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● *Original Contribution*

IDENTIFICATION OF THE POSITION AND THICKNESS OF THE FIRST ANNULAR PULLEY IN SONOGRAPHIC IMAGES

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Abstract—The purpose was to identify the A1 pulley's exact location and thickness by comparing measurements from a clinical high-frequency ultrasound scanner system (CHUS), a customized high-frequency ultrasound imaging research system (HURS) and a digital caliper. Ten cadaveric hands were used. We explored the pulley by layers, inserted guide pins and scanned it with the CHUS. After identifying the pulley, we measured each long finger's thickness using the CHUS and excised the pulley to measure its thickness with a digital caliper and the HURS. The thin hypo-echoic layer was revealed to be the synovial fluid space, and the pulley appears hyper-echoic regardless of scan direction. We also defined the pulley's boundaries. Moreover, the CHUS provided a significantly lower measurement of the pulley's thickness than the digital caliper and HURS. Likewise, based on the digital caliper's measurement, the HURS had significantly lower mean absolute and relative errors than the CHUS. (E-mail: fcsu@mail.ncku.edu.tw and jkkuo@mail.ncku.edu.tw) © 2016 World Federation for Ultrasound in Medicine & Biology.

Key Words: **Flexor tendon pulley, High frequency ultrasound, Sonographic image, Trigger finger, Pulley thickness.**

INTRODUCTION

In the annular pulley system, the pulleys accomplish the efficient transmission of muscle forces by stabilizing the tendons and keeping them close to the phalanges during flexion (Boutry et al. 2004; Martinoli et al. 2000). The working relationship between the pulleys and tendons can be disrupted when various factors cause the pulleys to thicken or the tendons to swell, impeding tendon movement within the pulley-sheath system and causing the finger to snap and lock painfully during extension (Bodor and Flossman 2009; Yang et al. 2014). Trigger finger treatment usually begins with non-operative options such as rehabilitation, immobilization, anti-inflammatory drugs and local steroid injections. Operative treatment is usually recommended if these options fail (Saldana 2001; Zhao et al. 2014).

Surgeons used conventional open release until percutaneous release was introduced in 1958 (Lorthioir 1958). Open release is still the standard, in which surgeons can clearly identify the pulley and critical neurovascular bundles and can more easily ensure a complete release of the pulley. However, this procedure often causes soft tissue damage, adhesion, scarring, infection and longer recovery times. Percutaneous techniques, which are minimally invasive, avoid these disadvantages (Dunn and Pess 1999; Ha et al. 2001; Lorthioir 1958). This alternative has become more popular but remains controversial due to the less-clear view of the pulley

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and high risk of damage to nearby neurovascular bundles (Dunn and Pess 1999; Ha et al. 2001; Jou and Chern 2006). To overcome this disadvantage, sonography has been used to obtain a complete and accurate image of the pulley and other structures of the hand before and during surgery (Chern et al. 2005; Serafini et al. 1996). Therefore, with accurate identification of the pulley's thickness, clinicians could more easily identify the differences between a normal and pathologic pulley as well as use a follow-up ultrasound image to determine whether conservative treatment is sufficient for the disease or if surgery is needed.

To maximize the effectiveness of sonography in diagnosis and treatment, two problems need to be resolved. First, although researchers consistently believe the pulley is hyper-echoic in sagittal-view images, they are inconsistent in identifying the pulley as hypo-echoic or hyper-echoic in axial-view images (Boutry et al. 2005; Guerini et al. 2008; Kim and Lee 2010; Miyamoto et al. 2011; Sato et al. 2014). Second, the thickness of the pulley in sonographic images has yet to be determined accurately. The purpose of this study was to (i) identify the correct boundaries of the A1 pulley in the sonographic image and (ii) compare the measurement of the A1 pulley's thickness by ultrasound systems of different frequencies and measurement of the actual thickness by a digital caliper. We hypothesized that the A1 pulley would be hyper-echoic in the sonographic images. Furthermore, we hypothesized that there would be a greater margin of error in measuring the thickness of the A1 pulley in the sonographic image compared to actual measurement using a digital caliper.

MATERIALS AND METHODS

Specimen preparation

Ten fresh frozen human cadaveric hand specimens with no diagnosis or indications of musculoskeletal disease, metabolic disorder or major trauma were amputated at the mid-forearm. The specimens included five males and five females with a mean age of 66.9 ± 10.3 y (52–79 y). This study was approved and the need for informed consent was waived by the Institutional Review Board of National Cheng Kung University Hospital, Taiwan. The Asian Institute of TeleSurgery Center, Chang Bing Show Chwan Memorial Hospital, Taiwan, provided the cadavers. Each specimen was thawed and kept moist at room temperature for future use.

Experimental system

A clinical high-frequency ultrasound scanner system (CHUS; Terason t3000, Teratech Co., Burlington, MA, USA; Fig. 1a) with a 5- to 12-MHz linear-array transducer (12 L5, Teratech Co.) mounted on a customized frame was used to identify the correct location of the A1 pulley in the sonographic image and measure the pulley's thickness. The frame was adjustable with six degrees of freedom and included a stepper-motor controller and a 25-lb load cell (MDB-25, Transducer Techniques, Temecula, CA, USA). The frame allowed us to eliminate individual differences between researchers in two ways. First, it could be used to place the transducer consistently and accurately in relation to the palm plane (perpendicular) and the tendon axis (rotating between perpendicular and parallel). Second, it could be used to place the transducer with consistent contact force. In addition, a previously customized high-frequency ultrasound imaging research system (HURS; Lin et al. 2011, 2013, 2014; Fig. 1b) was used to measure the thickness of the isolated A1 pulley. This system had a 30-MHz single-element ultrasonic transducer (NIH Ultrasonic Transducer Resource Center, USC, Los Angeles, CA, USA), with acoustic characteristics summarized in Table 1, which was positioned on the three-dimensional motorized stage. A motor controller (DMC-1842, Galil Motion Control, Inc., Rocklin, CA, USA) was used to control a piezoceramic motor (HR8, Nanomotion Ltd., Yokneam, Israel) and two microstepping motors (CM1-C-17 L30 A, Cool Muscle, Japan). The high-frequency ultrasonic transducer was excited by a 200 peak-to-peak voltages generated from a monocycle generator (AVB2-TB-C, AVTECH Electrosystems Ltd., Ogdensburg, NY, USA).

Experimental procedure

Sonographic identification of A1 pulley. The ring finger of a randomly chosen cadaveric hand specimen was used to identify the correct location of the A1 pulley in the sonographic image. The proximal and distal outlets of the A1 pulley region were scanned and marked by the CHUS. A 1.5-cm zigzag incision was made in the skin proximal to the proximal outlet of the A1 pulley. The subcutaneous tissue was dissected carefully to preserve the whole layer structure, and the proximal outlet of the A1 pulley was carefully identified. Guide pins (paperclips straightened at one end) were inserted between the pulley and the dissected subcutaneous fat and in the synovial fluid space between the pulley and the flexor tendons. Next, the incised skin with the connected subcutaneous tissue was recovered and restituted with temporary sutures. The scanned images of the ring finger were then acquired and recorded by the CHUS. Finally, the locations of the guide pines in the images were compared to their locations in the actual anatomic structures to determine the A1 pulley's boundaries.

Sonographic measurement of A1 pulley thickness. After the correct A1 pulley position was