MRI-COMPATIBILE LOADING DEVICES FOR MEASUREMENT OF TENDON AND MEDIAN NERVE MOTION WITHIN THE CARPAL TUNNEL

[1]Jessica E Goetz, [1]Thomas E Baer, [1]Nicole M Jensen, [2]Daniel R Thedens,
[1]Ericka A Lawler, and [1]Thomas D Brown
[1]Department of Orthopaedics & Rehabilitation, University of Iowa, Iowa City IA, [2] Department of Radiology, University of Iowa, Iowa City IA
email: jessica-goetz@uiowa.edu web: http://poppy.obrl.uiowa.edu/

INTRODUCTION

Carpal tunnel syndrome (CTS) is the most commonly encountered peripheral neuropathy. It results from mechanical insult to the median nerve as it passes through the carpal tunnel among the digital flexor tendons (Figure 1). While a substantial body of work has focused on variations in carpal tunnel fluid pressure associated with CTS [1], newer work addresses the effects of impingement of the flexor tendons on the median nerve [2].

It is well known that the digital flexor tendons move significantly in the longitudinal direction through the tunnel during various hand activities [3]. Less understood, however, is how the tendons move transversely in response to various CTS-provocative activities. This work describes the development of a suite of MRI-compatible instruments designed for imaging the contents of the carpal tunnel during controlled functional activity. Images collected while using these specialized loading devices demonstrate dramatic transverse tendon and nerve movement, providing evidence to support the importance of tendon impingement studies in CTS research.

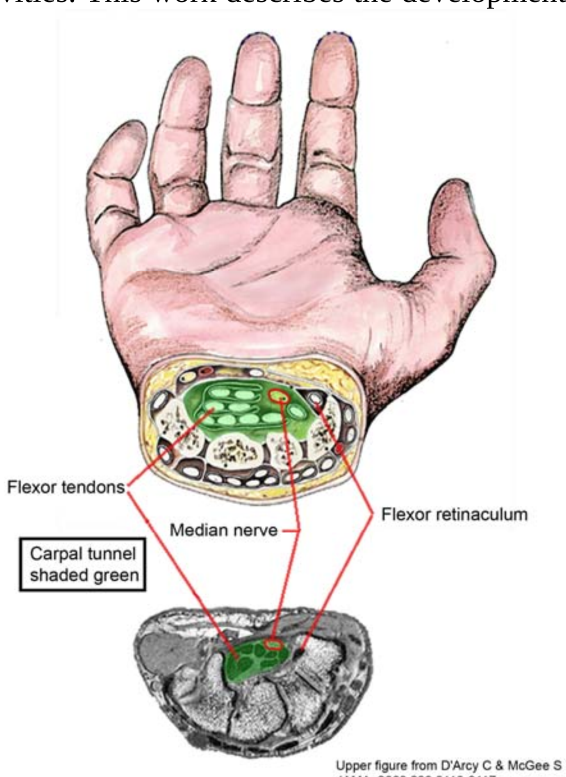

Figure 1: Illustration of carpal tunnel location (top) and MRI of carpal tunnel cross-section (bottom).

METHODS

Four CTS-provocative hand activities were chosen for study: squeeze grip, single-finger key press, and volar press with fingers either straight or bent. Fixtures were constructed from MRI-compatible materials (acetal, acrylic, nylon and polypropylene) to position a subject's hand in a specific position while holding a predefined isometric load. Each loading device included a purpose-built switch to provide the subject with audio feedback when the load was within a predetermined range. During the MRI scan, the subject was instructed to maintain the load on the device so that a buzzer remained active.

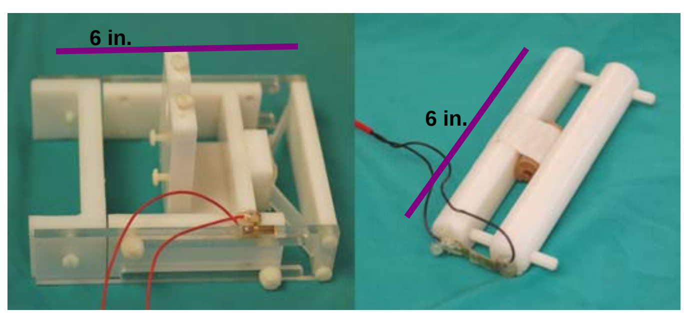

Figure 2: Device for volar flat and bent finger press and single finger key press (left). Squeeze grip device (right).

The loading fixtures were used in conjunction with a splinting system that held the wrist in a specific flexed or extended position. Two subjects were scanned while using the loading devices. Each subject was splinted at wrist angles ranging from 45° of flexion to 45° of extension with the carpal tunnel positioned centrally within a transmit/receive lower extremity coil for MR imaging. Three-dimensional images of the tunnel and wrist were acquired using a Dual Echo Steady State (DESS) pulse sequence with water excitation. The resolution was 0.3mm x 0.3mm x 0.8mm over an 8cm x 6cm x 7.5cm field of view (FOV) for the resting state scan and 0.4mm x 0.4mm x 1.0mm over the same FOV for imaging under load. The slight reduction in resolution reduced the scan duration to 90 seconds, allowing the subjects to remain still during the specified loading tasks.

RESULTS AND DISCUSSION

The loading devices allowed MRI capture of the movements of the digital flexor tendons and their interaction with the median nerve associated with changes in wrist angle and hand loading activities. No visible artifact resulted from having the loading devices in the magnet.

The tendons and the nerve demonstrated dramatic transverse movement during changes in wrist position (Figure 3). The tendons and the nerve demonstrated noticeable, although somewhat less pronounced, changes when moving from an unloaded to a loaded condition. The loads assigned to the activities were sufficient to cause a deviation from the unloaded tendon/nerve geometries and stacking arrangements, but not so large as to prevent the subject from remaining still while maintaining the load through the 1.5 minute scan.

CONCLUSIONS

The strikingly large transverse motions and deformations of the tendons and, most importantly, of the nerve itself offer a compelling imaging-based argument for further research to better understand median nerve insults from tendinous impingement as a key factor potentially contributing to carpal tunnel syndrome. The work described here addresses the problem of measuring soft tissue deformation *in vivo* during normal loading activities.

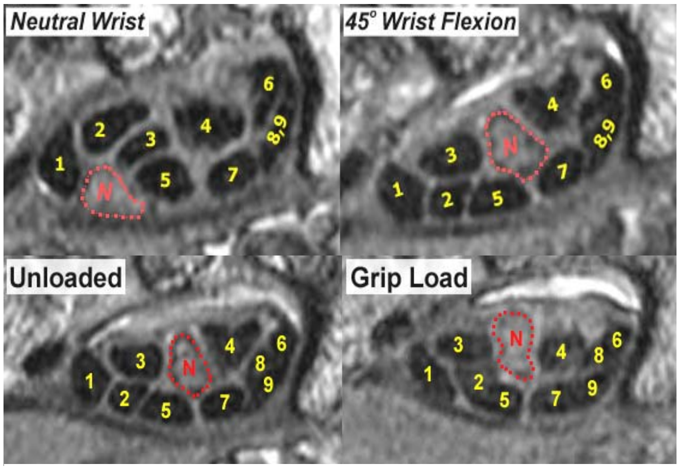

Figure 3: MR images of a single longitudinal section of the carpal tunnel during hand motion. Moving the unloaded wrist from straight to 45° of flexion caused the median nerve to extrude through the tendons (top). Movement from a relaxed to a squeeze grip loading caused changes in tendon and nerve shapes (bottom).

REFERENCES

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Figure 4: The squeeze grip (left), the volar press with bent fingers (center), and the volar press with straight fingers (right) demonstrated inside the MR coil. During scanning, the subjects were stabilized to reduce movement artifact with additional padding which was removed here for clarity of the loading devices.