervertebral rotation and shear measurements alone, although whatever measurements are made must be easily acquired and interpreted in clinical practice. Additional information on normal intervertebral motion is clearly needed to help interpret measurements in patients. Only a comprehensive understanding of normal motion will allow the clinician to critically assess abnormal motion. The goal of this research is to provide additional insight into motion within the cervical spine of asymptomatic subjects.

METHODS: IRB approval to study 300 subjects was obtained through our institution. To date, videofluoroscopic studies have been obtained for 31 asymptomatic subjects as they performed maximum voluntary flexion and extension maneuvers. All subjects had no current neck pain and no history of cervical spine trauma, surgery, or chronic neck pain. After rehearsing the flexion and extension until it could be consistently performed, fluoroscopic images were obtained at 30 frames per second with an all digital 1024x1024 fluoroscopic imaging system. FDA approved software (KIMAX QMA, Medical Metrics, Inc) was used to track individual vertebrae and calculate intervertebral motion from the maximum flexion and maximum extension images. The software requires identification of anatomic landmarks in the first image, and then uses all of the radiographic information about each vertebrae to track the position of that vertebra in subsequent images. The software has been validated to be accurate to less than 0.5 degree rotation and 0.5 mm translation, with inter- and intra-
observer errors of approximately 0.45 deg. At each intervertebral level, the software calculates the rotation between vertebrae, the amount of displacement of the superior vertebra over the inferior vertebra (shear), and the change in distance between the anterior and posterior corners of adjacent vertebrae (disc displacement).

RESULTS: Measured intervertebral rotations were entirely consistent with results from previously reported studies, as summarized by Bogduk and Mercer. Rotation between C2 and C3 was significantly smaller (p < 0.001) than at all other levels (Figure 1). The difference in the amount of rotation between levels was less than 11 degrees in 95% of subjects, although differences as high as 19 degrees were found. The percent of the total rotation occurring at each level was smaller at C2-C3 than at the other levels, and the standard deviations in the percent rotation data were generally smaller than with the absolute rotation data. (Figure 2) Analysis of variance showed that shear between vertebrae was significantly (p << 0.001) different for the intervertebral levels. Shear between C3-C4, C4-C5, and C5-C6 were similar and greater (p< 0.014) then at C2-C3 and C6-C7 (Figure 3). During flexion and extension, the total maximum amount of displacement of the anterior and posterior disc was generally 1 to 2 mm (Figure 4). The change in posterior disc dimensions was generally 25 to 50% smaller then the change anteriorly, although there were substantial variations between individuals.

CONCLUSIONS: Data for the 31 patients in this abstract represent the initial effort to collect and analyze data for 300 asymptomatic individuals in order to establish an externally valid, quantitative database of normal intervertebral motion. In the larger study, several variables that may effect intervertebral motion will be analyzed (neck size, age, general activity level, etc). These variables may help explain the substantial variability measured within as well as between asymptomatic individuals. Our data suggest that current guidelines (< 3.5 mm) for normal intervertebral shear in the cervical spine should be lowered by about 1 mm for C2-C3 and C6-C7. In addition, because many patients with spinal disorders experience pain during flexion and extension, intervertebral motion may be smaller than normal at all levels. It may therefore be more useful to assess intervertebral motion at each level as a percent of total motion. In this study, the percent of total motion was between 15 and 25% for all levels below C2-C3, where the percent of total motion was between 7 and 20%. Finally, measurements of displacements at the anterior and posterior edges of the disc during flexion and extension may ultimately prove useful in assessing anterior or posterior soft tissue disruptions respectively. In this study, 1 to 2 mm of motion at the anterior and posterior disc space was found in asymptomatic subjects, with posterior motion generally being 25 to 50% smaller than anterior
disc space motion. These new data may help refine the clinician’s ability to interpret quantitative assessments of intervertebral motion.

REFERENCES:
Figure 3

Average Amount of Shear (mm)

C2C3 C3C4 C4C5 C5C6 C6C7

Figure 4

Change in Disc Height during Flexion and Extension (mm)

Ant Disc Post Disc

74