Sonoelastographic assessment of the age-related changes of the Achilles tendon

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Abstract

Aims: Tendons are crucial for optimal muscle force transfer and subject to changes with aging which may impair functional ability of elderly individuals. Achilles is the largest and the strongest tendon in the body; therefore it is an excellent site for the radiologic investigation of aging of tendons. Sonoelastography (SE) is a new ultrasound-based imaging technique that provides information on elastic properties and stiffness of tissues. The aim of our study was to investigate the age-related alterations in Achilles tendons using SE. **Material and methods:** Forty five geriatric (age $\geq$ 65 years) and 42 young (age 18-40 years) healthy consecutive subjects were enrolled. Subjects with known history of metabolic or endocrine diseases, sports or traumatic injuries, peripheral vascular disorders were excluded. Both Achilles tendons were scanned with a real-time SE probe at a frequency of 6–15 MHz. Strains of Achilles tendons' proximal, middle and distal parts were assessed semi-quantitatively with comparing a reference tissue. **Results:** Both SE methods -color coded evaluation and strain measurement- showed a remarkably stiffer tendon in the elderly subjects compared to young subjects in all thirds of Achilles tendons. In young subjects 84.9 % tendon thirds were blue, and 15.1% were green whereas, in elders 93.7% were blue and 6.3% were green ($p=0.024$). There was a significant correlation between age and stiffness of tendons assessed with strain indices. **Conclusion:** Our result showed increased tendon stiffness in elderly subjects which might be responsible for the high prevalence of Achilles tendinopathies observed in elderly subjects.

Keywords: Achilles tendon, aging, sonoelastography

Introduction

Integrity of tendons are essential for optimal muscle force transfer and functional ability [1]. Achilles tendon is the thickest and strongest tendon in the body but has the highest risk of failure and rupture in aging which is believed to be related with alterations in the elastic properties of the tendon [2]. Muscle mass, strength and physical functionality declines with aging. Furthermore tendon composition changes in the elderly, while col-

lagen concentration reduces, other extracellular matrix components increase, such as proteoglycans and glycosaminoglycans. Despite the fact that tendon characteristics influence the overall function of the muscle-tendon complex, there is a relative lack of human data that describe potential age-associated alterations in the mechanical properties of tendons [3]. Animal studies demonstrate that aging yields a stiffer tendon, a weaker tendon [4,5], or leaves the tendon unaffected; hence data are inconclusive [3]. There are a number of in vivo and ex-vivo human studies on aging of tendons which are using variable methods such as ultrasonography (US) and tendon biopsy investigation. However, all of the present studies have significant technical pitfalls [3,6].

Sonoelastography (SE) is a new US-based imaging technique that gives information on elasticity properties of various tissues and lesions [7]. Depending on their elastic properties, tissues deform and move away from

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the US transducer when a pressure is applied on them. The amount of displacement from the probe is called a "strain" and a specific computer software converts strains to the color codes representing different degrees of stiffness superimposed on the gathered B-mode images [8,9]. SE was first described by Ophir et al in 1991 [10]. Since then, SE has found various clinical applications and extensive use in the diagnosis and evaluation of liver diseases, mass lesions and many other disorders [11,12]. Given its clinical utility most of the commercial systems now include SE on their US machines as a standard equipment.

The clinical utility of SE has been shown in various musculoskeletal disorders including tendon pathologies [13-15]. Previous studies have already shown that SE is superior to B mode US in the assessment of tendons when taking histological examination as a standard reference [15,16]. Achilles is the largest tendon in the body; furthermore, it is superficial, making it easily accessible to all kinds of US examinations including SE [17]. In addition, there is an adequate experience for the evaluation of tendons with this method [14,18,19]. However, SE has not been studied for the investigation of the aging of tendons. Hence, we investigated age-related alterations in the elasticity of Achilles tendon with this new method.

Materials and methods

Study population

Forty five geriatric (23 female, 22 male), median age 70 (65-87 years) and 42 young (26 female, 16 male), median age 23 (18-40 years) healthy consecutive subjects were enrolled. A standardized questionnaire was used to record the demographic data of the study subjects and musculoskeletal complaints were meticulously questioned. Subjects under 18 years of age and those with a known history of metabolic or endocrine, cardiac or peripheral vascular diseases and sports-related or traumatic injuries were excluded. In addition, subjects with significant lower extremity osteoarthritis, knee prostheses and under any medication were not considered eligible for the study. The study was approved by the institutional Ethics Committee, and all subjects gave their written informed consent.

Ultrasound technique

All subjects underwent US examination with a real-time sonoelastographic scanner (Logiq S7 Expert GE Healthcare, South Korea) at a frequency range of 6–15 MHz matrix linear transducer in the transverse and longitudinal planes. Examinations were performed while the patient was lying prone with his/her feet hanging freely down the side of the table and the Achilles tendon in a

relaxed position. Both Achilles tendons were divided into three parts during examination; proximal third (musculotendinous junction), middle third (2–6 cm above the insertion) and distal third. All examinations were performed by two examiners who had more than 5 years of experience in the field of musculoskeletal radiology.

B-mode evaluations included tendon homogeneity, thicknesses and structural abnormalities. SE was assessed by applying repetitive, mild, uniform perpendicular pressure to the Achilles tendon in the longitudinal plane with avoiding from anisotropy. The amount and uniformity of compression is standardized via using a pressure graph that appears on the screen. The best cine-image derived from at least three compression-relaxation cycles was used for the assessment of SE. We have used color-scales and strain ratios for the description of elastographic findings which is defined in the literature [18,20]. In this method, blue and green colors represented hard, whereas yellow and red colors represented intermediate and severely soft tendons, respectively. The strain ratio was calculated by comparing the Achilles tendon to the adjacent fat tissue. The first region of interest (ROI)(A) was placed in the fat tissue as a reference tissue and, the other ROIs(B) were placed in each part of the Achilles tendon [20]. The strain ratio (B/A) was automatically calculated by the sonography machine. Therefore strains of Achilles tendons were assessed semi-quantitatively with comparing a reference tissue. SE color gathering and image quality were standardized by using a color bar located on the US screen during examination.

Statistics

SPSS for Windows version 12 (SPSS Inc, Chicago, IL) was used for the statistical analyses. Demographic data and other categorical parameters were analyzed using the Chi-square test. Differences of tendon thicknesses between young and old subjects were compared using the Student t test. Comparison of strain ratios were made by Mann-Whitney U test. The statistical significance was set at $p \leq 0.05$ in all analyses.

Results

B mode examinations revealed a thicker tendon in elderly people compared to young subjects 5.3 ± 0.88 mm vs. 4.4 ± 0.69 mm ($p < 0.001$), which is measured from the middle of the tendon. Furthermore tendons of elders were more homogenous structure compared to youngsters. There were no significant tears or pathologic in-homogeneity in both groups.

In both groups SE showed most tendons in the color shades of blue. In young subjects 214/252 tendon thirds were blue, 28/252 thirds were green and remaining was

Fig 1. A) An elastogram showing the intense blue-shaded Achilles tendon in an elderly person. B) Homogenous stiff tendon in shades of blue and relatively soft linear areas in shades of green in a young individual.

Table I. Strain ratio of the Achilles tendon in young and elderly subjects

	Young patients (n= 84)	Older patients (n= 90)	p
Proximal third	1.8 (0.6-5.2)*	3.0 (1-6)	<0.001
Middle third	1.0 (0.4-4.0)	1.6 (0.3-4.0)	<0.001
Distal third	0.75 (0.4-1.9)	1.1 (0.4-3.9)	<0.001

*All values are given as median (minimum-maximum), n- number of patients

yellow. In elderly subjects 253/270 tendon thirds were blue, 16/270 were green and one was yellow ($p=0.024$). In addition there were slightly homogenous green regions among blue-coded areas in young subjects which were not observed in any of the elderly subjects (fig 1). Measured strain ratios showed that Achilles tendons from elderly subjects were significantly harder than young subjects in all segments of the tendon but it was most remarkable in the proximal third (Table I).

There was a significant positive correlation between age and thickness of the tendon ($r=0.45$, $p=0.001$). Similarly strain ratios of proximal, middle and distal thirds of tendons significantly correlated with the age of subjects ($r=0.44$, $r=0.31$ and $r=0.35$, respectively; $p<0.001$ for each).

Intra-observer agreement of color scorings was assessed with the re-evaluation of randomly selected 40 subjects (20 older + 20 younger) which revealed a K value of 0.95. Inter-observer agreement was assessed with the re-examination of randomly selected 30 subjects on the same day which revealed a K value of 0.80.

Discussion

In this study the Achilles tendon was found to be remarkably stiffer in elderly subjects compared to young subjects in all parts of the tendon examination. Moreover, there was a positive correlation between the age of

subjects and stiffness of the tendon. Our results suggest that the Achilles tendon becomes stiffer by aging which might explain the increased incidence of tendon ruptures in the elderly population.

Through aging, muscle mass, strength and physical function declines [21]. Although tendon properties determine the overall function of the muscle-tendon complex, there is a relative lack of human data that describe age-related alterations in the mechanical properties of tendon [1]. Maintenance of elasticity is crucial for the optimal function of a tendon which is determined by the composition and molecular content of tendons. Tendons consist of parallel bundles (30% collagen and 2% elastin) embedded in an extracellular matrix composed of 68% water, tenocytes, mucopolysaccharide, and proteoglycan gel [22]. Certain molecular alterations occur through aging in the structure and composition of tendons as in the other tissues which might stiffen the tendon [23,24].

There are numerous in vivo and in vitro studies regarding the aging of tendons. All of the in vivo histological studies were performed on animal models, cadavers, or ruptured tendons: therefore, all have significant methodological drawbacks [24]. US, SE, and magnetic resonance imaging are noninvasive tools for the assessment of in vivo properties of tendons. Despite the development of imaging methods to evaluate the human tendon in vivo, the effect of aging on the human tendon is yet to be determined [3]. SE is a new US-based imaging technique which is superior to the conventional B-mode US [15,16]. Moreover it has other advantages such as real-time examination, lower cost, ease of accessibility, lack of radiation exposure, and accurate discrimination ability.

Similar to our study, Klauser et al showed increased stiffness in 10 cadaveric subjects aged between 70 and 86 years [16]. Likewise, Onambele et al found increased gastrocnemius tendon strain values in middle aged and older individuals compared to young individuals. In previous studies an increased stiffness in surgically repaired Achilles tendons and in subjects with Achilles tendinopathy have been evidenced [14]. Therefore, we suggest that increased tendon stiffness may explain -at least in part- the increased prevalence of Achilles tendon ruptures in elderly subjects.

This study has several limitations. First, the metabolic disorders were ruled out by oral interview without laboratory testing. SE is an US-based technique therefore it has the limitations of all US-based methods such as relatively high operator dependency. To avoid these limitations, two highly experienced SE examiners performed the elastography. Finally the histological confirmation of SE findings was lacking. However we do not think that it is a

major limitation, since as previously shown, SE has an excellent correlation with histological examination [16].

In conclusion, SE offers value for the evaluation of age-related tendon changes *in vivo*. Further studies are warranted to establish standardized strain ratios of different tendons to increase the widespread use of this relatively new method.

Conflict of interest: none

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