IN VIVO FLEXION AND EXTENSION CARPAL BONE KINEMATICS

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INTRODUCTION

Documentation of normal three-dimensional (3D) in vivo carpal kinematics is essential to the understanding of wrist and carpal mechanics and to provide unique insight into the effects of injury and treatment. It is also important to validate the wealth of cadaveric data, which is the only data base currently available. However, measuring 3D in vivo carpal kinematics is difficult due to the small size and tight articular spacing of the bones. Previous in vitro methods have used invasive techniques such as tracking radiopaque markers embedded in bones [e.g. 1,2]. These methods are technically demanding, and are not acceptable for in vivo studies.

To overcome these limitations, we developed an in vivo, non-invasive computed tomography (CT) technique to measure the 3D motions of the carpal bones. In this study, we report the motions of the capitate, scaphoid and lunate during wrist flexion and extension in male and female subjects.

MATERIALS AND METHODS

Both wrists of five healthy males and five healthy females (n = 20) were imaged in five wrist flexion positions (neutral, -30°, -60°, 30° and 60°) using a specially designed positioning jig. Institutional Review Board approval was obtained for all subject protocols. CT volume images (voxel size: (0.2-0.9) x 1 mm³) from the distal radius through the proximal metacarpals were acquired at each position. Cortical bone surfaces were extracted and registered to neutral [3]. Capitate, scaphoid and lunate motions were described relative to a radially-based orthogonal coordinate system [1]. 3D motions were described as a rotation about and translation along a unique helical axis of motion (HAM) axis. The error in this technique was estimated to be less than 2° rotation and 1.0 mm translation [3]. The intersection of the HAM axis with the sagittal plane was also calculated [4]. Radio-capitate motion was used as an indicator of wrist motion [1]. Gender differences in carpal volumes, HAM axis intersections with the sagittal plane, and rotations about the HAM axis were determined using Student’s t tests (Instat, Graphpad, San Diego, CA).

RESULTS

CT volume images for a total of 98 positions were successfully acquired and used for analysis. Capitate flexion did not correlate with wrist flexion, measured by a protractor on the positioning jig.

Intra-subject variations in carpal bone volumes were less than 7% for a fixed resolution range (0.7-0.9 mm/pixel). Male carpal bones were significantly larger than female carpal bones (p < 0.05). Scaphoid

Figure 1. Scaphoid and lunate volumes plotted verses capitate volume. Error bars indicate variations in a subject's bone volume over five CT volume images.
and lunate volumes increased linearly with capitate volume (Figure 1).

Figure 2. Mean and standard deviation of HAM intersections with the sagittal plane for the full range of capitate flexion-extension motion in males (square) and females (triangle). Data (mm) is plotted on a lateral projection of a single subject’s capitate (light gray) and radius (dark gray) in neutral position.

The HAM axis intersections with the sagittal plane were significantly more distal in males than in females for the capitate (Figure 2) and scaphoid. Rotations out of the sagittal plane were generally less than 10%. Translation along each HAM axis was less than 3.0 mm.

Scaphoid and lunate rotations were not different in males and females at 30° and -30°. Scaphoid rotation closely tracked capitate rotation in extension, but rotated approximately 75% of the capitate rotation in flexion. Lunate rotation was approximately 75% of capitate rotation in extension, but was only 50% of capitate rotation in flexion (Figure 3).

DISCUSSION

This study documents in vivo 3D scaphoid and lunate kinematics in wrist flexion and extension. Scaphoid and lunate rotation patterns suggest that male and female carpal motion mechanics are not significantly different. Differences in male and female HAM axis locations appear to be related to differences in carpal volumes.

The scaphoid and lunate tracked more closely with the capitate than previously reported in cadaveric studies, possibly indicating less intercarpal motion in vivo than in vitro [e.g. 1,2].

These results are limited to capitate, scaphoid and lunate kinematics in wrist flexion and extension. In addition, the images were acquired statically and required extensive computation time. Further research on the complete 3D motion of all of the carpal bones is underway.

REFERENCES

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