Ultrasound Assessment of Motion Patterns of Human Flexor Digitorum Superficialis and Profundus Tendons with Speckle Tracking

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INTRODUCTION:
Speckle tracking is an angle independent method that calculates and displays regional movement and velocities within ultrasound images. The purpose of this study was to test the suitability of speckle tracking to evaluate the correlations between tendon excursions and finger joint angle, and to distinguish quantitatively the motions of the flexor digitorum superficialis (FDS) and profundus (FDP) tendons.

METHODS:
This study protocol was approved by our Institutional Review Board (IRB). Fifteen normal volunteers (eight male, seven female), with a mean age of 35 +/- 8 years, participated. The forearm of the examinee was fastened on a custom-made fixation jig with the wrist in the neutral position. An ultrasound scanner (Acuson Sequoia CS12, Siemens Medical Solutions, Malvern, PA) equipped with a multi-frequency (8-14 MHz) 1L8 linear array transducer was also fixed in the jig, to maintain a constant relationship of the transducer to the wrist during testing. The field of view was 20mm (depth) x 25mm (width).

Image Acquisition Procedure
The transducer was placed so that both the FDS and FDP tendons of the middle finger could be seen in the center of the cross-sectional image, and the transducer position was marked on the skin. The direction of the transducer was aligned with the direction of tendon motion. Since tendons are fibrillar in morphology, we were able to recognize the flexor tendon as a moving structure with a multitude of parallel striations (Figure 1).

RESULTS:
To evaluate the discrimination sensitivity of our method, small, medium and large acrylic tubes, 3.8, 5.1 and 6.4 cm (1.5, 2.0 and 2.5 inch) in diameter, respectively, were used to limit joint angles. The participants were asked to flex and extend with four fingers (index, middle, ring, little) from full finger extension to the maximum flexion possible when gripping the various tubes. The participants were asked to move consistently and repeatedly at 0.8 Hz for each direction (flexion or extension) of motion.

The image was recorded for three flexion-extension cycles for each tube size. A cine loop function was used to edit the motion cycles of the tendons for analysis. Images were acquired for both wrists in each subject. Images were analyzed with Syngo VVI software (Siemens Medical Imaging, Malvern, PA) and the velocity-time data analysis was performed using the software’s generic curve mode. The FDS and FDP tendon excursions were calculated based on the area under the velocity/time series data. (Figure 1) The averages of excursions for three cycles for both FDS and FDP tendons for each tube size were used for further analysis. The FDP/FDS excursion ratio was calculated.

Joint Angle Measurement
To estimate the ability of the ultrasound methods to accurately measure tendon excursion, the joint angles were measured for each tube size. With the participants holding the tubes used in the ultrasound examination, the angles of the distal interphalangeal (DIP), proximal interphalangeal (PIP) and metacarpophalangeal (MP) joints were measured at the dorsal aspect of the joints with a goniometer.

Pearson correlation coefficients were calculated for FDS excursion and PIP + MP joint angle, FDP excursion and DIP + PIP + MP joint angle and total FDP + FDS excursion and DIP + PIP + MP joint angle. The results were expressed as the mean ± standard deviation (SD). A mixed linear model was used to analyze the data. When the comparisons of excursion and ratio were made, the size of the tubes was considered to be the fixed effect. Hands and persons were considered as random effects. P values of <0.05 were considered significant. All analyses were performed by SAS/STAT version 9.1.3 software (SAS institute Inc., Cary, NC).

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SIGNIFICANCE:
This tool might be useful in looking for abnormal motion patterns in the carpal tunnel in association with conditions such as carpal tunnel syndrome or tendon injury.

DISCUSSION:
Speckle tracking ultrasound appears to be a potentially useful method to evaluate the relative motion of flexor tendons in the human carpal tunnel. We found that the excursions and FDP/FDS ratio were distinguishable by this method, and that the FDP correlated better than FDS with joint motion. This seems to be a unique aspect of ultrasound imaging, which is impossible with other clinical imaging methods.

Figure 1. A sample of velocity-time data analysis.

Figure 2. Results of tendon excursion and excursion ratio. *shows the significant difference for the different tube sizes (P<0.01).