Dynamic (4D) Computed Tomography of the Wrist : Proof of Feasibility in a Cadaveric Model

Shian Chao Tay[1,3], Andrew N. Primak[2], Joel G. Fletcher[2,4], Bernhard Schmidt[5], Kimberly K. Amrami[4], Cynthia H. McCollough[2], Richard A. Berger[1]

[1]Biomechanics Laboratory, Mayo Clinic College of Medicine, Rochester, MN; [2]CT Clinical Innovation Center, Mayo Clinic College of Medicine, Rochester, MN; [3]Department of Hand Surgery, Singapore General Hospital, Singapore, Singapore; [4]Department of Radiology, Mayo Clinic College of Medicine, Rochester, MN; [5]Siemens Medical Solutions, Forchheim, Germany

Introduction: High resolution real-time 3D imaging of the moving wrist may provide novel insights into the pathophysiology of dynamic joint instability, in particular of the carpus. The purpose of this work was to assess the feasibility of using retrospectively-gated spiral computed tomography to perform dynamic (4D) imaging of the moving wrist joint in an interdisciplinary collaborative effort.

Materials and Methods: A cadaver forearm from below the elbow was mounted on a custom motion simulator which performed periodic radioulnar deviation of the wrist at 30 cycles per minute. (Figure 1)

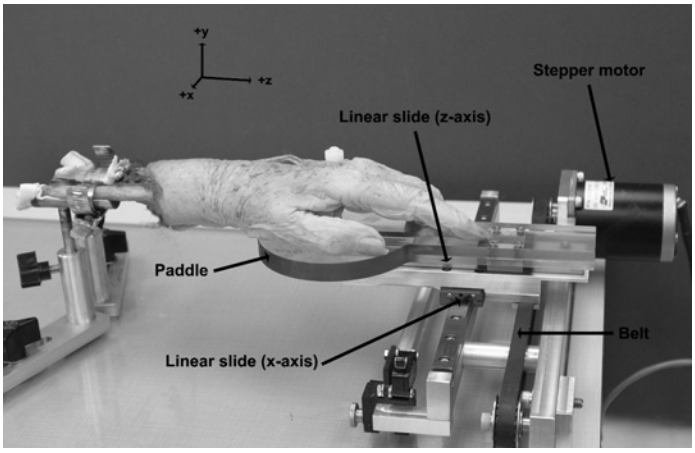

Figure 1. The cadaveric wrist mounted on the custom made motion simulator which is controlled by a laptop.

An electronic trigger from the motion simulator provided the "electrocardiogram" (ECG) signal required for gated reconstructions. The wrist was scanned on a 64-slice CT scanner using a retrospectively-gated CT protocol. (Figure 2)

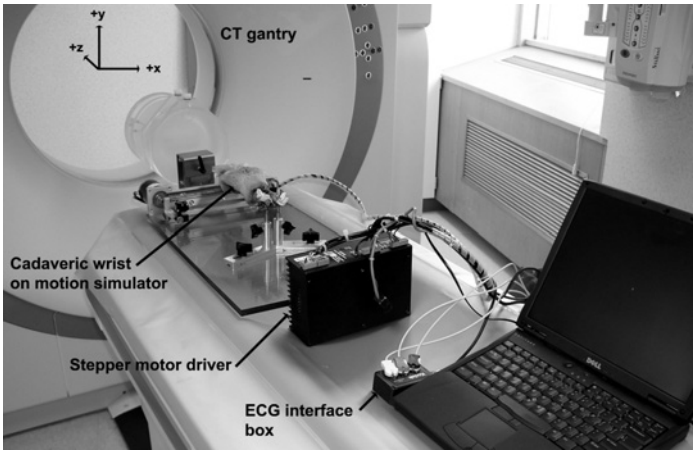

Figure 2. The setup used for 4D CT scanning.

The first condition was scanned with the wrist moving in periodic radioulnar deviation. This condition was designated the 4D condition. The second scan, designated the 3D condition, served as a control where the wrist was precisely moved to four designated static positions and scanned. The image data from both conditions were reconstructed with slice widths of 0.6 mm, 150 mm field of view, and a sharp reconstruction kernel of B70f. The voxel size was 0.29 mm (x), 0.29 mm (y) x 0.6 mm (z). Two independent observers compared the image quality of the 4D and 3D conditions. The motion of the scaphoid and lunate bone during 4D motion was also measured and quantified.

Results: Dynamic (4D) CT scans of the moving wrist demonstrated excellent image quality of the 4D images, comparable to the 3D images, at the extremes of radial and ulnar deviation. In all phases, carpal joint spaces were well resolved. (Figure 3).

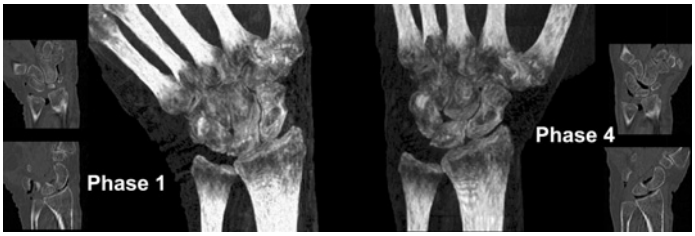

Figure 3. Images from the 4D condition showing excellent image quality of the carpal bones. Carpal joint spaces are well resolved.

A hysteresis effect in the scaphoid and lunate bone motion was quantified during 4D scanning.

Discussion: The fast temporal resolutions in current state-of-the-art CT scanners have allowed the development of an imaging technique that permits imaging of the wrist joint during motion. This technique is potentially an important tool for the diagnosis and assessment of dynamic carpal instabilities. The advantage of 4D CT over real-time fluoroscopy is the ability to provide high-resolution 3D visualizations of carpal bone motion which can be quantified after appropriate image segmentation and registrations. Our understanding of dynamic carpal instabilities will be further advanced with in-vivo development of this imaging method.

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