

SEMI-AUTOMATED TENDON IDENTITY TRACKING IN MR IMAGES

¹Nicole M Jensen, ¹Jessica E Goetz, ²Daniel R Thedens,

¹Thomas E Baer, ¹Ericka A Lawler, and ¹Thomas D Brown

¹Department of Orthopaedics & Rehabilitation University of Iowa, Iowa City IA,

²Department of Radiology, University of Iowa, Iowa City IA

email: nicole-jensen@uiowa.edu

web: <http://poppy.obrl.uiowa.edu/>

INTRODUCTION

Carpal tunnel syndrome (CTS) is a commonly encountered compressive peripheral neuropathy. There is increasing evidence that CTS may be caused at least in part by impingement on the median nerve by the digital flexor tendons. Finite element (FE) analysis offers an attractive means to provide definitive information about mechanical insult to the median nerve. However, to provide useful data, these models must be driven with realistic anatomic motion [1]. Due to inter-subject variability of tendon “stacking” and the unpredictability of tendon deformation, the identification of respective segmented tendons within the tunnel is indeterminate [2], and the nine individual digital flexor tendons can be reliably distinguished only at a distal location within the hand (Figure 1). Therefore, a method has been developed using a region-growing technique to track tendon identities from the hand through the carpal tunnel in a MR image series, starting from a more distal location where identities are unambiguous. This in turn allows for tracking individual tendons’ transverse motions within the carpal tunnel.

METHODS

An MRI section within the hand in which each tendon is easily distinguished is used as the starting image for the region-growing technique. Each tendon on the starting image is identified and traced. The area within this boundary is calculated and used as a growth limitation parameter to ensure that one tendon does not merge into another. The centroid of the initially traced area is used as the center of a 3x3 seed region for growth on the next proximal image in the series. Each tendon region is grown using a 4-connected neighborhood comparison scheme, with a pixel being added to the tendon region if the absolute value of the difference between its intensity and the mean gray value of the

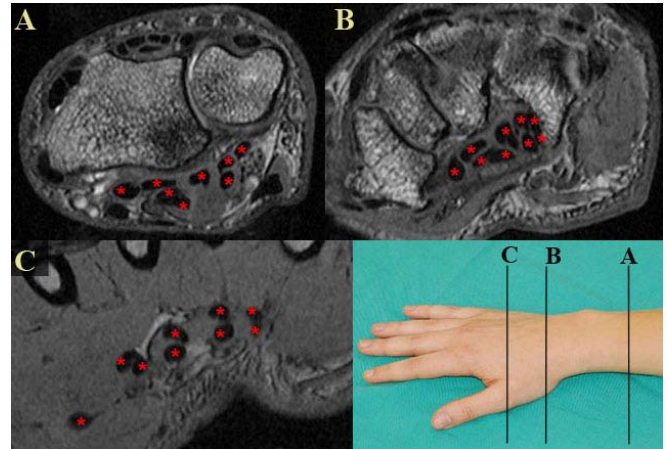


Figure 1: MR images, with flexor tendons identified by red dots within (B) and on either side of (A&C) the carpal tunnel. Only in the distal image in the hand (C), where the tendons align in pairs going to each finger (one to the thumb) and in two layers (deep and superficial), is tendon positive identification possible.

seed region is less than 50% that of the seed value. The tendon region continues to grow until either there are no remaining candidate boundary pixels or its area has reached the area growth limitation parameter. The centroid of the resulting region is then used to define the 3x3 seed region to grow the tendon region on the subsequent proximal image, and so forth. The tendon tracking process is complete once the slice-by-slice region growing has propagated to one of the previously segmented tunnel images.

The known tendon identities are then continued through the series of segmented slices, by determining in which segmented region the centroid of an identified tendon lies. When this process is complete, each segmented tendon in the tunnel has a unique anatomic identifier. This identifier will be assigned to the same tendon in any image series processed with this method, thereby allowing for assessment of tendon movement with wrist motion.

RESULTS AND DISCUSSION

Three-dimensional magnetic resonance images of the wrist of a male subject were acquired using a transmit/receive lower-extremity coil and a ninety second Dual Echo Steady State (DESS) pulse sequence with water excitation. The acquired resolution was 0.4mm x 0.4mm x 1.0mm over an 8cm x 6cm x 7.5cm field of view. Wrist positions ranged from 55 degrees of flexion to 55 degrees of extension. For each scan, the nine flexor tendons, the median nerve, and the carpal tunnel boundary were segmented on images spanning the length of the carpal tunnel.

Dramatic transverse motions of the flexor tendons and nerve were observed as the wrist moved from extension to flexion (Figures 2 & 3). Excursion of the nerve from the volar to the dorsal side of the tunnel was apparent as the wrist moved from neutral into flexion. Large deformations of the tendons are also visible as the wrist moved (e.g., tendon 5 in Figure 2). The positively identified tendon segmentations allowed generation of a 3D model of the carpal tunnel including both the tendons and nerve (Figure 3). Tracking the excursions of the flexor tendons and the median nerve during wrist movement is necessary for driving realistic FE models.

CONCLUSIONS

The close proximity of the tendons in the carpal tunnel, their substantial transverse motion during functional activities, and individual “stacking” variability contribute to the difficulty of positively identifying each tendon in an image of the carpal tunnel. The work described herein addresses the development of a semi-automated method for

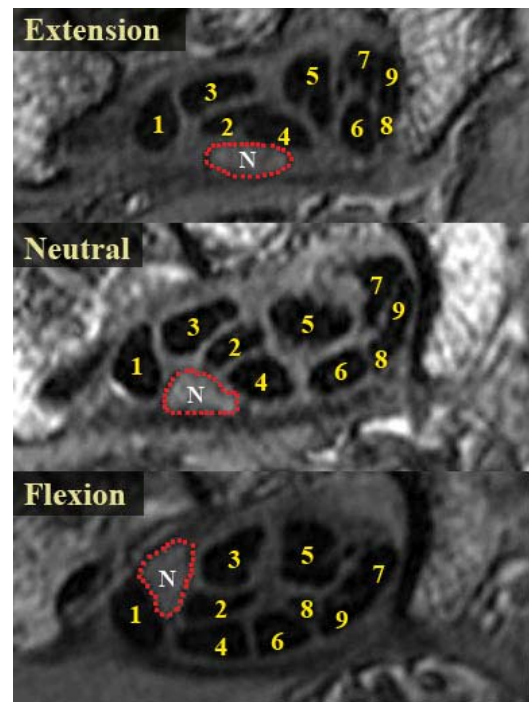


Figure 2: Identified tendons in extension (Top), neutral (Middle), and flexion (Bottom). N represents the nerve; 1 corresponds to the FPL (thumb); 2,4,6,8 to the superficial tendon of each finger (index to little); and 3,5,7,9 to the deep tendon of each finger.

section-to-section tracking of the identity of each tendon in the carpal tunnel using a region-growing technique.

REFERENCES

1. Keir PJ, et al. *Clin Biomech*, **14**, 635-645, 1999.
2. Valverde FL, et al. *Computer Methods and Programs in Biomedicine*, **73**, 233-247, 2004.

ACKNOWLEDGEMENTS

Funding provided by NIH AR053899.

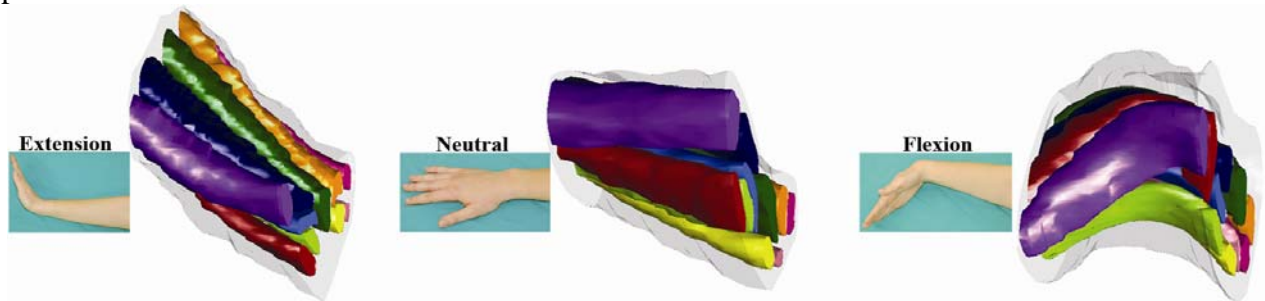


Figure 3: Isosurface of carpal tunnel segmentations in extension (Left), neutral (Middle), and flexion (Right). After identification with the region-growing techniques, the individual tendons can be compared in different wrist positions. Purple corresponds to the flexor pollicis longus (thumb) tendon; red to the nerve, dark colors to deep finger tendons, light colors to superficial finger tendons, and opaque gray to the carpal tunnel boundary.