Shear wear elastography of the human Achilles tendon: a cadaveric study of factors influencing the repeatability

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1. Introduction

Achilles tendinopathy is a frequent disease, which can lead to tendon rupture (Hess 2010). Its treatment is controversial, partly due to the actual lack of reliable diagnostic tools in clinical practice.
Shear waves elastography (SWE) is a new mode of ultrasound imaging, allowing real-time and *in vivo* assessment of tendon stiffness. It may facilitate tendinopathy management as this pathology is usually associated with an increase of tendon stiffness (Hess 2010; Aubry et al. 2013).

The reproducibility of SWE is good in tissues such as breast (Evans et al. 2010) or liver (Muller et al. 2009), but it varies among different published studies (with variable protocols) on human Achilles tendon (AT).

The aim of this study was to assess the reproducibility of human cadaveric AT SWE and to study the influencing factors, in real and optimal conditions.

2. Methods

2.1. 'Clinical practice-like' protocol

Twelve lower limbs of fresh frozen human cadavers (age = 84 ± 5 years, mean ± SD) were examined. The ATs were assessed with SWE (Aixplorer®, Supersonic Imagine, Aix-en-Provence, France), randomly and blindly by three operators. Longitudinal and axial slices were performed at three successive levels (0, 3, and 6 cm from the calcaneal insertion), in three ankle positions (position #1: neutral position, position #2: maximal dorsal flexion, position #3: 25° plantar flexion), maintained by custom-made splints (Figure 1). The longitudinal measurement at the 2nd level was made five times by every operator. The probe was held by the operator and stationed lightly on top of a generous amount of

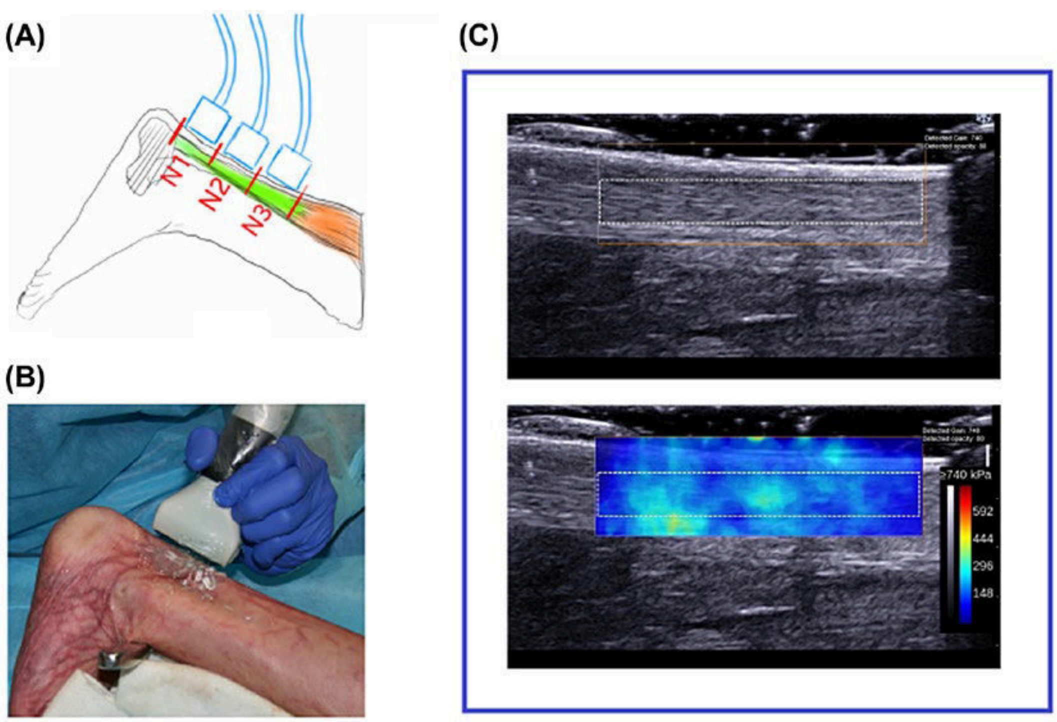

Figure 1. (A) Schema representing the different levels for the SWE probe (picture from MS); (B) Experimental set-up and (C) Screenshot of ultrasound B-mode and SWE, with ROI.

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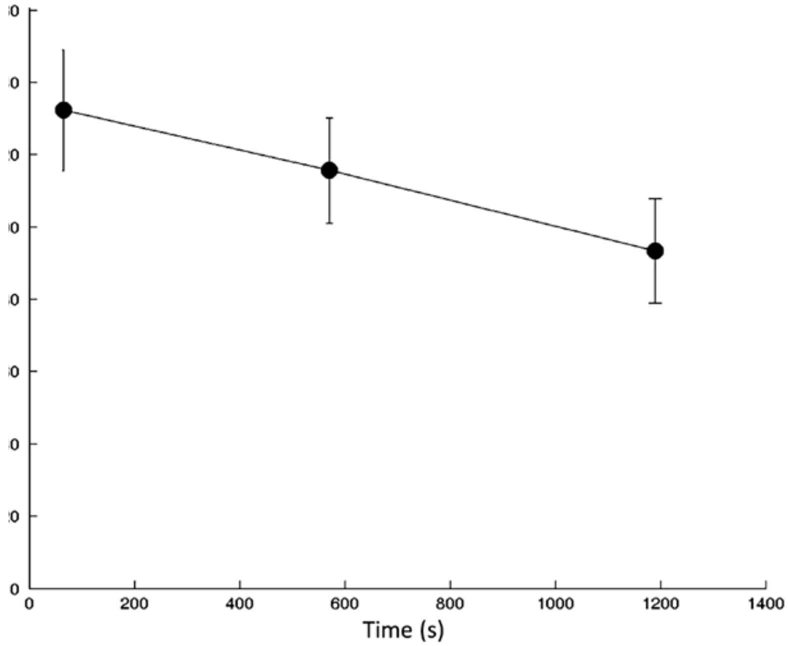

Figure 2. Decrease of mean shear modulus value over time (position #2).

coupling gel, perpendicularly to the skin, motionless during 10 s (time of acquisition of a video clip of data).

Data processing was performed blindly by one operator, who positioned the region of interest (ROI) inside the tendon area, in which the mean shear modulus was defined. Repeatability and reproducibility were calculated.

2.2. *Comparison to measurements in optimal conditions*

Then, the limbs were surgically prepared: the ATs (with bone insertions) were sampled and mounted in a testing machine. A standardized load (10 N) was applied, and three SWE measurements were done for each tendon sample, in order to assess the reproducibility.

3. Results and discussion

Mean shear modulus values were equal to 290.4 kPa (SD: 49.8), 392.0 kPa (SD: 67.6) and 126.7 kPa (SD: 40.6) for positions #1, 2 and 3, and 47.3 kPa (SD: 18.8) for the tendon samples.

In longitudinal slices, our 'clinical practice-like' protocol reproducibility was equal to 22.1, 20.7, and 33.4% for ankle positions #1, #2, and #3, and the repeatability was equal to 15.8, 18.5, and 16.3%, respectively. The reproducibility of the tendon samples SWE was equal to 12.8%.

Our results are consistent with Aubry, who demonstrated that shear modulus increased during dorsal flexion of the ankle (Aubry et al. 2013).

The repeatability of SWE in tendons has been reported as 'good' to 'very good' in animal tendons through increasing loads (Peltz et al. 2013), but varies among different studies, in human AT *in vivo*. Turan (Turan et al. 2013) reported intra-observer agreement of 0.77, and inter-observer agreement of 0.79, while Aubry (Aubry et al. 2013) found lower inter-observer reproducibility (intra-class coefficient (ICC) equal to 0.46 and less), as well as Peltz (Peltz et al. 2013) for the repeatability (ICC = 0.42).

Our results were better for the repeatability than the reproducibility, as well as for the isolated tendon SWE's repeatability (considered as the reference value). It can be explained by the time needed to achieve a complete measurement session with three operators, which is longer than a repeatability study session (one operator). Indeed, AT has viscoelastic properties (Brum et al. 2014), such as relaxation (once the tendon has been installed on the splint), which leads to a decreasing of tendon stiffness over time. In our study, we found a mean 23% decrease of shear modulus after 20 min of installation, for position #1, 29% for position #2 (Figure 2), and 19% for position three.

4. Conclusions

The repeatability of AT SWE is higher in maximal dorsal flexion, but values decrease faster over time in that position, making it necessary to take every SWE measurements after a constant time once the patient has been positioned.

These findings were a prerequisite for the realization of another study, in order to validate SWE in human tendon. This study, which compares shear modulus (SWE) with apparent elastic modulus obtained by simultaneous tensile tests, will be presented soon.

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