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Original Article

Management of rotator cuff calcific tendinosis guided by ultrasound elastography

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Abstract

Background: Ultrasound (US) elastography can provide information about the hardness of calcification and might help decide treatment strategy. The purpose of this study was to evaluate the hardness of the calcific area within rotator cuffs by US elastography as an aid for the selection of aspiration or fine-needle repeated puncture for the treatment of rotator cuff calcific tendinosis.
Methods: This prospective study included 39 patients (32 males, 7 females; mean age, 52.9 years) who received US elastography and gray-scale ultrasonography before US-guided treatment for rotator cuff calcific tendinosis. The morphology of the calcifications was classified as arc, fragmented, nodular, and cystic types. US elastography using virtual touch imaging (acoustic radiation force impulse) technique was performed to examine the calcified region to obtain an elastogram that was graded dark, intermediate, or bright. The hardness of the calcifications were recorded, and graded as hard, sand-like, or fluid-like tactile patterns during the US-guided treatment, and the tactile patterns were compared with the results of US elastography and gray-scale ultrasonography.
Results: Though the morphologies of the calcifications were significantly related to the tactile pattern of the needle punctures ($p < 0.001$), gray-scale US could not accurately demonstrate the hardness of the calcifications. With the aid of elastography, the fluid-like tactile pattern could be predicted well as a nondark pattern by elastography ($p < 0.001$).
Conclusion: Ultrasound elastography is a useful modality for evaluation of rotator cuff calcific tendinosis, and as an aid to guide management. If elastography shows the calcified area as a non-dark pattern, then fine-needle aspiration should be performed.

Keywords: calcific tendinosis; fine-needle repeated-puncture treatment; rotator cuff; ultrasound elastography

1. Introduction

Rotator cuff calcific tendinosis is one of the common tendon degenerative conditions, occurs more commonly on the supraspinatous tendon,[1] and usually causes inflammation and pain over the shoulder region. It has been reported that chronic or acute calcific tendinitis is predominantly caused by the deposition of hypdroxyapatite in the periarticular tendon.[2] Calcific tendinosis can be diagnosed by plain radiography, gray-scale ultrasonography (US), computed tomography (CT), or magnetic resonance imaging (MRI). On gray-scale US, calcific tendinosis may be categorized as arc, fragmented, nodular, and cystic types.[3] On the basis of hemodynamic changes, there is also a good correlation between color Doppler US (CDUS) and clinical symptoms of pain, and the

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prognosis of calcification can be predicted from CDUS findings.[3,4] The management of rotator cuff calcific tendinosis is varied, and treatments include physical therapy with a short course of oral nonsteroid anti-inflammatory drugs,[1] lithotripsy by arthroscopy[5,6] or an imaging-guided fluoroscopic procedure,[7,8] extracorporeal shockwave therapy,[9,10] and US-guided techniques.[3,4,11–16] In order to perform a single- or double-lavage technique, more needles or larger needles should be inserted, which can result in tendon injury. In our previous study, US-guided fine-needle aspiration or repeated puncture resulted in marked clinical improvement and marked decreases in the size of calcifications or complete disappearance in 80% of patients.[4] However, some patients with rotator cuff calcific tendinosis had liquefied calcium deposition, which could be aspired for relief of symptoms, and US-guided fine-needle repeated puncture was not necessary.[4]

Ultrasound elastography was introduced in 1991,[17] and started to be used clinically in 1997, especially for breast lesions.[18] Most applications have used free-hand external compression of the tissue through an imaging transducer or vascular balloon.[19] With free-hand manual techniques, some US equipment can provide relatively high-energy sound waves for tissue compression, such as those achieved with acoustic radiation force impulse (ARFI) equipment from the Siemens company, Mountain View, CA, USA. Such equipment is associated with the advantage of less operator dependency because of the consistent pressure. After reviewing the literature, we found no previous study of elastography applied to the evaluation of rotator cuff calcific tendinosis.

Ultrasound elastography could provide information about hardness of the calcification and might help decide the treatment strategy. The purpose of this study was to evaluate the hardness of calcifications within the rotator cuff by US elastography using the ARFI technique, and examine its utility as an aid for the selection of aspiration or fine-needle repeated-puncture treatment.

2. Methods

2.1. Patients

This was a prospective study involving patients who were referred from the outpatient departments of orthopedics or rehabilitation due to shoulder pain for more than 6 months. The primary inclusion criterion was the presence of calcifications within the rotator cuff confirmed by gray-scale ultrasonography. The exclusion criteria were previous invasive treatment for calcifications within the rotator cuff including lithotripsy by arthroscopy or other imaging-guided procedure and extracorporeal shockwave therapy. Patients with concomitant rotator cuff tears were also excluded. A total of 39 patients (32 males, 7 females; mean age, 52.9 years) receiving US elastography and an US-guided procedure for rotator cuff calcific tendinosis were enrolled from October 2010 to December 2011. All patients received US elastography and gray-scale ultrasonography immediately before the US-guided treatment for rotator cuff tendinosis was performed. The hardness of calcifications was recorded as three tactile patterns by the operator during the US-guided treatment, and the tactile patterns were compared with the US elastography and gray-scale ultrasonography results. All patients provided written consent for the US-guided procedure for treatment of rotator cuff calcific tendinosis. Investigative and interventional procedures were performed according to the guidelines of the Declaration of Helsinki, and were approved by the Institutional Review Board in Taipei Veterans General Hospital.

2.2. Ultrasound elastography

US elastography using the ARFI Virtual Touch Imaging system (ACUSON S2000; Siemens, Mountain View, CA, USA) was performed with the 9L4 linear transducer, and applied to the calcified region to obtain a colored static elastogram. All patients received gray-scale ultrasonography and US elastography before the US-guided procedure. The morphology of calcifications on high-resolution ultrasonography (HRUS) was classified into four types: arc shaped (an echogenic arc with clear shadowing); fragmented (at least 2 separate echogenic spots with or without shadowing); nodular (an echogenic nodule without shadowing); and cystic (a bold echogenic wall with an anechoic area, weak internal echoes, or layering content).[3] An oval circle was manually drawn by the operator within the calcification in the gray-scale image, which then was reflected to the same area in the elastogram just beside the gray-scale image. The encircled area was no larger than the calcification. All of the images were stored in the Picture Archiving and Communication System (PACS) system. The hardness of calcifications were represented by the brightness of the encircled area in the elastography, and the brightness was calculated and recorded as a histogram from zero (darkest region) to 255 (brightest region) using Image J software version 1.44 (National Institutes of Health, Bethesda, MD, USA). The histogram values were graded as dark (0–85), intermediate (86–170), and bright (171–255). The darker the elastography image, the greater the hardness of the calcification. All US examinations were performed and elastograms interpreted by the author (HJC), who had more than 20 years' experience of ultrasonography and 15 years' experience in musculoskeletal ultrasonography.

2.3. The hardness of calcifications determined by US-guided treatment for rotator cuff calcific tendinosis

All patients received repeated puncture or aspiration with a 3.8-cm #21 needle attached to a 10-mL syringe. An US-guided free-hand method was used to place the needle tip above the calcified lesion, which was then punctured repeatedly by moving the needle back and forth. No large-needle lavage was performed in this study. Before the procedure, the skin of the puncture site was sterilized with povidone-iodine, and the transducer was covered with a sterilized plastic bag. Less than 2 mL of 2% xylocaine was injected in the subcutaneous and muscle layer. When the US-guided aspiration was performed,

removal of >50% of the calcifications was defined as successful aspiration. When US-guided repeated puncture was performed, the needle was moved back and forth 20–40 times according to the size of the calcification without removing the needle from the initial skin puncture site. The needle tract was monitored by HRUS to make sure the needle penetrated the calcification with each puncture. After the procedure, 2 mL of 2% xylocaine was injected into the subdeltoid bursa.

The puncture site was bandaged, and hand compression administered by the patients for 15 minutes, after which the patients were sent home. The patients were recommended to actively exercise the affected shoulder the next day and thereafter for some time following the procedure.[3,4] The hardness of the calcified lesion was recorded by the operator and graded as hard, sand-like, and fluid-like tactile patterns. During US-guided treatment, aspiration was performed first because successful aspiration was one of the tactile patterns. If > 50% of the calcifications could be aspirated, it was recorded as a fluid-like pattern. If ≤ 50% of the calcifications could be aspirated, US-guided repeated puncture was performed, which was recorded as a hard or sand-like pattern. The hard tactile pattern that was defined as calcifications was hardly broken by repeated punctures. The sand-like pattern was defined as calcifications that were easily broken into small fragments but could not be aspirated. Therefore, the hard and sand-like tactile patterns were treated with US-guided repeated punctures, whereas the fluid-like tactile pattern was treated with US-guided aspiration. The US-guided procedure for rotator cuff tendinosis was also performed by the author (H.J.C.).

2.4. Statistical analysis

The tactile patterns were compared with the imaging findings of US elastography and gray-scale ultrasonography, and were compared with the morphology of the calcifications observed on gray-scale US. The morphology of the calcifications was observed on gray-scale US, and tactile patterns were compared with US elastography histogram results. Fisher's exact test was used to test the significance of the results using SPSS, version 17 for Windows (SPSS Inc., Chicago, IL, USA). Results with $p < 0.05$ were considered to be statistically significant.

3. Results

3.1. Tactile patterns compared with calcification morphology

By US, there were 13 arc, five fragmented, 16 nodular, and five cystic morphological types of rotator cuff calcification. The tactile pattern of the needle puncture findings showed that all of the arc morphological types were of the hard tactile pattern. All of the cystic morphological type had a fluid-like tactile pattern, and could be aspirated. Of the fragmented morphological type, four exhibited the sand-like tactile pattern. One patient presented with a fluid-like tactile pattern, which could be aspirated. Of the nodular morphological type, three had a hard tactile pattern and seven a sand-like tactile pattern. Six patients had a fluid-like tactile pattern, which could be aspirated (Table 1). The morphology of the calcifications was significantly related to the tactile pattern of the needle punctures ($p < 0.001$). However, the tactile pattern of repeated punctures could not be predicted accurately by the morphology of the calcifications by gray-scale US alone.

3.2. Morphology of calcifications compared with ultrasound elastography

The histogram findings of US elastography showed that all of the 13 arc morphological types had a dark appearance (Fig. 1). The five fragmented morphological types presented as dark (Fig. 2) in four patients, and as bright in one patient (Fig. 3). The 16 nodular morphological types presented as dark in 10 patients, intermediate in four patients, and bright (Fig. 4) in two patients. The five cystic morphological types presented as intermediate in three patients and bright in two patients (Fig. 5 and Table 2). The morphology of the calcifications was significantly related to US elastography ($p = 0.001$). However, the US elastography could not be predicted by the morphology of the calcification, except the arc type always presented as the dark pattern.

3.3. Tactile patterns compared with US elastography

The tactile pattern of needle punctures showed that 16 patients had hard tactile patterns, all of which presented with dark histograms, and 11 patients had sand-like tactile patterns, all of which also presented with dark histograms. Of the 12 patients who had a fluid-like tactile pattern that allowed aspiration, seven presented with intermediate and five with bright histogram patterns (Table 3). The tactile pattern of the needle punctures was significantly related to US elastography ($p < 0.001$). In addition, there was a significant difference between the tactile pattern of the needle punctures and the elastography findings when the tactile patterns were simplified to only nonfluid and fluid-like patterns; in this case, elastography findings were simplified to dark and nondark, respectively. The fluid-like tactile pattern could be predicted by a nondark pattern by elastography. All patients who received US-guided repeated punctures or aspiration had decreased calcifications within the rotator cuff, and pain relief. No complications such as bleeding, infection, or ligament tear were noted.

Table 1
Relationship between ultrasound calcification morphology and the tactile pattern of repeated puncture ($p < 0.001$).

Ultrasound morphology	Tactile pattern		
	Hard	Sandy	Fluid
Arc	13	0	0
Fragmented	0	4	1
Nodular	3	7	6
Cystic	0	0	5

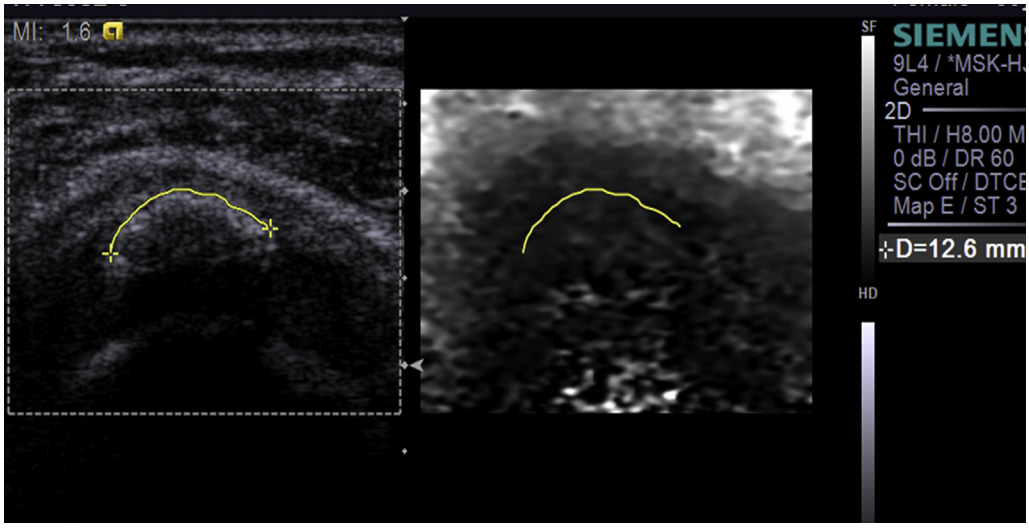

Fig. 1. Imaging studies from a 56-year-old woman who complained of right shoulder pain for 6 months. Gray-scale ultrasound (US) showed arc-type calcific (curved line) tendinosis within the rotator cuff, and elastography exhibited a dark pattern (curved line). The patient received US-guided repeated puncture, and had pain relief 6 months later.

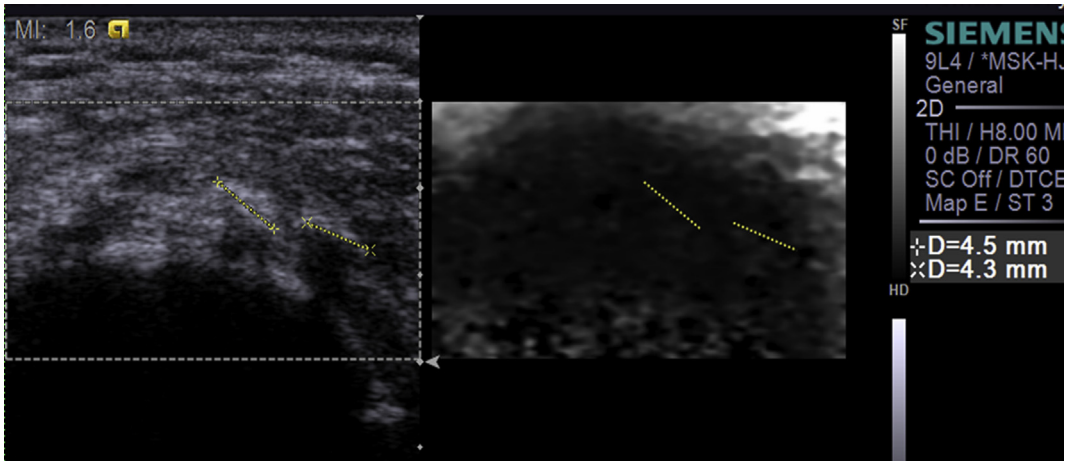

Fig. 2. Imaging studies from a 57-year-old woman who complained of severe left shoulder pain for 1 year. Gray-scale ultrasound (US) showed fragmented calcific tendinosis (dotted line), and elastography exhibited a dark pattern (dotted line). The patient received US-guided repeated puncture, and had pain relief.

4. Discussion

ARFI elastography has been investigated in many studies, and applied to evaluate many organs, such as liver, thyroid, breast, and kidney.[20–24] However, the application of ARFI elastography to evaluate rotator cuff calcific tendinosis has not been explored. In our study, the hardness of the calcifications was recorded as three tactile patterns during US-guided treatment, and the tactile patterns were compared with the results of US elastography and gray-scale ultrasonography. The results showed that when elastography depicted the calcified area as a nondark pattern, the calcification could be aspirated, and aspiration was enough to relieve symptoms and US-guided repeated punctures were not necessary. For the patients who received repeated punctures, most complained of severe pain for $\geq$1 week after this procedure, whereas for those who received aspiration, most had pain relief instantly. Elastography had an additive value in the treatment selection for calcific tendinosis.

On the one hand, when the morphology of the calcifications on gray-scale US were compared with the tactile patterns, arc-shaped calcifications were associated with a hard tactile pattern of needle puncture, which indicates that the calcium hydroxyapatite deposit was very compact. On the other hand, the cystic type was characterized by liquefied calcific deposition, which might be due to an acute reaction of the surrounding tissue to the calcium hydroxyapatite. In these cases, the liquefied calcific deposition had the fluid-like tactile pattern and could be aspirated.

Though gray-scale US was able to predict the hard tactile pattern in arc-type calcific tendinosis, and the fluid tactile pattern in cystic-type calcific tendinosis, it was not useful for predicting the fragmented and nodular types of calcific tendinosis. Aspiration could be performed in one of the patients

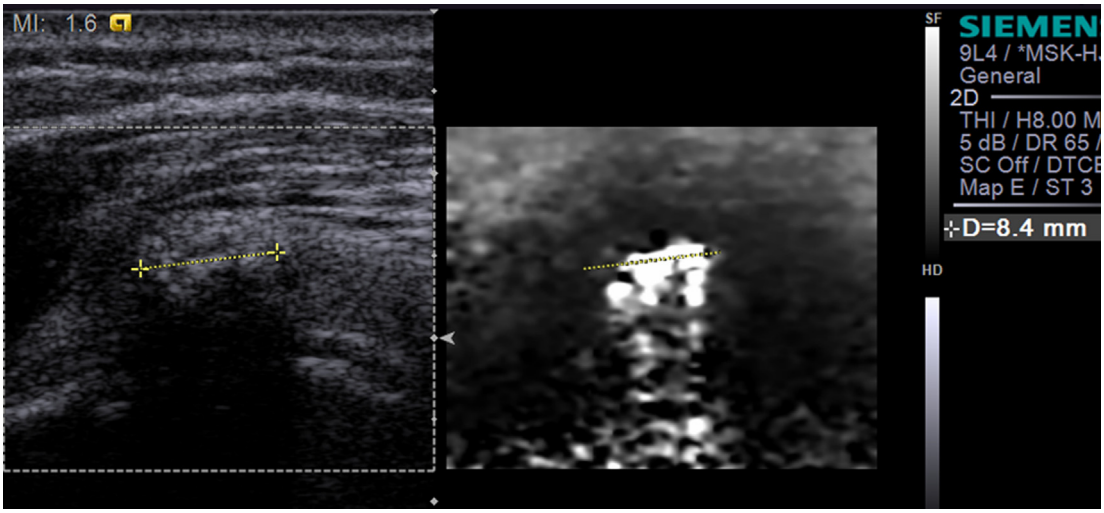

Fig. 3. Imaging studies from a 52-year-old woman who complained of left shoulder pain for 1 year. Gray-scale ultrasound (US) showed fragmented calcification (dotted line), and elastography exhibited a bright pattern (dotted line). This patient received US-guided aspiration, and had pain relief.

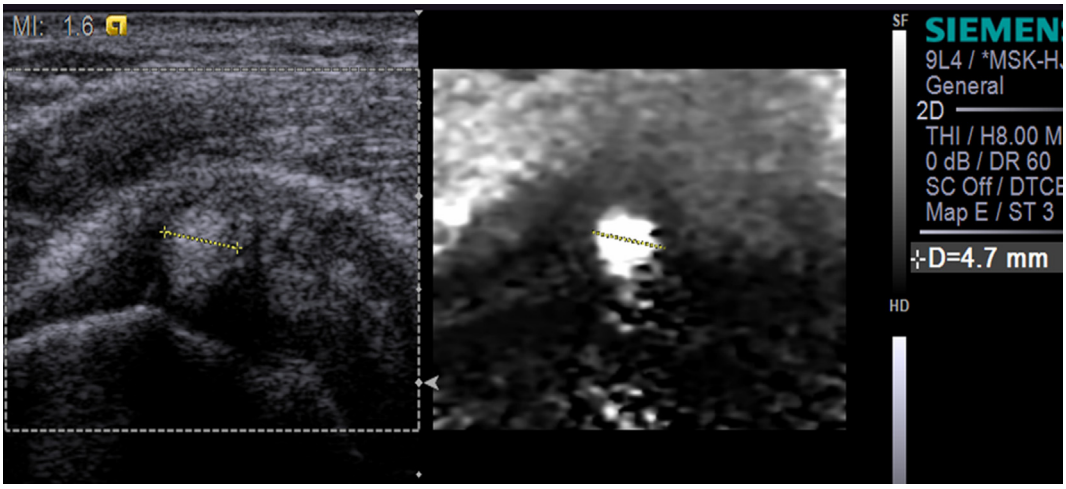

Fig. 4. Imaging studies from a 52-year-old woman who complained of severe right shoulder pain for 8 months. Gray-scale ultrasound (US) showed echogenic nodular type calcific tendinosis (dotted line), and elastography exhibited a bright pattern (dotted line). This patient received US-guided aspiration and had pain relief.

with fragmented-type calcific tendinosis, whereas the rest needed US-guided repeated punctures. In cases of nodular-type calcific tendinosis, six could be aspirated to relieve symptoms, whereas the rest required US-guided repeated punctures. This study also showed that nodular-type calcific tendinosis could have a hard needle puncture tactile pattern, which results from compact accumulations of calcium hydroxyapatite as arc-shaped calcifications. This phenomenon could be due to calcium hydroxyapatite deposition from the center to the periphery; therefore, the center of the calcification would be more compact than the periphery. For this reason, the needle puncture tactile pattern of fragmented and nodular types of calcific tendinosis could not be predicted by gray-scale US.

The management of fragmented and nodular type calcific tendinosis was limited based on gray-scale US alone. In this situation, ultrasound elastography was helpful to guide the appropriate management. When the morphology of the calcifications were compared with the elastography histograms, one of the patients with fragmented type calcific tendinosis who received aspiration exhibited the bright histogram pattern, whereas the others who received US-guided repeated puncture exhibited the dark pattern. As for the nodular type of calcific tendinosis, six of the patients who received aspiration exhibited an intermediate or bright pattern, whereas the rest who required US-guided repeated puncture exhibited the dark pattern. In addition, all arc-types exhibited the dark pattern, and all cystic-types exhibited the bright pattern at elastography.

When the elastography was compared with the tactile patterns, elastography that exhibited the dark pattern had either the hard or sand-like tactile pattern of needle puncture. Therefore, if elastography showed a dark pattern, then US-guided repeated puncture was performed. All of the

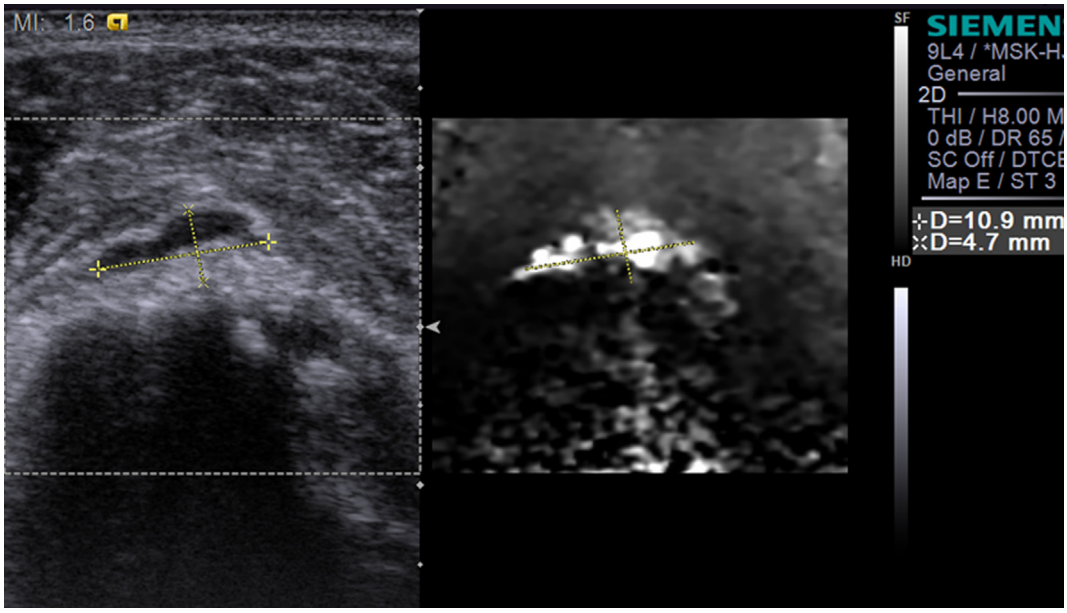

Fig. 5. Imaging studies from a 57-year-old man who complained of severe right shoulder pain for 6 months. Gray-scale ultrasound (US) showed cystic type calcific tendinosis (dotted line), and the elastography exhibited a bright pattern (dotted line). This patient received US-guided aspiration and had pain relief.

Table 2
Relationship between ultrasound calcification morphology and elastography histogram ($p = 0.001$).

Ultrasound morphology	Elastography		
	Dark	Intermediate	Bright
Arc	13	0	0
Fragmented	4	0	1
Nodular	10	4	2
Cystic	0	3	2

Table 3
Relationship between the tactile pattern and elastography histogram ($p < 0.001$).

Tactile pattern	Elastography		
	Dark	Intermediate	Bright
Hard	16	0	0
Sand	11	0	0
Fluid	0	7	5

intermediate- and bright-pattern elastograms were associated with the fluid-like tactile pattern, which means that there was some liquefied material retained in the calcified area that required aspiration to achieve decompression, which provided symptom improvement. Therefore, more useful information for the management of calcific tendinosis was provided by US elastography than by gray-scale US alone; there was an additive value when gray-scale US and US elastography were combined to evaluate calcific tendinosis. Though gray-scale US was able to predict the management of arc-type and cystic-type calcific tendinosis, elastography also provided the same information. However, gray-scale US was not able to predict the management of fragmented-type and nodular-type calcific tendinosis, whereas the elastography could provide helpful information for the management of these types.

This study has limitations that should be considered. First, the sample size was small, especially the number of patients with cystic- or fragmented-type calcifications. Second, the management in this study was US-guided repeated puncture or aspiration. No other treatment, such as large-needle lavage or extracorporeal shockwave therapy, was performed.

In conclusion, US elastography is a useful modality for evaluation of rotator cuff calcific tendinosis, and an aid to guide management. We recommend that US elastography be performed for all patients with calcific tendinosis, except for those with the arc morphological type, before making management decisions. If elastography shows that the calcified area is the nondark pattern, then fine-needle aspiration should be performed to relieve the symptoms.

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