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MUSCULOSKELETAL

Ultrasound-guided percutaneous irrigation of calcific tendinopathy: redefining predictors of treatment outcome

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Abstract

Objectives To identify prognostic factors affecting the clinical outcome in patients treated with rotator cuff ultrasound-guided percutaneous irrigation of calcific tendinopathy (US-PICT), by evaluating the degree of calcium removal, the size and consistency of calcific deposits, and baseline level of shoulder pain and functionality.

Methods From January 2017 to December 2019, 79 patients (23 males, 56 females; mean age, 45.7 years) who underwent US-PICT were prospectively enrolled. The calcifications' location, consistency, and size were evaluated. For US-PICT, local anesthesia, lavage of calcific material, and intrabursal steroid injection were performed. The degree of calcium removal was graded as total/partial. Shoulder pain and functionality were assessed with the visual analogue scale (VAS) in all and Constant score (CS) in a subset of patients, respectively, at 4 time-points. Mann-Whitney *U* test, Fisher's test, and linear and binary logistic regression were utilized for analysis.

Results Pain improvement correlated with the presence of larger calcifications and lower baseline VAS score, at 1 week ($p = 0.001$, $p < 0.001$, respectively) and 1 year ($p < 0.001$, $p = 0.002$, respectively). Improved functionality correlated with total calcification retrieval, higher baseline CS, and fluid/soft calcific consistency at 1 week ($p = 0.013$, $p = 0.003$, $p = 0.019$, respectively). Increased calcification size, cystic appearance, and lower baseline VAS scores independently predicted complete pain resolution at 1 year.

Conclusion Large calcifications and low-grade pain at baseline correlated with short- and long-term pain improvement. The degree of calcium removal did not impact pain or functional improvement beyond 1 week. Increased calcification size, cystic appearance, and low-grade baseline pain predicted complete pain recovery at 1 year.

Key Points

- *The presence of larger calcifications and lower-grade baseline pain appear to correlate with pain improvement at 1 week and 1 year after ultrasound-guided irrigation of rotator cuff calcific tendinopathy (US-PICT).*
- *Total calcification retrieval, less affected baseline shoulder functionality, and presence of fluid/soft consistency of calcific deposits appear to correlate with improved shoulder functionality at 1 week post-treatment.*
- *Baseline pain intensity and calcifications' morphologic characteristics, but not the degree of calcium retrieval, represent predictors of complete pain recovery at 1 year after US-PICT.*

Keywords Calcinosis · Tendinopathy · Therapeutic irrigation · Ultrasonography, Interventional · Rotator cuff

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Abbreviations

CS	Constant score
RC	Rotator cuff
RCCT	Rotator cuff calcific tendinopathy
SASD	Subacromial-subdeltoid bursa
SD	Standard deviation
US-PICT	Ultrasound-guided percutaneous irrigation of calcific tendinopathy
VAS	Visual analogue scale

Introduction

Rotator cuff calcific tendinopathy (RCCT) represents a significant cause of shoulder pain, characterized by the deposition of calcium hydroxyapatite crystals on either inside of the rotator cuff (RC) tendons or in the peritendinous soft tissues, subacromial-subdeltoid bursa (SASD), and the underlying humeral head [1–3]. The critical zone of the supraspinatus tendon represents the most common target, while the disease may occur bilaterally in up to 25% of patients [4, 5]. RCCT is a common disorder with a reported prevalence of up to 7.8% in asymptomatic individuals and 42.5% in patients with subacromial pain syndrome, affecting mostly women aged between 30 and 60 years [6, 7]. Despite its benign and self-limiting nature, symptoms may vary from low-grade to intense and highly disabling pain, resistant to high doses of oral anti-inflammatory drugs, often associated with restriction of joint mobility [1, 7, 8].

No treatment is required for asymptomatic calcifications. Mild symptoms can be managed conservatively with physical therapy and oral anti-inflammatory drugs. For a subset of patients with RCCT refractory to conservative therapy, different treatment methods, including extra-corporeal shockwave therapy, subacromial steroid injections, ultrasound-guided percutaneous irrigation of calcific tendinopathy (US-PICT), and surgical removal of calcific deposits, are in use [9, 10].

Currently, although no gold standard has been established to treat RCCT, US-PICT is widely accepted as a first-line treatment with determined clinical effectiveness and superiority compared to subacromial steroid injections and extracorporeal shockwave therapy, combined with a low complication rate [11–17]. The technical aspects, including the number, size, and positioning of the needle(s) as well as procedural details of the method, have been extensively studied [11–14]. However, to the best of our knowledge, there is scant and discordant literature regarding the factors affecting or predicting the treatment outcome. In this manner, there are conflicting reports about the relationship between satisfactory calcium removal and improved clinical outcome [4, 11, 18–21]. Additionally, small-sized calcific deposits, longer symptom duration, and requirement of repeated procedures have been proposed to represent factors denoting inferior outcomes, among others [20, 22, 23]. On the other hand, favorable initial response to US-PICT, larger size and softer calcification consistency, female gender, and younger age have been associated with success of the procedure [20, 22, 24].

Therefore, the aim of our study was to identify predictors of short- and long-term clinical outcomes in patients undergoing US-PICT for RCCT. For this purpose, (i) the degree of retrieved calcific material during US-PICT, (ii) the initial calcification size, (iii) the consistency of the calcific deposits at presentation, and (iv) the baseline level of pain and/or functionality were evaluated as possible predictors of treatment outcome.

Materials and methods

Patients

This study was conducted according to the principles of Helsinki Declaration in a university hospital and a district general hospital. Ethical committee approval was obtained together with written informed consent of all patients prior to each interventional procedure.

From January 2017 to December 2019, 195 consecutive patients who underwent US-PICT for painful RCCT were prospectively studied. All patients with ipsilateral partial/full-thickness RC tear (n = 19), painful shoulder pathology other than RCCT based on the diagnostic US examination and/or MRI (inflammatory arthritis, n = 4; adhesive capsulitis, n = 6), intraosseous or intrabursal extension of the calcific deposits confirmed by diagnostic US and/or MRI (n = 7), partially effective previous treatment with extracorporeal shockwave therapy (n = 5), physical therapy (n = 15), or local steroid injection (n = 38) during the last 3 months before inclusion; patients lost during follow-up (n = 6); and those with incomplete/failed US-PICT procedure (n = 16) were excluded (Fig. 1). Definition of treatment failure/non-completion is provided in "US-guided intervention." The remaining 79 patients (23 males and 56 females; mean age, 45.7 years ± 7.88; range, 31–62 years) comprised our study population. Demographic data are shown in Table 1.

Diagnostic US examination

A diagnostic US evaluation of the affected shoulder, performed with a GE Logiq F8 ultrasound machine equipped with a 6–12-MHz probe, preceded all interventional procedures. All US examinations were performed according to the guidelines proposed by the European Society of Musculoskeletal Radiology by a single radiologist in each center (A.H.K. and E.E.V. with 34 and 7 years of experience in musculoskeletal imaging and intervention, respectively) [25, 26].

Tendons affected by RCCT were recorded and the consistency of calcific deposits was classified based on US appearance as (i) hard, when appearing as a hyperechoic rim causing posterior acoustic shadowing; (ii) soft, when depicted as a hyperechoic formation lacking posterior acoustic shadowing; and (iii) fluid, when presenting with a hypoechoic center, surrounded by a thin hyperechoic rim [18, 19] (Fig. 2). The maximum diameter of the calcific deposits was measured.

Table 1 Demographic characteristics of study participants

Participants (*n*)	79
Sex (M/F)	23 M/56 F
Age (mean years ± SD)	45.66 ± 7.88
Affected tendon (SSP, ISP, SSP-ISP, SSC)	52 SSP/10 ISP/13 SSP-ISP/4 SSC
Calcium removal (total/partial)	49 total/30 subtotal

M male, *F* female, *SD* standard deviation, *SSP* supraspinatus, *ISP* infraspinatus, *SSC* subscapularis

US-guided intervention

All interventional procedures were performed by the operators who conducted the corresponding diagnostic US examinations. Patients were placed in the supine position to avoid movement and prevent vagal reactions. The ipsilateral arm was laid along the body in neutral position or slight internal/external rotation.

The US-PICT procedure was performed based on a 3-step algorithm [13, 14, 18]:

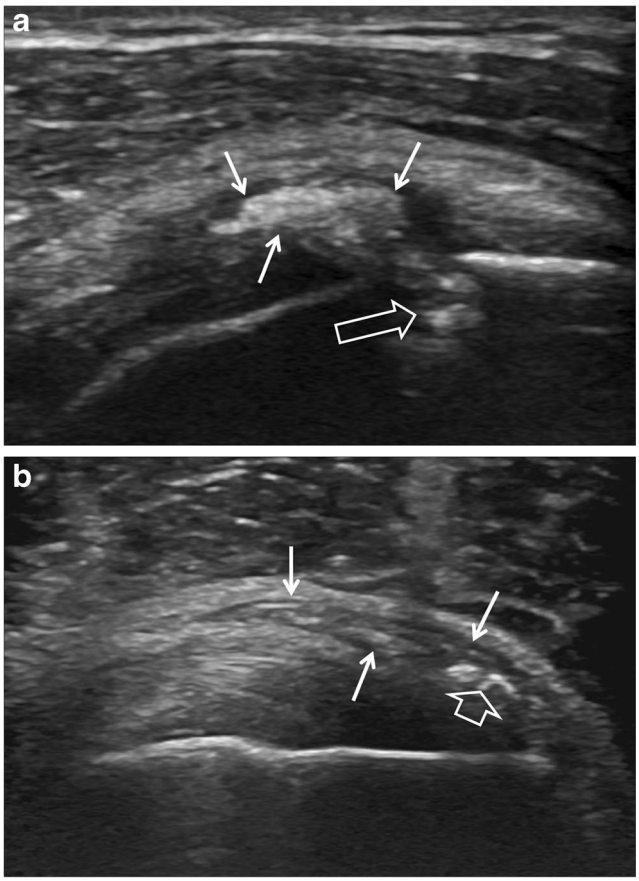

Fig. 1 Exclusion of patients based on US findings. **a** Coronal US image in a 54-year-old male with painful calcific tendinopathy showing the calcific deposit (arrows) within the supraspinatus tendon with intraosseous extension into the humeral head (open arrow), through cortical disruption. **b** Coronal US image in a 46-year-old female with calcific bursitis. Bursal distension with synovial thickening (arrows) and intrabursal calcific material (open arrow) is depicted

1. *Probe preparation, skin antisepsis, and local anesthesia*: A sterile probe cover was used and ordinary skin antisepsis was applied over the area of interest. For local anesthesia, up to 10 ml of 1% lidocaine hydrochloride was injected into the SASD bursa and around the calcifications, with a 23-gauge needle under continuous US guidance (Fig. 3).
2. *Aspiration of calcific material*: Irrigation of calcific deposits was performed with a single-needle technique [14, 18]. In detail, by using an in-plane approach, an 18-gauge needle connected to a 10-ml syringe with 4 ml of NaCl 0.9% at room temperature was inserted into the center of the calcification, under constant sonographic monitoring. The calcification was hydrated by applying gentle and intermittent pressures on the syringe plunger, allowing the calcific material to reflux back in the syringe when the plunger was released. This step was repeated several times until the backflow saline was free of visible calcific material, with special attention given as not to disrupt the peripheral calcific rim. Gentle, rotational maneuvers of the needle or small adjustments of the needle tip location were occasionally performed to achieve an adequate washing circuit, in cases that aspiration was initially unsuccessful. A 23-gauge spinal needle was used to restore patency in cases of needle obstruction by calcific material [27]. The degree of aspirated calcific material at the end of the procedure was graded as either "total" or "partial" according to the absence or presence of measurable, residual calcification on US, apart from the thin, peripheral calcific rim, respectively (Fig. 4).
3. *Intrabursal steroid injection*: At the end of the procedure, a 23-gauge needle was advanced into the SASD bursa, where 1 ml of triamcinolone 40 mg/ml was injected under US guidance for preventing the occurrence of post-procedural bursitis.

The US-PICT procedure was characterized as failed/non-completed when leakage of the injected saline was identified outside the calcification, after the initial compressions on the syringe plunger, implying disruption of its peripheral rim [14].

Following the completion of US-PICT, a thorough US examination of the shoulder was conducted to assess potential complications including tendinous rupture or acute

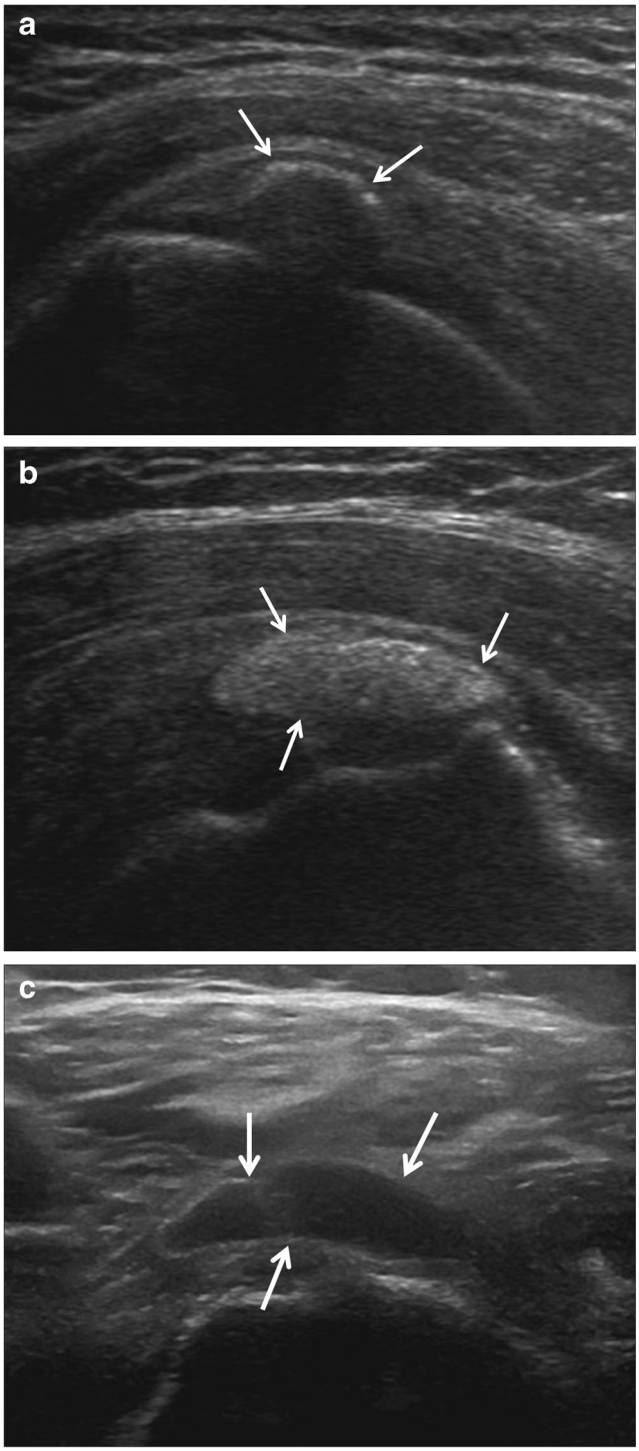

Fig. 2 Classification of calcific deposits based on US appearance. **a** Hard calcification (arrows) within the supraspinatus tendon in a 50-year-old male, causing posterior acoustic shadowing. **b** Soft calcification (arrows) at the insertional portion of the supraspinatus tendon in a 35-year-old male, depicted as homogeneous hyperechoic formation without posterior acoustic shadow. **c** Fluid calcification (arrows) within the supraspinatus tendon in a 52-year-old female. Note the presence of a fluid-like center surrounded by a thin, peripheral calcific rim

hemorrhage. All patients were clinically observed for 30 min after the procedure by an experienced nurse and subsequently discharged with written information for management of potential short-term symptoms with oral painkillers (paracetamol up to 1000 mg for a maximum of 5 days post-procedure depending upon the presence of pain). Oral instructions to avoid shoulder overloading and intense exercise for 2 weeks following the injection were given to all patients. All patients were encouraged to provide us with all concerns regarding their treated shoulder during the timeframe of the study.

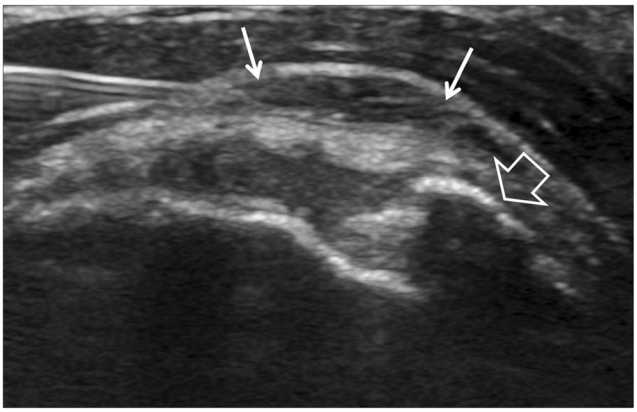

Fig. 3 Coronal US image in a 41-year-old female with painful calcific tendinopathy, showing distension of the subacromial-subdeltoid bursa (arrows) during anesthetic injection. The needle was advanced with an in-plane approach. Calcific deposit is also depicted within the supraspinatus tendon (open arrow).

Clinical evaluation and follow-up

Clinical evaluation was performed for all patients, at baseline (pre-treatment) and during scheduled visits at 1 week, 1 month, 6 months, and 1 year after the treatment. Clinical examination at baseline was performed by two orthopedic surgeons (15 and 20 years of experience in shoulder pathologies) according to usual clinical practice and included definition of the level of pain, assessment of the active and passive shoulder range of motion, manual muscle and impingement testing (Hawkins-Kennedy or Neer impingement sign, arc test, and infraspinatus muscle strength test), cross-arm evaluation for acromioclavicular joint disease, and evidence of glenohumeral joint instability [28]. Clinical assessment at subsequent time points, including assessment of the active and passive shoulder range of motion and manual muscle testing, was performed by two musculoskeletal radiologists (34 and 7 years of experience) who were formally trained to perform clinical examination and assessment of the Constant score in an identical manner. All patients ($n = 79$) were evaluated with the use of a 10-cm visual analogue scale (VAS) for the assessment of pain [19]. VAS scores were assessed by the orthopedic surgeons at baseline and the musculoskeletal radiologists at subsequent time points. Part of the study group ($n = 30$) was assessed with the use of the Constant score (CS) for a multitude of parameters including activity level, shoulder pain,

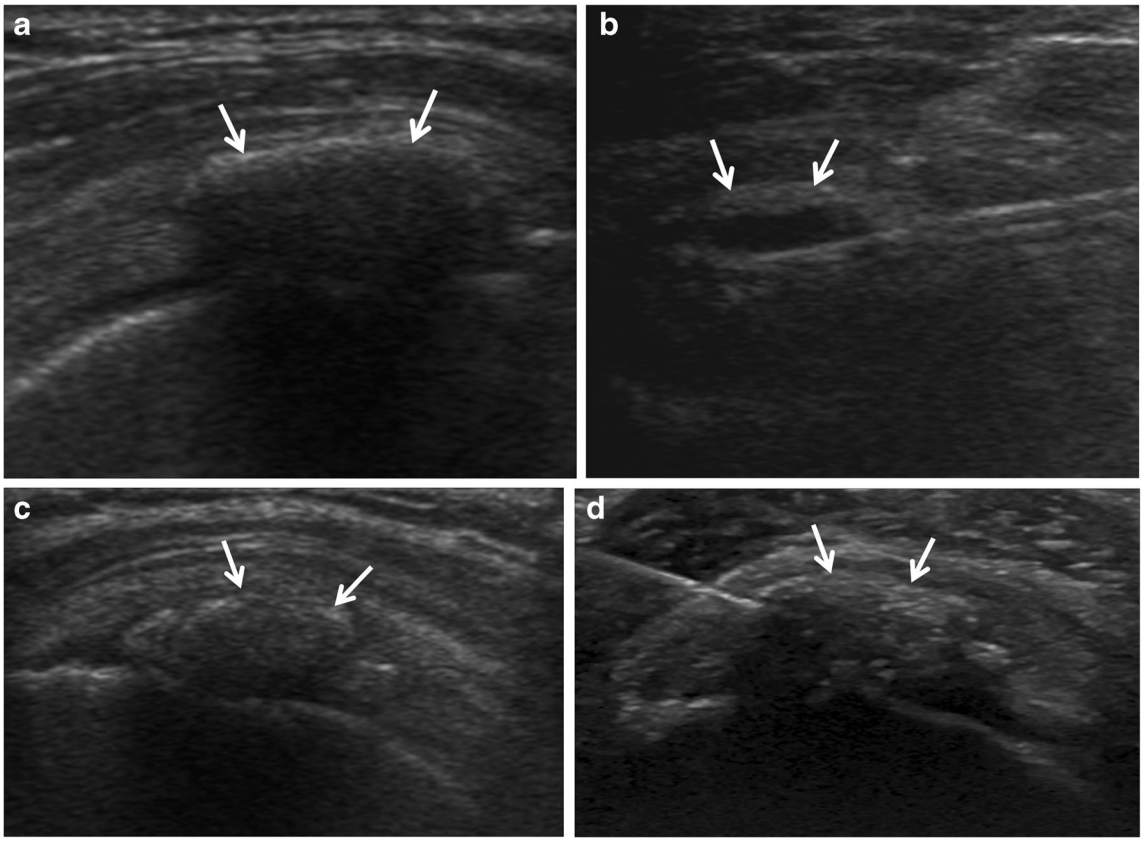

Fig. 4 US images of two different patients treated with US-guided percutaneous irrigation of calcific tendinopathy, showing total and partial aspiration of calcific material. **a**, **b** Coronal US images in a 43-year-old female. **a** A hard calcification (arrows) with moderate acoustic shadowing is depicted in the supraspinatus tendon. **b** At the end of treatment, there is total removal of the calcific material, leaving only a peripheral calcific wall (arrows) surrounding the empty calcific cavity. The needle is still visible inside the calcification. **c**, **d** Coronal US images in a 51-year-old female. **c** A soft calcification (arrows) is shown within the supraspinatus tendon. **d** At the end of treatment, persistent calcific material (arrows) is depicted, denoting partial emptying of the calcification. The needle can be seen inside the calcification.

strength, and range of motion [29]. Complete resolution of symptoms was defined as a VAS score of 0 or 1, since the minimum clinically important difference in VAS score has been calculated to be 1.4 cm for patients with RC pathology [30].

Statistical analysis

Descriptive statistics were expressed as counts or mean ± standard deviation (SD) for categorical or continuous variables, respectively. Linear regression analysis was performed at all time-points to identify predictors significantly correlated with VAS and CS. Beta coefficients with their 95% confidence intervals were calculated for all variables included in the linear models, and R^2 was used to assess model fit. At the final time-point (1 year), binary logistic regression was used to identify independent predictors of complete resolution of pain (VAS score 0 or 1 cm) at the end of the follow-up. Odds ratios and 95% confidence intervals of experiencing complete pain resolution were calculated for all clinical variables included in the model, and the Hosmer and Lemeshow test was utilized to assess goodness of fit. Two-group univariate comparisons were performed with the use of the Mann-Whitney *U* test for continuous or Fisher's exact test for categorical variables. Statistical analysis was performed with SPSS v. 25 (IBM Corp.), and significance was defined at a p value < 0.05.

Results

Location of calcifications, consistency, and size

Calcific deposits were located in the supraspinatus, infraspinatus, and subscapularis tendon in 52, 10, and 4 patients, respectively, while they affected both supraspinatus and infraspinatus tendons in 13 patients (Table 1). These calcifications were classified as hard, soft, and fluid in 44, 27, and 8 patients, respectively, and were characterized by a mean maximum diameter of 12 mm (SD, 4.23; range, 6–22 mm).

Treatment results and follow-up

No significant complications occurred during the US-guided procedure or the immediate post-procedural period. Three patients (3.8%) complained of exacerbation of pain within the first 48 h following the intervention which resolved with oral painkiller drugs. Five patients (2 males, 3 females; mean age, 46.8 years) referred pain flare-up within 3 months after the procedure (mean time of pain recurrence, 86.6 days). A diagnostic US was subsequently performed which diagnosed subacromial bursitis, as distension of the SASD bursa larger than 2 mm, in all cases. Subsequently, these patients received a US-guided intrabursal injection of 1 ml of triamcinolone 40 mg/ml which resulted in complete pain resolution. Beyond the aforementioned cases, no other patient reported additional painkiller intake.

Retrieval of calcific material, ranging from partial to total, was possible in all patients as signified by the presence of solid or milky-like material in the syringe. Calcifications were totally aspirated in 49 patients (62%), leaving only a thin peripheral calcific rim depicted on US, and partially in 30 patients (38%), where US showed residual calcific deposits at the end of the treatment despite the backflow clear aspirate.

Linear regression analysis demonstrated that pain improvement (as assessed with VAS scores) was significantly correlated with the presence of larger calcifications and a lower baseline VAS score, at 1 week ($p = 0.001$, $p < 0.001$, respectively) and 1 year ($p < 0.001$, $p = 0.002$, respectively) after treatment. Importantly, the degree of calcification retrieval (total vs. partial) did not correlate with pain scores at any time-point (Table 2, Fig. 5). With regard to functionality improvement (based on CS), it was significantly correlated with total calcification retrieval ($p = 0.013$), higher baseline CS ($p = 0.003$), and the presence of fluid or soft calcifications ($p = 0.019$) only at 1 week post-treatment (Table 3).

A multivariable logistic regression model was built to identify the independent predictors of complete pain resolution at 1 year post-treatment. Specifically, the presence of large-sized calcifications at baseline was found to independently predict complete recovery of symptoms at 1 year (OR 1.2, 95% CI 1.039–1.42, $p = 0.014$), whereas higher baseline VAS scores were related to lower chances of complete pain resolution (OR 0.516, 95% CI 0.267–0.996, $p = 0.049$). The presence of fluid calcifications predicted complete resolution of symptoms compared to hard calcifications (OR 9.056, 95% CI 1.24–66.141, $p = 0.03$). Interestingly, the degree of calcific material retrieved during US-PICT did not impact symptom resolution at 1 year ($p = 0.485$) (Table 4).

Discussion

Herein, patients undergoing US-PICT for RCCT have been clinically evaluated over the course of 1 year and significant predictors of treatment outcomes have been identified. Importantly, the degree of retrieved calcific material did not appear to impact symptom remission, whereas large-sized baseline calcifications, a lower baseline VAS score, and the presence of fluid calcifications were identified as independent predictors of complete pain resolution at 1 year post-treatment. To the best of our knowledge, the worthlessness of maximal retrieval of calcifications has already been implied in the literature [4]. The present study comforts this finding by its prospective design.

The degree of retrieved calcific material during US-PICT did not have an impact on clinical outcome at 1 year and did not correlate with VAS scores at any time-point. Our finding challenges the common belief that US-PICT should achieve maximal extraction of the calcification [14]. The lack of relationship between post-treatment pain and the degree of calcium retrieval could be attributed to local bleeding and decompression of the calcium hydroxyapatite-containing cavity caused by the aspiration of even minimal calcific material or by dry-needling over the calcification, eventually leading to resorption of the remaining calcification and spontaneous healing [4, 10, 31, 32].

Complete arthroscopic removal of calcific material was previously found to lead to improved clinical outcome [33]. However, the follow-up time-point was set at 2 months post-arthroscopy, which, compared to our results, may imply a delayed clinical response of patients with partial removal of calcific material. This may be attributed to the inherent differences between the utilized methods, with US-PICT being less invasive compared to arthroscopic treatment.

In 38% of our patients, the degree of calcific material removal was graded as partial. Other studies on patients with RCCT treated with US-PICT report that all calcifications were mostly washed out at the end of the procedure [18, 19, 34]. Although these studies are oriented towards correlating the ease of calcium hydroxyapatite dissolution with clinical outcome rather than identifying predictors of complete symptom remission, the difference in effectiveness of calcific material removal could be explained by the utilization of room-temperature saline and single-needle technique in our study, instead of warm saline and double-needle technique.

Partial calcification retrieval was significantly correlated with a lower CS at 1 week post-treatment; however, it did not correlate with VAS scores at any time-point. Unlike the VAS scoring system, CS enables a holistic evaluation of functionality, including beyond shoulder pain, activity level, strength, and joint range of motion [29, 35]. Considering this inherent difference between the two scoring scales, the correlation between partial removal of calcific material and lower CS without correspondingly correlated VAS scores at 1 week may reflect the elimination of pain with persistent impaired shoulder functionality, by means of limited activity level, reduced strength, or restricted range of motion. This has also

Table 2 Multivariable linear regression analysis of VAS score predictors over time after US-PICT

Time point	Variable	R^2	*B* coefficient	95% CI of *B*	*p* value
1 week		0.375			
	Initial calcification size*		− 0.074	− 0.117 to − 0.032	0.001 #
	Calcification retrieval**		0.286	− 0.082 to 0.654	0.126
	Baseline VAS score		0.416	0.236 to 0.595	< 0.001 #
	Calcification type***		0.167	− 0.103 to 0.438	0.221
1 month		0.072			
	Initial calcification size		− 0.033	− 0.073 to 0.007	0.106
	Calcification retrieval		− 0.084	− 0.432 to 0.265	0.633
	Baseline VAS score		0.12	− 0.049 to 0.29	0.162
	Calcification type		0.082	− 0.174 to 0.337	0.527
6 months		0.093			
	Initial calcification size		− 0.043	− 0.086 to 0	0.049
	Calcification retrieval		0.128	− 0.245 to 0.501	0.495
	Baseline VAS score		0.103	− 0.079 to 0.284	0.265
	Calcification type		0.165	− 0.109 to 0.438	0.234
1 year		0.288			
	Initial calcification size		− 0.082	− 0.126 to− 0.039	< 0.001 #
	Calcification retrieval		− 0.113	− 0.488 to 0.263	0.552
	Baseline VAS score		0.289	0.106 to 0.473	0.002 #
	Calcification type		0.254	− 0.022 to 0.529	0.071

US-PICT ultrasound-guided percutaneous irrigation of calcific tendinopathy; *VAS* visual analogue scale; * maximum dimension; ** total/partial; *** hard, soft, fluid; # statistical significance

Table 3 Multivariable linear regression analysis of Constant score predictors over time after US-PICT

Time point	Variable	R^2	*B* coefficient	95% CI of *B*	*p* value
1 week		0.629			
	Initial calcification size*		− 0.051	− 0.397 to 0296	0.766
	Calcification retrieval**		4.216	0.979 to 7.453	0.013 #
	Baseline Constant score		0.585	0.225 to 0.946	0.003 #
	Calcification type***		− 3.076	− 5.614 to − 0.538	0.019 #
1 month		0.1			
	Initial calcification size		0.24	− 0.237 to 0.716	0.310
	Calcification retrieval		1.405	− 3.046 to 5.856	0.522
	Baseline Constant score		0.258	− 0.238 to 0.754	0.295
	Calcification type		0.666	− 2.824 to 4.156	0.698
6 months		0.078			
	Initial calcification size		− 0.048	− 0.514 to 0.418	0.834
	Calcification retrieval		− 1.052	− 5.404 to 3.301	0.623
	Baseline Constant score		0.077	− 0.408 to 0.562	0.746
	Calcification type		− 2.116	− 5.529 to 1.297	0.213
1 year		0.075			
	Initial calcification size		− 0.11	− 0.456 to 0.235	0.517
	Calcification retrieval		− 0.625	− 3.855 to 2.605	0.694
	Baseline Constant score		− 0.064	− 0.424 to 0.296	0.717
	Calcification type		− 1.081	− 3.614 to 1.452	0.388

US-PICT ultrasound-guided percutaneous irrigation of calcific tendinopathy; * maximum dimension; ** total/partial; *** hard, soft, fluid, # statistical significance

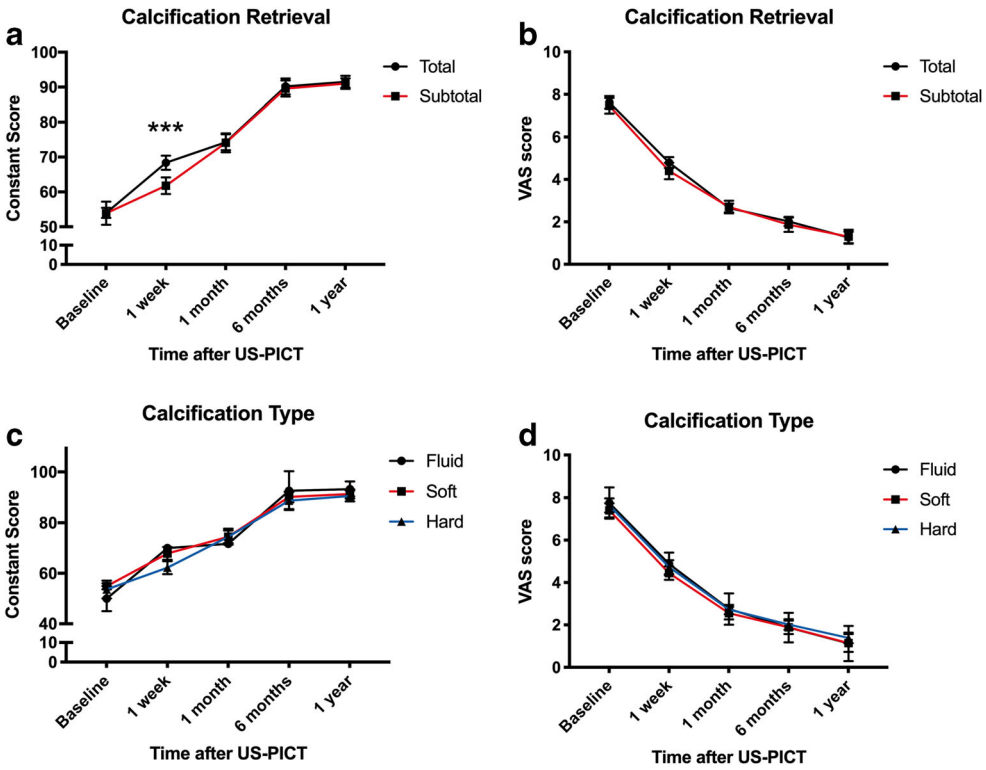

Fig. 5 Influence of calcific material retrieval and calcification type on Constant scores (**a**, **c**) and visual analogue scale scores (**b**, **d**). US-PICT, ultrasound-guided percutaneous irrigation of calcific tendinopathy; VAS, visual analogue scale; values represent mean ± 95% CI; ***$p < 0.001$

been reported by Rizzello et al who observed more substantial benefits in pain and external rotation than in activity level, range of motion, and strength, in the short term, after arthroscopic removal of calcific deposits [33]. This issue stresses the importance of careful selection and interpretation of the scoring scale, for both clinical and research purposes.

Regarding the size and consistency of the calcific deposits, identification of large and fluid calcifications at baseline predicted complete resolution of symptoms at 1 year. Existing data support a correlation between the presence of pain and increased size as well as cystic appearance of the calcific deposits, which may imply that these morphologic characteristics denote evolution of the calcifications into the highly symptomatic, resorptive phase [31, 36]. This, at least for patients with partial calcium removal, may explain our results by assuming that when performed during the resorptive phase, US-PICT may induce an accelerated and more effective auto-resorption process of the remaining calcific material. Our results regarding the correlation of long-term outcome with calcification size at baseline are in keeping with those provided by Oudelaar BW et al in their recent, interesting study [22].

Finally, baseline VAS scores served as an independent predictor of complete pain resolution, with higher scores at presentation being negatively related to symptom remission, defined as VAS score ≤ 1, at 1 year [30]. Considering that pain improvement after US-PICT, ranging between 17 and 80%, is

Table 4 Multivariate logistic regression analysis of independent predictors of symptom resolution at 1 year

Variables	β value	Odds ratio	95% CI	p value
Calcification size*	0.188	1.207	1.039–1.42	0.014
Calcification removal method **	− 0.444	0.641	0.184–2.23	0.485
Baseline VAS score	− 0.662	0.516	0.267–0.996	0.049
Calcification type				
Fluid	2.203	9.056	1.24–66.141	0.03
Soft	1.006	2.735	0.763–9.812	0.123
*Hard****				0.071

* maximum dimension, ** total/partial, *** reference category (odds ratio of "soft" and "fluid" are calculated with reference to "hard")

changing proportionally with regard to the initial pain score, patients with lower baseline scores are more likely to achieve complete pain resolution post-treatment [11].

There are some limitations that should be considered in the present study. First, both diagnostic US and interventional procedures were performed by two different operators, which may have an impact on the evaluation of calcification characteristics and/or the amount of retrieved calcific material. However, both radiologists had received the same training regarding the performance of US-PICT. Second, two different scoring systems were utilized in the present study. Although CS was assessed in about half of patients, to our viewpoint, the comparative evaluation of the two scoring methods is adequately enabled. Third, the number of included patients may be regarded as a limitation. This is attributed to the application of strict inclusion criteria, which by themselves led to the exclusion of a large number of patients having a potential impact on the clinical applicability of our results. However, merely for research purposes, exclusion of patients with interfering causes of shoulder pain or impaired functionality ensured the homogeneity of the study group, by avoiding confounding effects. Finally, based on the study design implemented herein, a treatment algorithm for patients with RCCT having predictors of poor outcome for US-PICT, cannot be suggested. In this regard, further research in the context of randomized control trials comparing the efficacy of the method with alternative therapeutic options is required.

In conclusion, the morphologic characteristics of calcific deposits together with the pain/disability score at baseline may serve as predictors of clinical outcome following US-PICT. On the other hand, beyond the first week, the degree of extracted calcific material does not appear to show any prognostic significance or correlate with patients' symptoms, implying that it is not essential to completely remove the calcified deposit in order to obtain substantial clinical benefit. Judging from the ongoing interest in the utilization of US-guided procedures around the shoulder, further research is needed in order to establish the predictors of clinical effectiveness for US-PICT in the long term. Determination of such prognostic factors, with potential impact on patient selection criteria and technical parameters, is important as it may allow for individualized management and can eventually further enhance the value of the method. Nonetheless, US-PICT largely remains the treatment of choice for painful rotator cuff calcific tendinopathy, with reported superiority over other non-surgical therapeutic options.

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Ethical Approval Institutional Review Board approval was obtained.

Methodology
- prospective
- diagnostic or prognostic study
- multicenter study

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