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ORIGINAL ARTICLE

Sonographic evaluation of the association between calcific tendinopathy and rotator cuff tear: a case-controlled comparison

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Abstract

Objectives To compare the incidence of rotator cuff (RC) tears on shoulder ultrasounds of patients with RC calcific tendinopathy (CaT) to that of a control group without CaT.

Method In this retrospective case-control study, 50 shoulder ultrasounds of patients with CaT were compared independently by 2 musculoskeletal radiologists to 50 patients from a control group without CaT to catalog the number and type of RC tears. RC tears in the CaT group were further characterized based on location, into tears in the specific tendon(s) containing calcium versus all tendon tears.

Results RC tears were diagnosed in 38% (19/50) of the control group (16 full-thickness) as compared to 22% (11/50) with CaT (6 full-thickness). The fewer full-thickness tears in the CaT group (12%, 6 of 50) compared to that in the control group (32%, 16 of 50) was statistically significant ($P = 0.016$, odds ratio 0.29). Only 7 of the 11 tears in the CaT group were in a calcium-containing tendon (3 full-thickness). The fewer calcium-containing tendon tears compared to tears in the control group was also statistically significant ($P = 0.006$, odds ratio 0.27). Furthermore, the fewer full-thickness calcium-containing tendon tears (6%, 3/50) compared to full-thickness tears in the control group (32%, 16/50) were yet more statistically significant ($P = 0.001$, odds ratio 0.14).

Conclusions In patients with shoulder pain and CaT, we observed a decreased number of RC tears and especially calcium-containing tendon tears, as compared to similar demographic patients with shoulder pain but without CaT.

Key Points

- *Patients with rotator cuff calcific tendinopathy have few rotator cuff tears, especially full-thickness tears, compared to a control group without calcific tendinopathy.*
- *The tendons containing the calcium hydroxyapatite deposition were the least likely to have a rotator cuff tear.*
- *Future studies could evaluate if calcium hydroxyapatite deposition provides a protective mechanism against rotator cuff tears.*
- *Musculoskeletal ultrasound is more sensitive than MRI in the evaluation of rotator cuff calcific tendinopathy.*

Keywords Calcific tendinopathy · Calcium hydroxyapatite deposition · Musculoskeletal ultrasound · Rotator cuff tear · Shoulder

Abbreviations

CaT calcific tendinopathy
$CI_{95\%}$ 95% confidence interval
MRI magnetic resonance imaging
MSK musculoskeletal
RC rotator cuff
US ultrasound

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Introduction

Calcific tendinopathy (CaT) is a common disorder wherein calcium hydroxyapatite deposits in tendons. The rotator cuff (RC) is most commonly affected, and 80% of the time involves the supraspinatus tendon [1–6]. It is one of the most common causes of non-traumatic shoulder pain with a prevalence of up to 7.5% of adults, with middle-aged to elderly women mostly affected [1–4]. The exact cause and pathogenesis remain unclear, but hypotheses include hormonal factors, metabolic or endocrine diseases, and genetic predisposition [1, 3, 6, 7]. There are 3 distinct stages of CaT: pre-calcific, calcific, and post-calcific. The calcific stage is subdivided into the formative, resting, and resorptive phases. Patients most commonly seek medical attention during the especially painful, resorptive phase [1, 2, 8–11].

The relationship between CaT and RC tear is controversial given the differing findings in the literature [8, 12]. Studies published as early as the 1950s demonstrated that RC tears in the presence of CaT are rare [13–17]. Conversely, both older and very recent studies report that RC tears are not uncommon with CaT [9, 18–22]. With the exception of only one study focused on Doppler, these studies had all been performed without advanced imaging or by utilizing magnetic resonance imaging (MRI) [8].

However, MRI has been shown to have a low sensitivity and limitations for the detection of RC CaT and can misconstrue CaT for severe tendinosis or even a tear (Fig. 1). Consequently, MRI is not recommended as a first-line imaging modality for RC CaT [1, 9, 19, 22–29].

Musculoskeletal (MSK) ultrasound (US) utilization, especially at shoulder level, has significantly increased over the past few decades [30, 31]. Multiple studies have shown US to be more sensitive than MRI in the evaluation of RC CaT [24–26]. Also, contrary to traditional teaching, US can better delineate the stages and phases of CaT, especially the painful resorptive phase (Figs. 1 and 2) [1, 4, 9, 19, 23–28, 32–34]. Furthermore, multiple studies have demonstrated that US is comparable to MRI for the evaluation of RC tears and subsequently, in many institutions has become the imaging modality of choice for shoulder pain [4, 26, 32, 35–37].

In this first study of its kind, we found it imperative to further elucidate the relationship between CaT and RC tears utilizing shoulder US, in an attempt to help clarify the conflicting literature. We hypothesized fewer RC tears, especially full-thickness tears, in the presence of RC CaT.

Materials and methods

This study was performed in accordance with the ethical standards of our institutional research committee and with the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards. Institutional review board approval was obtained for this retrospective study, and informed consent was waived (Henry Ford Health System IRB # 12367, July 13, 2018). Our study complied with the Health Insurance Portability and Accountability Act.

Selection of study cohorts This retrospective study had a target population including all adult patients from April to July 2018 found by chart review and review of the radiology information system database to have had a shoulder US for an indication of shoulder pain. This resulted in 779 patients with a shoulder US examination. All the examinations had been initially interpreted by 1 of 7 fellowship-trained MSK radiologists, all of whom are highly skilled in MSK US performance and interpretation (clinical experience ranging from 10 to 33 years). These examinations were performed and interpreted in real-time, prior to any knowledge of this study.

Exclusion criteria by search of these US reports and chart review consisted of those patients with a prior RC repair, a history of gout or calcium pyrophosphate deposition disease, and those US shoulder examinations that were limited to only a portion of the shoulder for the purposes of an US-guided injection. The resultant 613 patients' shoulder US examinations were then separated by an MSK radiology fellow into two groups based on the initial MSK radiologists' report and divided into those diagnosed with RC CaT (n = 58) and those without CaT (n = 555), regardless of the presence or absence of a RC tear.

The final study cohorts consisted of such: one group comprised of 50 randomly selected patients from those with RC CaT using a random number generator, and the other group, a control group of 50 patients from those without CaT; age- and gender-matched by randomizing the 555 patients and using frequency matching, with age being grouped by decade (Fig. 3). Demographic information about age and gender were recorded for these 100 patients.

Using that sample size along with a 2-sided alpha level of 0.05, the chi-square test would result in a statistical power of 0.80 to detect an underlying group difference of 0.05 versus 0.25 for the proportion of patients with RC tears. Within each group, the patients' examinations were placed in a randomized order with a randomly assigned number. The US examination images were also placed in the original presentation state so that all image markings were removed.

Sonographic examinations All shoulder US examinations from these 100 patients were performed by trained dedicated MSK sonographers, all of whom possess the registered MSK sonographer (RMSKS) designation through the American Registry for Diagnostic Medical Sonography (Rockville, MD). For each patient, a complete shoulder US was performed utilizing 9–15-MHz linear transducers (GE LOGIQ E9 unit; General Electric Company, Milwaukee, WI).

The complete shoulder US protocol at our institution includes static and cine imaging of the long head biceps tendon, all rotator cuff tendons, the subacromial-subdeltoid bursa, the acromioclavicular joint, the posterior glenohumeral joint including the posterior superior glenoid labrum, the spinoglenoid notch, and the rotator cuff muscle bellies. Dynamic maneuvers are included to evaluate for subacromial and subcoracoid impingement and to evaluate for long head bicep tendon subluxation.

Examination review and categorization Those 100 shoulder US examinations were then randomly reevaluated and categorized independently by 2 fellowship-trained MSK radiologists (11 years and 3 years of clinical experience, respectively),

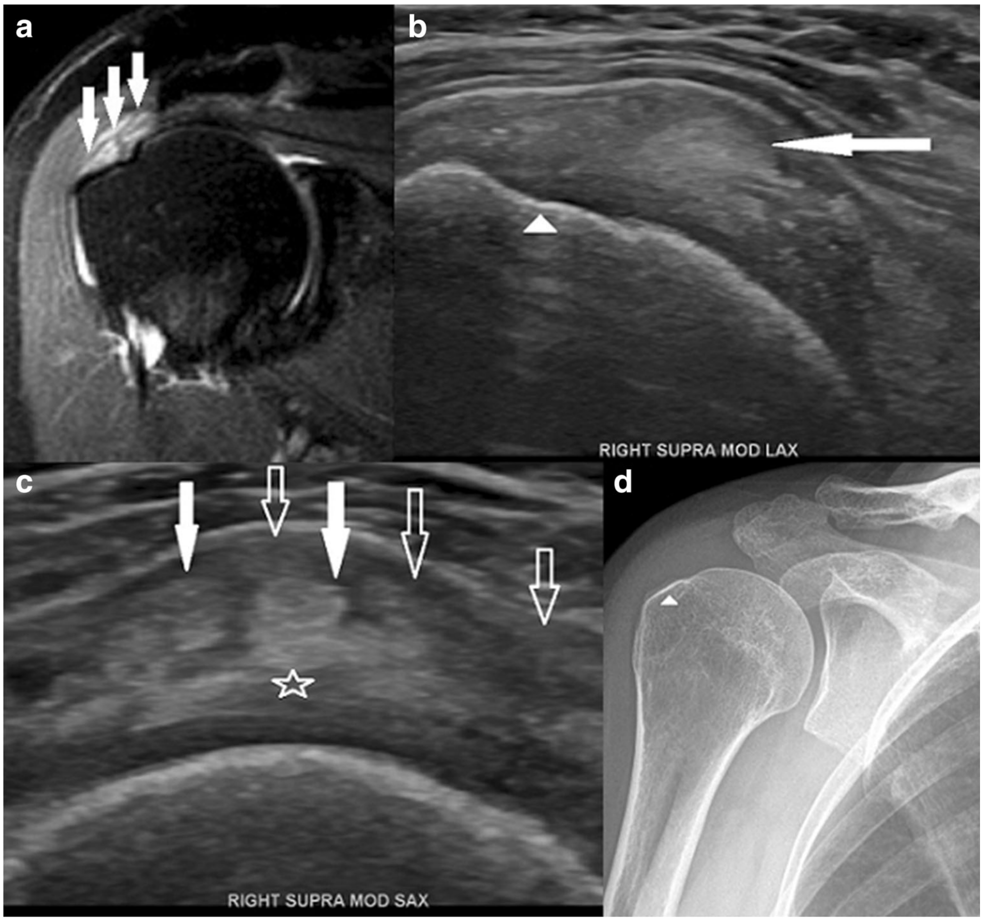


Fig. 1 Multi-modality imaging of a 58-year-old woman presenting with severe right shoulder pain. (**a**) Coronal T2-weighted magnetic resonance image of the right shoulder displaying diffuse increased T2-weighted signal within the supraspinatus tendon (arrows), diagnosed as severe tendinosis with likely high-grade intrasubstance partial-thickness tearing without mention of calcific tendinopathy. Note, the adjacent hyperintense fluid extending along the lateral aspect of the supraspinatus tendon consistent with an associated subacromial-subdeltoid bursitis. (**b**) Long-axis (LAX) and (**c**) short-axis (SAX) sonographic images of the same right shoulder, clearly demonstrating multiple amorphous non-shadowing isoechoic to slightly echogenic foci (solid arrows) within the supraspinatus (SUPRA) tendon (star) partially extending into the adjacent complex distended subacromial-subdeltoid bursa (open arrows) and resulting in a poorly defined junction of the tendon bursal surface and the bursa itself. Sonographic findings are consistent with supraspinatus calcific tendinopathy in the resorptive phase of the calcific stage with an associated subacromial-subdeltoid calcific bursitis. The arrowhead points to the greater tuberosity, and MOD indicates modified (Crass position). (**d**) Anteroposterior (Grashey) radiograph of the same shoulder shows no corresponding calcific foci adjacent to the greater tuberosity (arrowhead) consistent with radiographically occult supraspinatus calcific tendinopathy in the resorptive phase

who both have specific training and experience with MSK US. These 2 MSK radiologists independently reviewed the static and cine images of each of the 100 shoulder US examinations in a random order to determine the number of RC tears including full-thickness tears and all types of partial-thickness tears. These radiologists were not involved in the initial interpretation and were blinded to the patients' histories, study cohort, radiologists' initial reports, sonographers' notes, and any image markings.

A full-thickness tear was reserved for those with a hypoechoic or anechoic defect, communicating from the bursal surface to the articular surface, whether with or without tendon retraction (Fig. 4). Partial-thickness tears were diagnosed in those RC tendons with hypoechoic volume loss, not meeting full-thickness criteria. These partial-thickness tears were then further characterized as bursal-sided, articular-sided, or intrasubstance partial-thickness tears, depending on the portion of the tendon involved. RC tendinosis was ascribed to those not meeting criteria for either a full-thickness or a partial-thickness tear and with a heterogeneously hypoechoic RC tendon(s) without volume loss to suggest a RC tear [4, 30].

Additionally, RC tears in the CaT group were further characterized, based on location, into tears in the specific tendon(s) containing calcium hydroxyapatite versus all tendon tears, with or without calcium (Fig. 5). This categorization was done to ensure that the overall number of tears in the CaT group was not artificially lowered by evaluating a fewer number of tendons per patient. This was also done to preliminarily test the hypothesis of calcium deposition protecting a tendon against

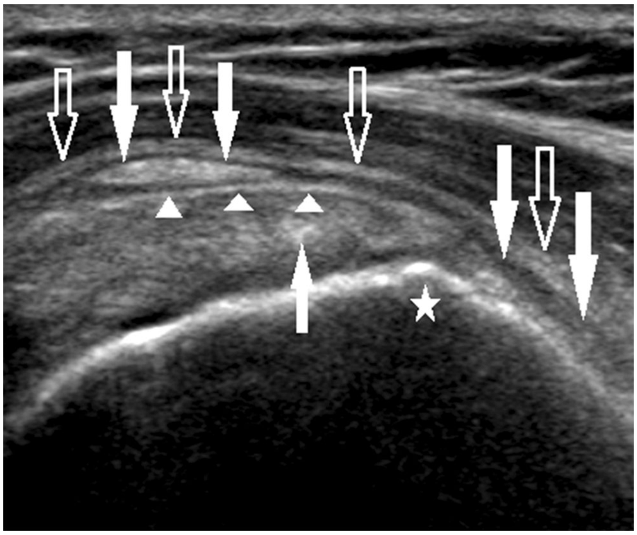


Fig. 2 Long-axis sonographic image of a 60-year-old man also demonstrating left supraspinatus calcific tendinopathy in the resorptive phase with associated calcific bursitis. The calcific deposits (solid arrows) are seen as slightly hyperechoic foci within the supraspinatus tendon and the distended subacromial-subdeltoid bursa, extending lateral to the greater tuberosity (star). The defined bursa lies between the supraspinatus tendon bursal surface (arrowheads) and the peribursal fat (open arrows)

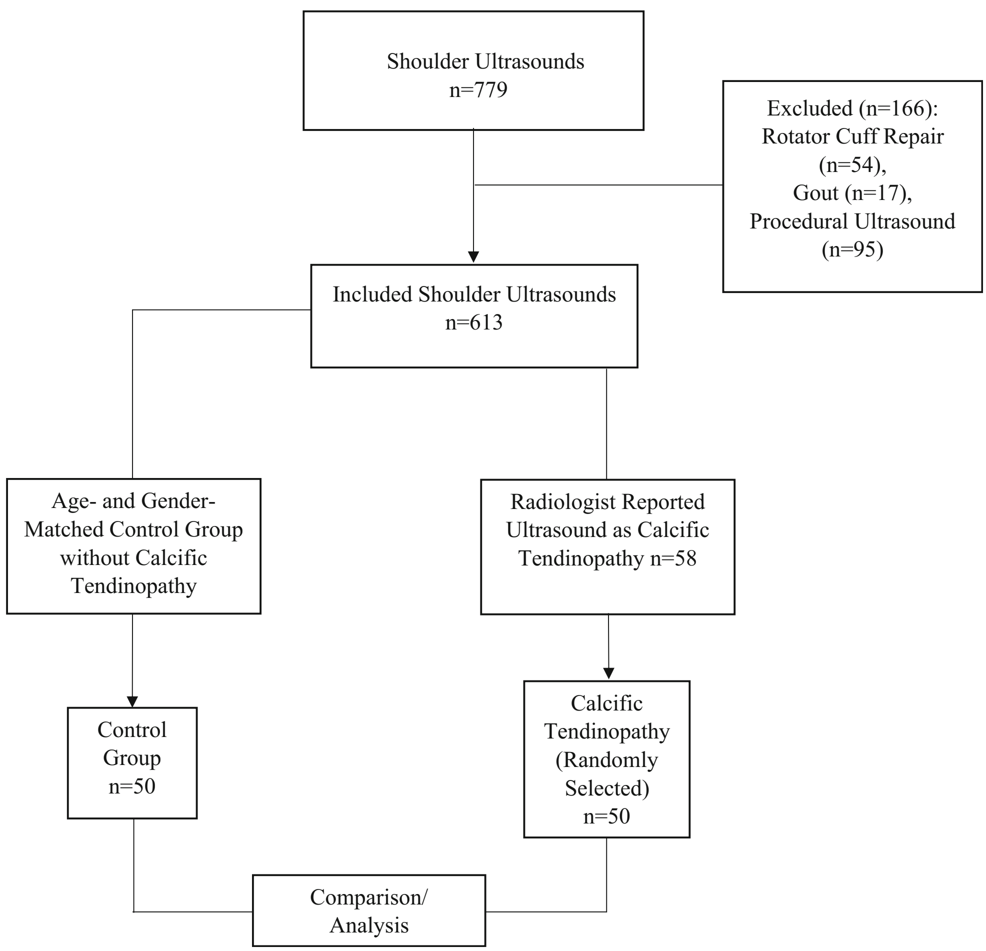
the RC tear or if there may be an unlikely protective mechanism for the adjacent tendon(s) without calcium.

CaT was diagnosed by US in those rotator cuff tendons containing variably shadowing or non-shadowing echogenic foci [1, 4, 23, 26, 27, 32]. This included shadowing hyperechoic foci, typical of the formative and resting phases of the calcific stage, as well as amorphous, isoechoic to slightly hyperechoic, non-shadowing to faintly shadowing and often fragmenting foci, characteristic of the painful resorptive phase [1, 4, 9, 23, 27, 32].

Differentiating the supraspinatus from the infraspinatus tendon was done by utilizing the short-axis US images, at the lateral aspect of the greater tuberosity. Measuring from anterior to posterior, the tendon located along the anterior 2.3 cm of the greater tuberosity was designated the supraspinatus tendon, while the tendon located along the posterior 2.2 cm (middle facet) of the greater tuberosity was designated the infraspinatus tendon [4, 30].

In any case of discrepancy between the 2 MSK radiologists' independent reevaluation, the initial radiologist's report functioned as an arbitrator, and the diagnosis was confirmed by simple majority. This occurred in 23% (23 of 100) of the cases; 11 related to the type of partial-thickness tear, 6 being

Fig. 3 Patient selection criteria flowchart



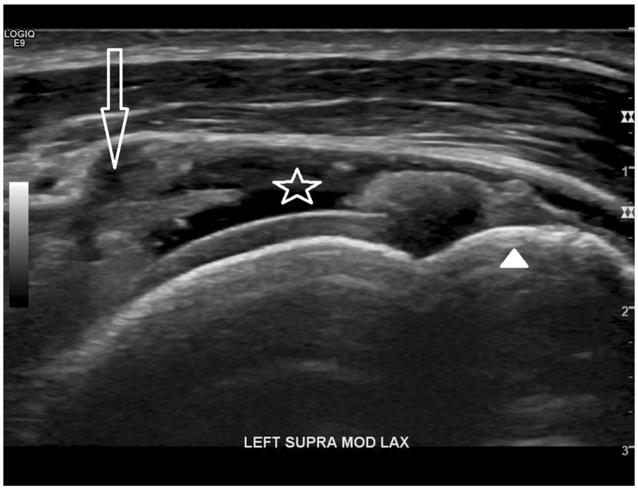


Fig. 4 Long-axis (LAX) sonographic image of a 63-year-old man from the control group with a supraspinatus (SUPRA) tendon tear. Image reveals a full-thickness retracted tear of the supraspinatus tendon presenting as an anechoic fluid-filled defect (open star) with delineation of the underlying curvilinear echogenic articular cartilage (cartilage interface sign). Echogenic debris is also seen adjacent to the greater tuberosity (arrowhead) at the proximal humerus with retraction of the supraspinatus tendon stump (open arrow) more medially. MOD indicates modified (Crass position)

discrepancies of a partial-thickness versus non-displaced full-thickness tear, and 6 in regard to a partial-thickness tear versus tendinosis.

Statistical analysis The association between the presence of a RC tear and the presence or absence of RC CaT by US was evaluated, and RC tear types were compared. Gender and age comparisons of the non-tear versus tear patients overall and within both groups was also performed. The comparisons were performed using chi-square tests for categorical data and the 2-sided sample *t* test for numerical data. Additionally, the odds ratio and its 95% confidence interval ($CI_{95\%}$) of having RC tear in the CaT group compared with the control group were calculated. Statistical significance was defined as a $P < 0.05$.

Results

Study groups Of the 50 patients with RC CaT, 28 (56%) were women and 22 (44%) were men. The age range was 36–88 years with a mean age of 64.7 (Table 1).

Of the 50 patients in the control group without CaT, 30 (60%) were women and 20 (40%) were men. The age range was 37–89 years with a mean age of 61.3 (Table 1).

Findings RC tear (partial- and full-thickness) was diagnosed in 38% (19 of 50) in the control group without CaT as compared to 22% (11 of 50) of patients with RC CaT. Of the 19 tears in the control group, 84% (16 of 19) were full-thickness tears. This compared to 55% (6 of 11) of full-thickness tears in the CaT group. Only 7 of the 11 overall RC tears in the CaT group were in a calcium-containing tendon, and furthermore, of these 7, only 3 were full-thickness tears (Fig. 6).

Statistical significance Statistical significance was seen when accounting for fewer full-thickness tears in the CaT group (12%, 6 of 50) compared to those in the control group (32%, 16 of 50) ($P = 0.016$, odds ratio 0.29, $CI_{95\%}$ 0.1–0.82). An increased number of both partial- and full-thickness RC tears in the control group without CaT (38%, 19 of 50) compared to both partial- and full-thickness tears in calcium-containing tendons in the CaT group (14%, 7 of 50) was also statistically significant ($P = 0.006$, odds ratio 0.27, $CI_{95\%}$ 0.1–0.71). Furthermore, the increased number of full-thickness tears in

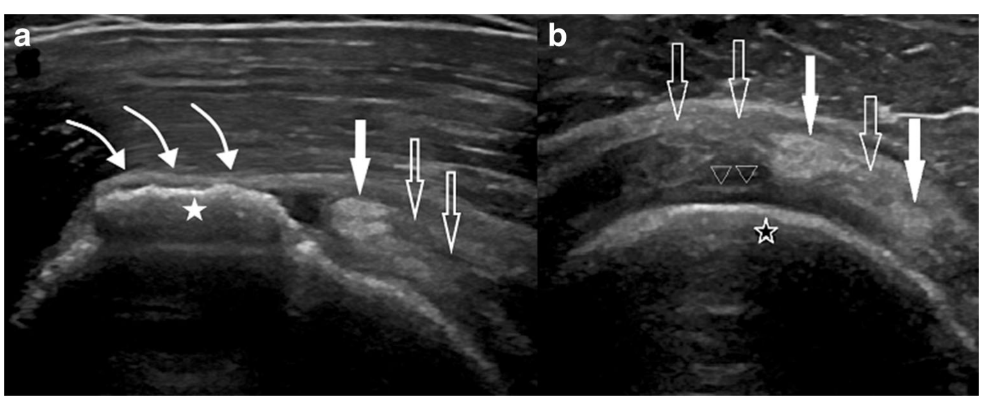


Fig. 5 Sonographic images of a 52-year-old man with a full-thickness retracted tear of the right supraspinatus tendon (the calcium-containing tendon). **a** Long-axis image demonstrates the full-thickness retracted tear of the supraspinatus tendon (open arrows) as a hypoechoic defect with volume loss extending from the bursal surface to the articular surface. The deltoid muscle and underlying peribursal fat are flattened and sagging (curved arrows) and contacting the underlying greater tuberosity (solid star) which is irregular secondary to chronic rotator cuff tendinopathy. A focal echogenic deposit of calcium hydroxyapatite (solid arrow) is seen at the retracted tendon stump. **b** Short-axis image at the level of the anatomic neck of the proximal humerus (open star) displays the retracted supraspinatus tendon stump (open arrows) and calcific deposits (solid arrows) with the cartilage interface sign (open arrowheads)

Table 1 Tear incidence and demographics comparison between the control group and the calcific tendinopathy patients

		Calcific tendinopathy (n = 50)	Control group (n = 50)	P value
Partial- and full-thickness tears		11 (22.0%)	19 (38.0%)	0.081 (C)
Full-thickness tears		6 (12.0%)	16 (32.0%)	0.016 (C)
Partial- and full-thickness tears (only calcium-containing tendons in calcific group)		7 (14.0%)	19 (38.0%)	0.006 (C)
Full-thickness tears (only calcium-containing tendons in calcific group)		3 (6.0%)	16 (32.0%)	0.001 (C)
Gender	Female	28 (56.0%)	30 (60.0%)	0.685 (C)
	Male	22 (44.0%)	20 (40.0%)	
Age, years (mean ± SD)		64.7 ± 12.1	61.3 ± 13.0	0.179 (T)

Categorical data is represented as frequency (percent of column). Numerical data is represented as mean ± standard deviation (SD). C indicates $\chi 2$ test and T indicates 2-sided sample t test

the control group (32%, 16 of 50) compared to full-thickness tears in calcium-containing tendons in the CaT group (6%, 3 of 50) was yet more statistically significant (P = 0.001, odds ratio 0.14, $CI_{95\%}$ 0.04–0.5). A difference was also detected for the overall number of both partial- and full-thickness RC tears in the control group (38%, 19 of 50) compared to a lower number of both partial- and full-thickness in any tendon (22%, 11 of 50) in the CaT group, albeit statistically insignificant (P = 0.081, odds ratio 0.46, $CI_{95\%}$ 0.19–1.1) (Table 1).

Tendons affected Of the 16 full-thickness tears in the control group, 100% involved the supraspinatus tendon with 87.5% (14 of 16) isolated to the supraspinatus tendon only and 12.5% (2 of 16) involving the supraspinatus, infraspinatus, and subscapularis tendons.

In the CaT group, 76% (38 of 50) had calcific deposits in the supraspinatus tendon, with 54% (27 of 50) isolated to the supraspinatus tendon only. The subscapularis tendon had CaT in 28% (14 of 50) of patients, with 18% (9 of 50) isolated to the subscapularis only. The infraspinatus tendon was affected with CaT in 24% (12 of 50) of patients, with 6% (3 of 50) isolated to the infraspinatus tendon only.

In the 6 full-thickness calcium-containing tendon tears in the CaT group, 100% (6 of 6) were isolated to the supraspinatus tendon (including the 3 full-thickness calcium-containing tendon tears).

Demographic associations Patients with RC tears were significantly older than those without tears both overall and within the control group without CaT. The mean age of patients overall (both groups combined) with a RC tear present was 65.2, while those with no tear present was 58.9 (P = 0.018). Within specifically the control group without CaT, the mean patient age with a RC tear present was 64.4, while the mean age in those without a tear was 52.3 (P = 0.008). Within specifically the group with CaT, the mean patient age with a RC tear present was 66.7, while the mean age in those without a tear was 64.1 (P = 0.53). No statistically significant age difference was seen in the group with CaT in regard to tears. Also, no statistically significant gender differences were seen

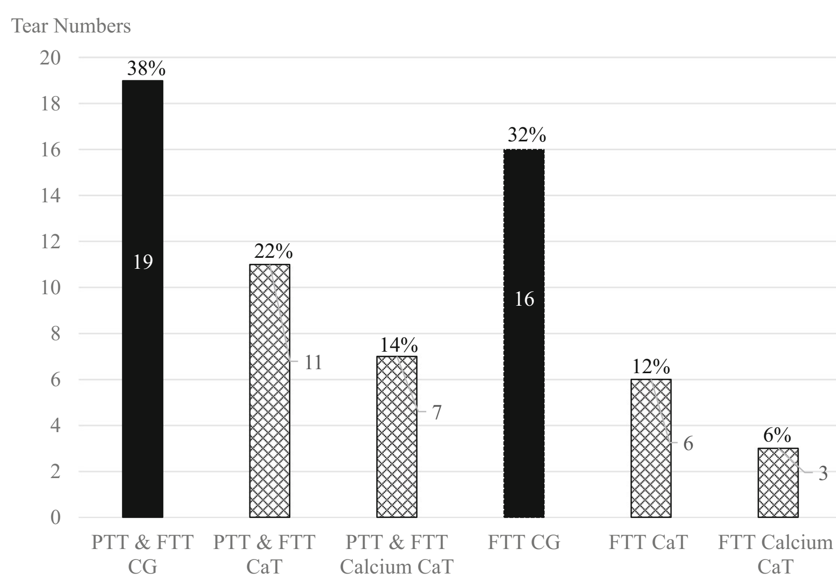


Fig. 6 Rotator cuff tear incidence comparison between the control group (CG) and the calcific tendinopathy (CaT) patients. Abbreviations: *PTT*, partial-thickness tear; *FTT*, full-thickness tear; *Calcium*, calcium-containing tendon

with regard to the presence of a RC tear overall or in either the CaT group or the control group.

Discussion

At a large institution performing a substantially high volume of MSK US and especially shoulder US, based on our experience, patients with RC CaT tend not to have associated RC tears. However, the literature has conflicting or controversial data as to the relationship between RC tears and CaT. Therefore, we found it essential to perform a study, specifically utilizing US, to help clarify this relationship. Our findings demonstrate that patients with RC CaT are significantly less likely to have a partial- or full-thickness tear in a calcium-containing tendon or even a full-thickness tear in any tendon (with or without calcium) when compared to a control group without CaT.

In a 1951 surgical study, McLaughlin and Asherman reported that a RC tear rarely occurred in the presence of RC CaT [13]. These results were corroborated by an additional operative study in 1957 by Friedman, which again advocated that the coexistence of CaT and RC tear was rare [14]. Studies in the decades to follow brought about much confusion and debate as to the exact relationship between CaT and RC tears. In 1974, Wolfgang in an operative study argued that RC tears are not uncommon in patients with CaT [20]. His findings were echoed in 1993 by Jim and colleagues who used conventional arthrography in their study [21]. Conversely, in a 2019 MRI-based study, Beckman and colleagues found that those with RC CaT are not at an increased risk for RC tear compared to those without CaT [16]. Finally, in 2020, two opposing MRI-based studies emerged. On the one hand, Brinkman et al. reported that in cases of CaT, the incidence of RC tears was higher than previously reported [22]. On the other hand, Sucuoğlu and Asan published that in patients with RC CaT, there was a decreased risk of RC tear when compared to those without CaT [17].

We suspect that the ongoing confusion in regard to the relationship of RC CaT and RC tear is at least in part related to the use of MRI in many of these studies. In fact, even Brinkman et al. in their MRI-based study mention that MRI is not commonly recommended for the diagnosis of CaT due to its appearance mimicking other pathologies including even tendon hemorrhage [22]. Given the limitations and low sensitivity of MRI in the detection of CaT, it is not endorsed as a first-line imaging modality for RC CaT [1, 9, 19, 22–29, 38]. Although dense calcific deposits, typical of the resting phase of the calcific stage, can be identified on MRI as a hypointense focus on both T1- and T2-weighted sequences, calcific deposits often present as varying signal intensities, ranging from hypointense to heterogenous, making them difficult to correctly identify. This is especially true, in the pre-calcific stage and the resorptive phase of the calcific stage, wherein CaT can present as vague, nonspecific hyperintense T2-weighted signal without identifiable calcific deposits and mimic severe tendinosis or even a RC tear (Fig. 1). In order to facilitate the detection of CaT by MRI, some studies have advocated the use of supplementary susceptibility-weighted sequences which are not routinely obtained [38, 39]. Furthermore, since patients most commonly present in the painful resorptive phase, we felt the use of MRI to evaluate this relationship is incomplete [1, 2, 8–11, 19].

Given MRI's limitations in the detection of CaT, it relies heavily on radiographs which are not always acquired or accessible. However, even radiographs are limited in the detection of less dense RC calcific deposits which are often radiographically occult (Fig. 1). This is typical of the pre-calcific stage, while deposits are still forming, and of the resorptive phase of the calcific stage, when deposits are fragmenting, dissolving, and migrating. US has been shown to be more sensitive than radiographs for early detection of CaT in both the pre-calcific stage and the resorptive phase [1, 4, 9, 19, 24, 25, 33, 38–41].

Since MRI and radiographs both have limitations in the detection of RC CaT, we elected to utilize US for this study. US has been shown in many studies to be more sensitive than MRI in the assessment of RC CaT, and, contrary to earlier teachings, US is superior to MRI in its ability to accurately determine the stage of CaT and predict the consistency of the calcific deposits [1, 23, 26, 27, 33, 34]. CaT on US presents as variably shadowing or non-shadowing echogenic foci [1, 4, 23, 26, 27, 32]. In the formative and resting phases of the calcific stage, RC CaT presents on US as shadowing hyperechoic foci. US is particularly well adept in identifying calcific deposits in the painful resorptive phase, typically lasting 2 to 3 weeks and wherein patients most commonly seek medical attention. During this phase, deposits appear as amorphous, fragmenting and faintly shadowing to non-shadowing echogenic foci migrating outside the RC tendons into the overlying bursa, often initiating a painful subacromial-subdeltoid calcific bursitis (Figs. 1 and 2) [1, 4, 8, 23, 27, 32–34]. Moreover, US can also identify concomitant RC tears with a sensitivity equivalent to MRI, making US fitting for our study (Figs. 4 and 5) [4, 26, 32, 35–37].

One possible explanation for the findings of our study is that CaT may serve as a protective mechanism against RC tears. One theory of the cause of CaT suggests that decreased oxygen tension within the tendon results in fibrocartilaginous metaplasia and secondary mineralization with resultant CaT [4, 5, 19]. These histopathologic remodeling changes that occur throughout the stages of CaT, especially in the post-calcific phase when formation of granulation tissue with fibroblasts and collagen takes place, could play a role in this theoretical protective effect [1, 2, 8, 9]. Further histopathologic and arthroscopic studies are necessary to verify this protective theory and attempt to identify specific causation.

The findings of our study support the use of MSK US by rheumatologists and other clinicians in any patient with suspected CaT. Furthermore, these findings could assist those performing and interpreting a shoulder US when struggling in a challenging case to differentiate between severe tendinosis and a RC tear. Similar to the use of secondary sonographic findings such as greater tuberosity cortical irregularity, RC volume loss, and subacromial-subdeltoid bursal fluid, favoring a RC tear over tendinosis, the presence of CaT could potentially be used as a secondary finding favoring tendinosis over a RC tear [4, 30, 32].

The limitations of this study should be acknowledged when interpreting the results. First, given the retrospective nature of the study, no asymptomatic patients were compared. A future prospective study could be performed with the inclusion of asymptomatic patients in both groups. Next, we did not have correlative arthroscopic findings to confirm the presence or lack of a RC tear diagnosed by US. In our experience, most patients with RC CaT, in the absence of a RC tear, do not undergo surgery. Lack of information regarding confounding factors such as types of daily activities, occupation, presence of a coexisting shoulder injury, and prior nonsurgical treatments is another limitation to our study. Finally, this retrospective study lacks both knowledge of a history of prior resolved CaT and long-term follow-up on our patient population. A future prospective investigation analyzing any temporal relationship between history of CaT and future development of RC tears could be informative and could confirm our findings.

In conclusion, this is the first study of its kind to use US to demonstrate an association of fewer RC tears, especially calcium-containing tendon tears in those with CaT as compared to similar demographic patients without CaT. This study paves the way for future prospective studies to evaluate if RC CaT could have a protective mechanism against RC tears, possibly related to the associated remodeling and histopathologic changes that occur within the affected tendons.

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Author contribution NCL, KAR, AT, and JRL interpreted data, contributed to the discussion and design of the study, and reviewed/edited the manuscript. CLK researched and interpreted data, contributed to the discussion and design of the study, and reviewed/edited the manuscript. SBS researched and interpreted data, contributed to the discussion and design of the study, and wrote the manuscript.

Data availability The authors commit to making the relevant anonymized data used and/or analyzed in the current study available on reasonable request.

Compliance with ethical standards

Disclosures None.

Ethics approval and consent to participate All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards. Institutional review board approval was obtained (IRB # 12367, July 13, 2018) and informed consent was waived. Our study complied with the Health Insurance Portability and Accountability Act.

Consent for publication We consent to publication.

Code availability Not applicable

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