ORIGINAL RESEARCH

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Evaluation of the Long Head of the Biceps Tendon Using Shear Wave Elastography and Superb Microvascular Imaging in Cases of Biceps Tendinopathy

Biseps Tendinopatisi Olgularında Biseps Tendonunun Uzun Başının Shear Wave Elastografi ve Süperb Mikrovasküler Görüntüleme Yöntemleri Kullanılarak Değerlendirilmesi

Fatma Ustabaşıoğlu[1], Gülşah Burgazdere[2], Burak Günay[2], Canan Büşra Akbaş[2], Fethi Emre Ustabaşıoğlu[2]

[1]Edirne Sultan 1. Murat State Hospital, Clinic of Physical Therapy and Rehabilitation, Edirne, Turkey
[2]Trakya University Faculty of Medicine, Department of Radiology, Edirne, Turkey

Abstract

Objective: To evaluate biceps tendon long head (LHBT) tendinopathy cases using shear wave elastography (SWE) and superb microvascular imaging (SMI) methods, compare the findings with magnetic resonance imaging (MRI) findings, and make an early diagnosis of tendinopathy.

Method: Twenty patients diagnosed with LHBT tendinopathy on MRI and 20 healthy volunteers with normal LHBT on MRI were prospectively evaluated using the SWE and SMI methods. Quantitative measurements of LHBT hardness by SWE were performed in kilopascals (kPa). SMI values were determined using a rating system. A four-stage grading system was used as follows: grade 0 (no significant vascularity focus), grade 1 (1-2 focal vascularity focus), grade 2 (1 linear or more than 2 focal vascularity focus), and grade 3 (more than 1 linear vascularity focus).

Results: While the average SWE values for the biceps tendon with tendinopathy were measured as 38.715 and 37.685 kPa in the longitudinal and transverse planes, respectively, the average SWE values of the control group were measured as 19.385 and 18.41 kPa in the longitudinal and transverse planes, respectively. This shows that there is a statistically significant difference ($p<0.01$). In the evaluation performed using SMI, intratendinous grade 1, 2, or 3 flow was detected in all patients with tendinopathy. According to the ANOVA test, there was a statistically significant difference between the degree of vascularization determined by the SMI method and the average symptom onset in cases with

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Amaç: Biseps tendon uzun başı (LHBT) tendinopatisi olgularını shear wave elastografi (SWE) ve süperb mikrovasküler görüntüleme (SMI) yöntemleriyle değerlendirmek, bulguları manyetik rezonans görüntüleme (MRG) bulgularıyla karşılaştırmak ve tendinopatinin erken tanısını koymaktır.

Yöntem: MRG'de LHBT tendinopatisi tanısı alan 20 hasta ve MRG'de LHBT'si normal olan 20 sağlıklı gönüllü SWE ve SMI yöntemleri kullanılarak prospektif olarak değerlendirildi. LHBT sertliğinin SWE ile kantitatif ölçümleri kilopaskal (kPa) cinsinden belirlendi. SMI değerleri bir derecelendirme sistemi kullanılarak belirlendi. Dört aşamalı bir derecelendirme sistemi şu şekilde kullanıldı: Derece 0 (önemli vaskülarite odağı yok), derece 1 (1-2 fokal vaskülarite odağı), derece 2 (1 doğrusal veya 2'den fazla fokal vaskülarite odağı), derece 3 (1'den fazla doğrusal vaskülarite odağı).

Bulgular: Tendinopatili biseps tendonunun ortalama SWE değerleri uzunlamasına ve enine düzlemde sırasıyla 38,715 kPa ve 37,685 kPa olarak ölçülürken, kontrol grubunun ortalama SWE değerleri uzunlamasına ve enine düzlemde 19,385 kPa ve 18,41 kPa olarak ölçüldü. Bu durum istatistiksel olarak anlamlı bir fark olduğunu göstermektedir ($p<0,01$). SMI ile yapılan değerlendirmede tendinopatili olguların tamamında tendinit içi derece 1, 2 veya 3 akım tespit edildi. ANOVA testine göre tendinopatili olgularda SMI yöntemiyle belirlenen vaskülarizasyon dereceleri ile

Address for Correspondence: Gülşah Burgazdere, Trakya University Faculty of Medicine, Department of Radiology, Edirne, Turkey
E-mail: gulsahakcelep@gmail.com **ORCID:** orcid.org/0009-0007-3839-7786 **Received:** 12.12.2023 **Accepted:** 17.05.2024

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Abstract

tendinopathy ($p<0.001$). No statistically significant correlation was found between symptom onset time and SWE values measured in the transverse and longitudinal planes.

Conclusion: The combined use of SMI and SWE in addition to conventional US can be useful diagnostic methods as easy and practical techniques in the evaluation of the tendon in cases with LHBT tendinopathy.

Keywords: Biceps tendinopathy, biceps tendon long head tendinopathy, shear wave elastography, superb microvascular imaging

Öz

semptom başlangıç ortalamaları arasında istatistiksel olarak anlamlı fark vardır ($p<0,001$). Semptomun başlangıç zamanı ile transvers ve longitüdinal düzlemde ölçülen SWE değerleri arasında istatistiksel olarak anlamlı bir ilişki bulunamadı.

Sonuç: LHBT tendinopatili olgularda tendonun değerlendirilmesinde konvansiyonel US'ye ek olarak SMI ve SWE'nin birlikte kullanımının kolay ve pratik teknikler olarak faydalı tanı yöntemleri olabileceğine inanıyoruz.

Anahtar kelimeler: Biseps tendinopatisi, biseps tendon uzun başı tendinopatisi, shear wave elastografi, süperb mikrovasküler görüntüleme

Introduction

Tendinopathy refers to pain that worsens with movement without tendon tear. The prevalence of tendinopathy is 2-5% (1). Although the risk of tendinopathy is high in active and sporty people, it is also common in inactive people. Biceps tendinopathy occurs as a result of tendon degeneration resulting from overhead movement or normal aging. Tendinopathy of the long head of the biceps tendon (LHBT) is often accompanied by rotator cuff tears or superior labrum anterior posterior lesions (2). Degeneration and repair processes that cause pain and swelling when exposed to forces such as tension, compression, and friction beyond the tendon's capacity play a role in its pathophysiology (3). Patients with LHBT tendinopathy report severe and throbbing pain in the anterior shoulder. Conventional ultrasonography (US) and magnetic resonance imaging (MRI) are diagnostic non-invasive imaging methods for LHBT tendinopathy. Conventional US has the advantages of being easily accessible and inexpensive compared with other imaging techniques. However, it has diagnostic limitations because it is user dependent and the echogenicity of the tendon and surrounding tissues is similar in cases of tendinosis. MRI is the gold standard non-invasive imaging method for the diagnosis of tendinosis (4).

Sonoelastography is a new US method that evaluates differences in tissue stiffness. Sonoelastography includes strain elastography and SWE. Strain elastography evaluates tissue tension by applying mechanical external pressure to the tissue. SWE is a method in which small displacements in the tissue are measured by applying a short-term (0.03-0.4 ms), high-power (frequency 2.67 MHz) acoustic driving force to the tissue with ultrasound probes (5). In healthy tendons, type 1 collagen fibers are responsible for the elasticity of the tissue. In patients with chronic tendinopathy, disorganization of type 1 collagen fibers in the tendon, deterioration in tissue organization, and scattered irregular proliferation of smaller collagen fibers occur. This causes thickening of the tendon, a decrease in energy storage capacity, and tendons exhibiting more tension for the same load. This results in an increase in tissue stiffness and a decrease in elasticity (3).

Neovascularization develops due to chronic degeneration in the tendon because of tendinopathy. Doppler US has been used to demonstrate neovascularization in pathological tendon. However, it has limitations such as angular dependence and inability to visualize small vessels. The SMI method is a technique that can show small-diameter slow-flow vessels (6). Thus, it has superiority over the Doppler US technique in showing neovascularization in the tendon.

SWE and SMI techniques have not yet been used in routine clinical practice. However, studies on these two methods have been conducted on the breast, testicles, lymph nodes, and thyroid (7). In addition, in recent years, it has been used as a new method to evaluate different conditions in the musculoskeletal system (8). There is no study in the literature that uses both the SWE and SMI methods in LHBT tendinopathies. The aim of our study was to compare the LHBT of the normal shoulder with the LHBT of the shoulder with tendinosis using these two methods and to verify it with MRI findings.

Materials and Methods

Ethics committee approval numbered 2019/184 was obtained from the Trakya University's Ethics Committee for our prospectively designed study.

We identified the cases who applied to our Trakya University Hospital with shoulder pain between June 2023 and September 2023 and subsequently requested MRI for further examination. We included patients with tendinosis detected in MRI examinations in our study group and evaluated them using the SMI and SWE methods.

A total of 60 shoulder MRI examinations were examined, and 20 patients with LHBT tendinosis who met the criteria of our study and participated voluntarily and 20 control groups with normal shoulder MRI were included in our study. LHBT tendinosis and the control group were prospectively examined using SWE and SMI methods. The ethics committee and approval forms were obtained.

Patient Selection

Patients with acute trauma, ipsilateral shoulder surgery, LHBT tendon rupture, advanced rotator cuff arthropathy, adhesive capsulitis, and muscle disease were excluded from the study because subluxation and dislocation of the LHBT tendon would cause tension in the tendon. In addition, uncooperative cases that could not be examined by US and cases whose MRI did not have sufficient resolution and diagnostic quality were excluded from the study. In addition, five patients were excluded from the study because they were used for standardization during the learning phase of the US method.

MRI Technique

MRI was performed using a 1.5 Tesla MRI device (MAGNETOM Aera, Siemens Medical Systems, Enlargen, Germany) using a superficial shoulder coil. In the images; T1-weighted: T1-TSE (Turbo Spin-Echo) axial, T1-TSE oblique coronal (780/15; FOV 14 cm; slice thickness 3.5 mm; intersection range 0.4 mm; matrix 320×256), T2-weighted: T2-FFE (Fast Field Echo) axial, T2-TSE oblique sagittal, T2-weighted fat suppressed, T2-SPAIR (spectral attenuated inversion recovery) axial and oblique coronal (3400/50; FOV, 14 cm; diagonal) -slice thickness 3.5 cm; intersection gap 0.4 mm; matrix, 256×256) images were obtained.

All MRIs were independently evaluated by two radiologists experienced in musculoskeletal pathology, and cases interpreted as tendinosis were subsequently evaluated. Cases in which no tear was observed in the LHBT tendon on MRI and in which fluid, signal, and increased thickness were observed around the tendon were evaluated as tendinosis. LHBT thickness was measured in the transverse plane, 1-2 cm distal to the tendon insertion level.

SWE and SMI Techniques

All participants were evaluated using B-mode US, SWE, and SMI methods, and measurements were made using the linear probe (PVT-375BT, Canon Medical Systems, Otawara, Japan) of the high-frequency US device in our department. Patients were informed in detail about the procedure to be performed and were asked to remain comfortable throughout the procedure. Afterwards, B-mode US, SWE, and SMI measurements of the patients; it was performed by two independent radiologists with 5 years of radiology experience. All measurements were performed with the participants sitting, arm neutral, forearm on the thigh, and hand in a supinated position (9). The linear probe was placed in the anterior shoulder, and LHBT was evaluated in the transverse and longitudinal planes of the bicipital groove. Tendon echogenicity, thickness, and fluid content in the tendon sheath were evaluated during B-mode US. Tendon thickness was measured in the transverse plane 2 cm distal to the insertion level of the LHBT. After B-mode US, measurements were made using the SWE and SMI methods. All measurements were performed in transverse and longitudinal planes. SWE and SMI measurements were performed separately by two radiologists and then decided by mutual consensus. During the SWE measurements, a 3 mm diameter ROI circle was placed, as shown in Figure 1. Measurements in the longitudinal plane were made 1-4 cm away from the proximal border of the bicipital groove (Figure 2). When measuring in the transverse plane, the place where the tendon was most prominent in the bicipital groove was used. The quantitative value for LHBT was obtained using at least three measurements, and the mean values were used for statistical analysis. A 3-mm diameter ROI circle was used to make standard measurements for all participants. All SWE measurements were calculated in kilopascals (kPa).

In the SMI evaluation, a grading system was used. A four-stage grading system was used as follows: grade 0 (no

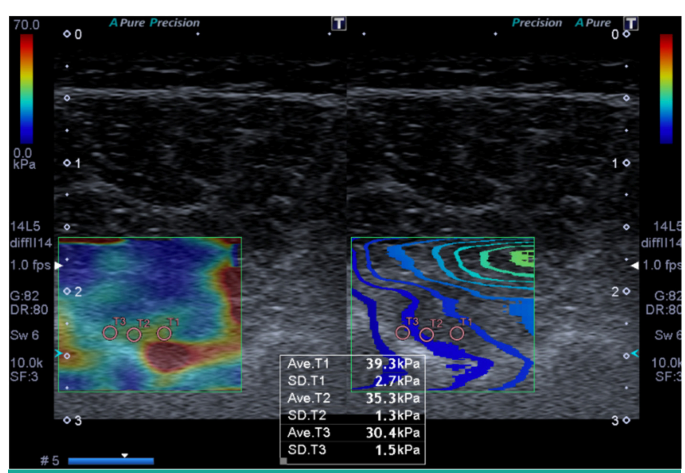

Figure 1. SWE measurement of the tendon of a patient with biceps tendinopathy in the transverse plane

SWE: Shear wave elastography

significant vascularity focus), grade 1 (1-2 focal vascularity focus), grade 2 (1 linear or more than 2 focal vascularity focus), and grade 3 (more than 1 linear vascularity focus). According to this grading system, biceps tendinopathy was considered positive in those with flow grades 1, 2, or 3 and negative in those with grade 0 (Figure 3).

The patients' images were transferred to our hospital's image storage (PACS) (Extremepacs, Ankara, Turkey) system. All measurements of the patients, and their characteristics, such as gender, age, biceps tendon thickness, and echogenicity, were recorded in the statistics program.

Statistical Analysis

Statistical Package for the Social Sciences (SPSS), version 16.0 (SPSS Inc, Chicago, IL) was used for all statistical analyses. Quantitative variables are expressed as mean ± standard deviation and categorical variables as frequencies or percentages. Baseline data were evaluated using the Kolmogorov-Smirnov test. Student's t-test was used for group comparisons of continuous variables with normal distribution; otherwise, Mann-Whitney U test was applied. Multiple subanalysis were performed. Pearson correlation analysis was used for the correlation quantitative values. The Wilcoxon signed rank test was used to evaluate differences in median SWE-SMI measurements between the biceps tendon with tendinopathy and the biceps tendon without tendinopathy. The area under the ROC curve and 95% confidence interval were calculated for each ROC curve analysis. For each statistical test, a p-value of 0.05 was considered significant.

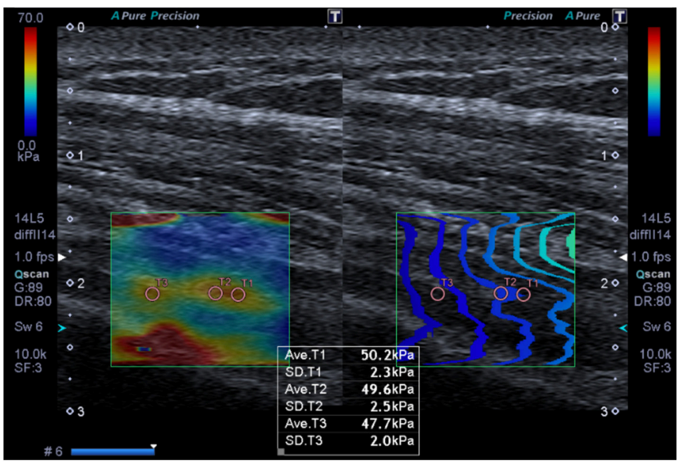

Figure 2. SWE measurement of the tendon of a patient with biceps tendinopathy in the longitudinal plane

SWE: Shear wave elastography

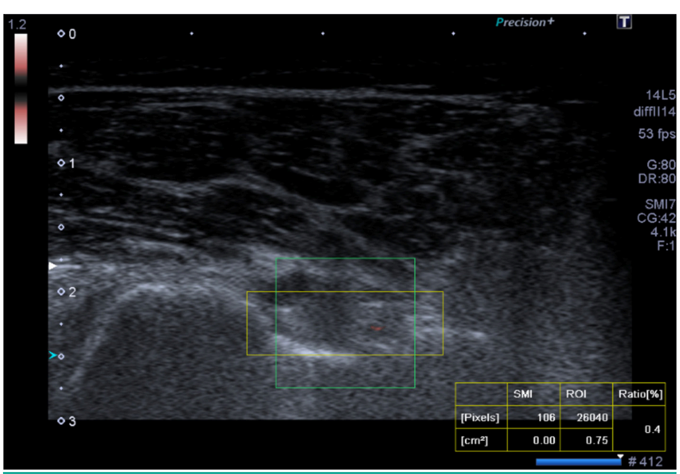

Figure 3. SMI measurement of the tendon of a patient with biceps tendinopathy in the transverse plane

SMI: Superb microvascular imaging

Results

The ages of the cases included in our study ranged between 25 and 83 years (mean: 50.05±16.15). Twenty patients, 12 (60%) females and 8 (47%) males, who met the inclusion criteria were included in the study group. Twenty cases were included in the control group; there were 10 (50%) women and 10 (50%) men.

Demographic data of all cases included in the study are shown in Table 1. The data of conventional US and MRI findings of all cases included in the study are shown in Table 2. Comparison of SWE mean values between the LHBT tendinopathy and control groups is shown in Table 3.

There was a statistically significant difference between the SWE values measured in the transverse plane of the cases with LHBT tendinopathy and the SWE values of the control group measured in the transverse plane. The mean SWE value of the control group (18.41) was significantly lower than the mean SWE value of the tendinopathy cases (37.685) ($p<0.001$).

There was a statistically significant difference between the SWE values measured in the longitudinal plane of the LHBT tendinopathy cases and the SWE values of the control group measured in the longitudinal plane. The mean SWE value of the control group (19.385) was significantly lower than the mean SWE value of the tendinopathy cases (38.715) ($p<0.001$).

Table 1. Demographic data of the patients and control group

	LHBT tendinopathy (n=20)	Control group (n=20)
Gender (F:M)	12:8	10:10
Age (years)	50.05±16.15	47.55±11.9

LHBT: Long head of the biceps tendon

There was a statistically significant difference between the thickness of the cases with LHBT tendinopathy measured on US and MRI and the thickness of the control group measured on US and MRI (p<0.001).

No significant difference was observed between the subcutaneous fat thickness between the skin and tendon of LHBT tendinopathy cases and the subcutaneous fat thickness of the control group (p=0.384).

The average symptom onset time of the patients before US was calculated as 59.25 (±40.4 to 78.0) days. There was no statistically significant correlation between the duration of symptom onset and SWE values measured in the transverse and longitudinal planes (p=0.836).

In the evaluation performed with SMI, intratendinous grade 1, 2, or 3 flow was detected in all cases with tendinopathy. Grade 1 flow was observed in 8 tendinopathy cases, grade 2 flow was observed in 4 cases, and grade 3 flow was observed in 8 cases. According to the ANOVA test, there was a statistically significant difference between the degree of vascularization determined by the SMI method and the average symptom onset in cases with tendinopathy (p<0.001). As the symptom duration increases, the average SMI value decreases; SMI values are high in the acute period (Table 4).

There was no statistically significant difference in terms of SMI values, tendon thickness, and tendon area averages in patients with tendinopathy (p=0.404).

Table 2. Tendon thickness measurements in US and MRI and tendon area measurements in US of patients and control groups

	LHBT tendinopathy (n=20)	Control group (n=20)	p-values
US tendon thickness (mm)	3.168 (±0.0549)	2.6645 (±0.395)	<0.001
MRI tendon thickness (mm)	3.1915 (±0.4216)	2.6755 (±0.4632)	<0.001
Tendon area (cm^2)	0.3085 (±0.045)	0.137 (±0.0249)	

LHBT: Long head of the biceps tendon, MRI: Magnetic resonance imaging, US: Ultrasonography

ROC analysis was performed between LHBT tendinopathy cases and the control group. SWE-kPa values measured in the transverse plane were found to have 85% sensitivity and 85% specificity with a cut-off value of 34.8. It was found to have 65% sensitivity and 70% specificity with a cut-off value of 38.1 in the longitudinal plane (p<0.001; p<0.002) [area under the curve (AUC): 0.823; AUC: 0.923, respectively] (Table 5, Figure 4).

Discussion

LHBT tendinopathy is a tendon injury that occurs as a result of chronic degeneration with an insidious onset, causing pain and functional impairment in the shoulder (3). Tendons experience cycles of damage and repair when they are exposed to more load than they can bear. Damage to type 1 collagen, the main structural component of the tendon, results in loss of normal fibril structure and disorganized fibrils. During the repair process, these damaged areas can heal with fibrosis. As a result, tendon elasticity decreases due to chronic degeneration and fibrosis (3,10,11). These structural changes in the tendon are evaluated on MRI as an increase in the tendon signal associated with the disruption of normal fibril structure. In US examination, there is an increase in tendon thickness, increased echogenicity, and fluid accumulation around the tendon. The SWE method can be used to evaluate the decrease in tendon elasticity, i.e., the increase in its stiffness. In addition, increased vascularity in the tendon is mentioned in tendinopathy cases (12). Studies have reported that the reason for this is that the release of angiogenic factors such as vascular endothelial growth factor increases in the tendon exposed to repetitive stress, resulting in local vascular hyperplasia (12). The Doppler US technique is not sufficient to show neovascularization in the tendon. The SMI method is a new US technique that can successfully demonstrate very small vessels and very low flow velocities.

Our study is usable in daily practice by comparing these current US methods with MRI findings in tendinosis cases.

Seo et al. (13) reported that sonoelastography showed a consistent correlation with conventional US in detecting intratendinous and peritendinous changes in LHBT in cases with symptoms related to biceps tendinopathy.

Table 3. SWE measurement averages of the patient and control groups in the transverse and longitudinal planes

	LHBT tendinopathy		Control group		p-values
	Transverse	Longitudinal	Transverse	Longitudinal	
SWE (kPa)	37.685 (±3.6985)	38.715 (±3.4581)	18.410 (±2.0504)	19.385 (±1.8633)	<0.001

SWE: Shear wave elastography, LHBT: Long head of the biceps tendon

Table 4. Comparison of symptom duration and SMI vascularization degree

SMI degree of vascularization	Symptom duration (days)
Degree 1	101.25 (±7.3649)
Degree 2	52.5 (±8.6603)
Degree 3	20.625 (±12.9387)

SMI: Superb microvascular imaging

Table 5. Receiver operating characteristic analysis results based on the evaluation of the SWE method for predicting biceps tendinopathy

	Cut-off	AUC	p	Sensitivity (%)	Specificity (%)
SWE transverse	>34.8	0.923	<0.02	85	85
SWE longitudinal	>38.1	0.823	<0.01	65	70

SWE: Shear wave elastography, AUC: Area under the curve

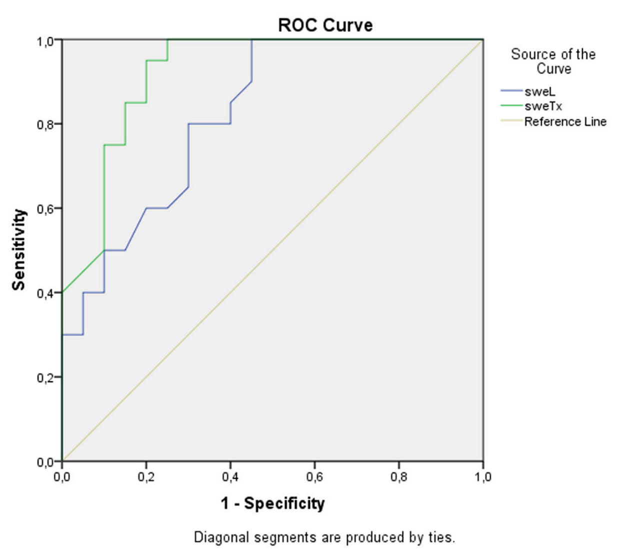

Figure 4. ROC curve
ROC: Receiver operating characteristic

Most studies on the elasticity properties of tendons are related to the Achilles tendon (14-16).

De Zordo et al. (14) compared conventional US and strain elastography methods in distinguishing the changes occurring in Achilles tendinopathy and found that strain elastography was more sensitive in detecting tendon changes before morphological changes appeared on US. In addition, softening of the tendon is observed in cases with tendinopathy compared with healthy volunteers, and they that this situation can be explained by very early changes in the tendon. In our study, we used the SWE method differently, and with this method, we observed an increase in SWE values in tendinopathy cases compared with the control group. We explained this situation with fibrosis that develops because of chronic degeneration in the tendon because of tendinopathy.

Klauser et al. (17) reported that adding sonoelastography findings to conventional US findings in the evaluation of lateral epicondylitis increased the sensitivity in detecting tendon pathology.

De Zordo et al. (18) evaluated the common extensor tendon using the sonoelastography method and stated that changes in the elasticity of the tendons of people with lateral epicondylitis symptoms may be useful in the diagnosis of lateral epicondylitis.

On the other hand, there is no difference between athletes and healthy volunteers in the sonoelastography evaluation of the patellar tendon (19). It has been reported that the sonoelastography technique has high applicability and reproducibility in the evaluation of healthy patellar tendon (20).

In a previous study, the accuracy of the sonoelastography technique in distinguishing tendon changes in patients with supraspinatus tendinopathy was compared with MRI and conventional US, and an excellent correlation was found between these modalities (21).

Many sonoelastography studies have been conducted on tendon pathologies in the evaluation of musculoskeletal system elastography, most of which are comparative studies with US, and most of them used the strain elastography technique. However, studies conducted using the SWE method are limited.

Unlike these studies in the literature, we used the SWE method and increased the reliability and specificity of our study by comparing it with MRI findings, which is a more objective modality.

In the study of Krepkin et al. (22), it was shown that there is a strong correlation between T2* values in MRI of the supraspinatus tendon and SWE values, and thus it was that it may allow a more quantitative evaluation of the rotator cuff tendons. Turkay et al. (23) evaluated tendons and found elasticity values to be lower in tenosynovitis cases than in healthy individuals. In our study, we observed higher elasticity values in patients with tendinopathy using the SWE method. We believed that this situation was related to the chronic process of the disease.

Color Doppler imaging methods have some limitations in showing small vessels and blood flow. It is insufficient to show thin vessels in the neovascularization that occurs in cases of tendinopathy. Zanetti et al. (24) reported that power Doppler imaging was insufficient to evaluate neovascularization in the tendon in cases with Achilles tendinopathy. To overcome these limitations, a new Doppler method, SMI, has been developed.

In the study by Arslan et al. (25), SMI was shown to have high accuracy rates in demonstrating common extensor tendon neovascularization in lateral epicondylosis cases, and a significant relationship was found between the SMI method and neovascularization and symptom duration. It has been reported that the degree of SMI decreases as the acute period progresses to the subacute period. In our study, an increase in vascularization was observed in patients with tendinopathy, and results consistent with the literature were found between symptom duration and vascularization. This may be due to inflammation in the acute phase.

Tendon studies with SMI are limited, and we believe that we have enriched our study by using the SMI method in addition to SWE. There are studies in the literature that use SWE and SMI methods together in the evaluation of breast, thyroid, lymph nodes, and testicles (26-28), but there is no study that we know of that uses the two methods in tendon evaluation.

According to our study, when we compared the results of tendinopathy cases evaluated with SMI and SWE methods with existing MRI findings, we obtained similar results, demonstrating the usability and reliability of these methods.

Study Limitations

There are a few limitations to our study. The first of these is the small number of patients, and we believe that more quantitative values can be found in large series studies. Our other limitation factors are that the majority of patients with biceps tendon pathology are associated with rotator cuff pathologies, and the effects of fluid in the tendon sheath on SWE and SMI results cannot be predicted. In addition, only MRI examination was used for comparison. More reliable information regarding the degree of tendinopathy can be provided with additional comprehensive studies using arthroscopy and histological findings.

Conclusion

The combined use of SMI and SWE in addition to conventional US may be useful diagnostic methods as easy and practical techniques in the evaluation of the tendon in cases with LHBT tendinopathy. SMI and SWE may be useful diagnostic tools for LHBT tendinopathy, considering their availability, cost-effectiveness, and patient preference compared with MRI.

Ethics

Ethics Committee Approval: Ethics committee approval numbered 2019/184 was obtained from the Trakya University's Ethics Committee for our prospectively designed study.

Informed Consent: Prospective study.

Authorship Contributions

Concept: F.U., G.B., B.G., C.B.A., F.E.U., Design: F.U., G.B., B.G., C.B.A., F.E.U., Data Collection or Processing: F.U., G.B., B.G., C.B.A., F.E.U., Analysis or Interpretation: F.U., G.B., B.G., C.B.A., F.E.U., Literature Search: F.U., G.B., B.G., C.B.A., F.E.U., Writing: F.U., G.B., B.G., C.B.A., F.E.U.

Conflict of Interest: No conflict of interest was declared by the authors.

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