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Ultrasound findings and prognosis of shoulder pain: A role for Doppler signal?

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Abstract

Purpose: To find ultrasound prognostic factors for shoulder pain.

Methods: This was an observational, prospective study, comparing the evolution of ultrasound findings with clinical outcomes, in patients with shoulder pain. Data were collected in two appointments, from February 2018 to March 2021. Two-tailed non-parametric statistics were used, and p values <0.05 were considered significant.

Results: A total of 79 participants were included in this study (median age 59 years, range 24–70, 61 women). A positive Doppler signal on tendons ($p = 0.002$) and absent tendon heterogeneity ($p = 0.01$) were associated with the patient's self-reported improvement. Tendon calcifications with poorly defined contours ($p = 0.03$) and sparse distribution ($p = 0.001$) were associated with VAS improvement. A reduction in the number of calcifications ($p = 0.004$), in the supraspinatus tendon thickness ($p = 0.01$), in subacromial effusions ($p = 0.03$), and in color Doppler grade ($p = 0.02$), between initial and follow-up exams, was found in patients with an improved DASH outcome.

Conclusion: A positive Doppler signal on shoulder tendons can be a marker for a better prognosis in shoulder pain. Poorly defined and sparsely distributed calcifications can also indicate a better course of the disease.

KEYWORDS

prognosis, rotator cuff, shoulder pain, tendinopathy, ultrasonography, Doppler

1 | INTRODUCTION

Shoulder pain is a common disorder, and its course varies from acute complaints to chronicity.[1–3] Prognosis is influenced by clinical, sociodemographic, and psychological factors. Higher intensity of pain or higher baseline disability, concomitant pain on other anatomical sites and especially on the neck, the presence of co-morbidities, a longer duration of pain or the existence of previous episodes of shoulder pain, older age and continued professional shoulder effort, are variables associated with poorer outcomes.[4–10] An association between a specific diagnosis and the outcome was not found in numerous studies.[3]

Imaging, and particularly ultrasound variables, were less commonly assessed as prognostic indicators for shoulder pain. Most of

Abbreviations: DASH, Disabilities of the arm, shoulder and hand outcome measure; US, ultrasound; VAS, visual analog scale.

the published work followed the course of disease after specific interventions, such as ultrasound-guided steroid injections and barbotage,[11–14] or in the setting of specific lesions, like rotator cuff tears and calcific tendinitis.[15,16] Better outcomes after corticosteroid injection occurred in patients with subacromial bursa thickening, fluid, or calcification, or with a positive response to diagnostic injections of local anesthetics into the acromioclavicular or glenohumeral joints.[12] Ultrasound-guided percutaneous treatment of rotator cuff calcific tendinitis, including needling or lavage, showed better results for soft and middle-sized calcifications,[14] and the presence of color Doppler signal within or close to the calcifications was associated with improvement of calcific plaques.[17] Doppler signal was thought to be due to an increased vascular supply linked to the acute inflammation involved in the spontaneous resorption of the calcified plaques and, overall, in the process of tendon healing. As so, Doppler might be a marker for a better prognosis of pain related to shoulder tendinopathy. Patients with calcific tendinitis showed a better prognosis when calcifications were smaller, more lateral, and transparent to x-ray with indistinct borders.[16] Of interest, in patients with hemiplegic shoulder pain after stroke, there was evidence that the number of sonographic findings correlated with clinical outcome.[18,19]

The purpose of this study was to find ultrasonographic prognostic factors for shoulder pain. We hypothesize that Doppler signal often found on tendons of painful shoulders represents hypervascularity related to the healing process and thus its presence is linked to a better patient's prognosis.

2 | PATIENTS AND METHODS

2.1 | Study design and participants

This was an observational, prospective study, intended to compare ultrasound findings with clinical outcomes, in patients with shoulder pain. Data were collected between February 2018 and March 2021, comparing an initial evaluation and a follow-up appointment. The study was approved by the Ethics Committee of our institution. All patients signed an informed consent document. All information was anonymously recorded.

Patients aged between 18 and 70 years old, referred for unilateral shoulder US in our hospital radiology department, and with two complete examinations, at least 9 months apart, were included in this study. Subjects previously participated in two cross-sectional studies.[20,21] Exclusion criteria included prior shoulder surgery, glenohumeral osteoarthritis, systemic infectious or inflammatory disease, an oncologic disease diagnosed in the previous 5 years, pregnancy, and inability to understand and accept informed consent or answer the study questionnaire. Patients referred for bilateral shoulder examination or whose exam was requested in the setting of occupational medicine, by a court of law or intending to define compensation or absence from work were excluded in order to avoid measurement bias. Only patients with a DASH (disabilities of the arm, shoulder and hand outcome measure) score of 20 or more[22] on the first appointment were included.

2.2 | Measurements

On each appointment, patients filled out a written form, including a visual analog scale for current pain (VAS) and a DASH questionnaire, scored as described in the literature.[23] VAS was assessed using a 100 mm horizontal line with two opposite labels on the extremes, and patients marked a score by drawing a vertical line. This method showed a good test–retest reliability (Spearman's correlation coefficient, $\rho = 0.87$, for current pain) and a moderate correlation with pain scores measured by other methods ($\rho = 0.54$ correlation with the one dimension of the SF-36 measuring pain).[24] The full version of DASH was used, which has excellent test–retest reliability (intraclass correlation coefficient, ICC = 0.89, for the Portuguese version that was applied[23]), a good responsiveness (standardized response mean, SRM = 1.1, with a minimal clinically important difference = 10.2), and a strong correlation ($r > 0.70$) with other questionnaires measuring shoulder function, without a known floor or ceiling effect.[22]

On follow-up, patients were asked to classify their evolution in a single question (translated: *Compared to the first evaluation, how did your shoulder complaints evolve? – better, equal or worse*), not previously validated, as improved versus non-improved (equal or worse); the answer to this question (mentioned below as self-reported improvement) and the variation of DASH and VAS scores between appointments were considered the outcomes of the study.

Clinical data collection and physical examination were accomplished, on each evaluation, by one of two rheumatology-trained clinicians. Range of motion was registered, and total degrees lost were calculated as the sum of the differences to maximum values (180° for abduction and flexion and 90° for internal and external rotation). Jobe, Neer, and palm-up signs were assessed.

All US exams were performed by a radiologist with 16 years of shoulder US experience, blinded to the results of questionnaires and physical exams. The exams were performed with an Acuson S2000 (Siemens Medical Solutions USA Inc., Issaquah, WA) using a multifrequency linear probe (14L5), operated between 11 and 14 MHz, with the patient seated in front of the examiner. The long head of the biceps tendon was assessed with the patient's forearm on his homolateral thigh, and the subscapularis tendon was examined in external rotation of the shoulder. The supraspinatus tendon was examined in internal rotation, with the hand on the back. The infraspinatus and teres minor tendons were evaluated in slight internal rotation of the shoulder.[25–27]

Rotator cuff calcifications were defined, like in previously published studies,[28,29] as echogenic focus with or without posterior acoustic shadow, identified in two orthogonal planes. The total number of calcifications and their largest diameter, location in lateral-medial direction (disclosed by the distance to osseous insertion in a direction parallel to tendon fibers), location in a particular tendon or structure, geometry, contour regularity and definition, the intensity of acoustic shadow and grouping were recorded.

Changes in tendon echotexture were reported as heterogeneity (variable echogenicity along the tendon) or hypoechogenicity (compared to muscle). Tendon rupture was assessed according to described criteria.[25,26,30]

The assessment of color Doppler in the rotator cuff and long head of biceps tendons used a pulse repetition frequency (PRF) of 488 Hz, as previously described,[28,30] and the signal was graded from 0 to 3 as follows: (0) no significative persistent signal and only minimal scattered noise; (1) one or two points or short lines; (2) three to six points or short lines; and (3) more than six points, a continuous line, or a bar of color. A grade ≥1 was considered positive for color Doppler signal. The gain was set at the highest value which provided none or only minimal noise in adjacent tissue (deltoid muscle). The occurrence of twinkling artifacts (fast alternating between colors near the limit of the spectrum) was registered.

2.3 | Statistical analysis

Demographic, clinical, and ultrasound variables were described by central tendencies and dispersion measures or by frequencies, as appropriate. The dispersion of each continuous variable was tested for normality using Shapiro–Wilk's statistics.

We hypothesize that ultrasound findings, including Doppler, differ at baseline between patients with good or poor outcomes. We also hypothesize that a different evolution of ultrasound findings can be found between those two groups of patients.

Frequencies of categorical variables were compared using a Fisher's exact test between independent groups and a McNemar test for comparison of related samples. To compare the distribution of continuous or ordinal data, a Mann–Whitney *U* test and a Wilcoxon test were employed, respectively. Spearman's coefficient was used for bivariate correlations. A binary logistic regression model (enter method) was applied to possible relevant predictors and possible confounders (therapy and time elapsed between evaluations) to test for independence of the effects.

All tests used were two-tailed and p values <0.05 were considered significant.

Data were analyzed with SPSS statistical software, version 24 (IBM Corp., Armonk, NY).

3 | RESULTS

3.1 | Characteristics of the patients

Seventy-nine patients with complete baseline and follow-up examinations were included in this study. The median number of days between both evaluations was 308 (interquartile range = 28; range 266–679). The sociodemographic and clinical characteristics of the 79 patients (61 female and 18 male, median age 59 years) are displayed in Table 1; clinical features are shown for both initial and follow-up evaluations. Among all variables assessed, only VAS and DASH scores showed a normal distribution, thus non-parametric statistics were applied in all comparisons. Lower DASH and VAS scores, and fewer positive palm-up tests were found on follow-up. When asked to classify the evolution of symptoms in a single question, on follow-up, 31 (39.2%) patients self-reported their complaints had improved since the initial evaluation and 48 (60.8%) patients felt equal or worse than before.

The DASH and VAS outcomes were moderately associated (Spearman correlation coefficient, $\rho = 0.546$, $p < 0.001$). A lower but significant association was found between self-reported improvement and DASH ($\rho = 0.414$, $p < 0.001$) and between self-reported improvement and VAS ($\rho = 0.436$, $p < 0.001$). None of the patients was submitted to surgery; 50 patients were treated with anti-inflammatory drugs, 44 with analgesics, 13 with antispasmodics, and 8 had physiotherapy.

TABLE 1 Sociodemographic and clinical characteristics of the participants.

Characteristics	Initial	Follow-up	*p* value
Number of participants	79		
Sex, women	61 (77)		
Age, years[a]	59 [13]		
Examined side, right	52 (66)		
DASH score[a]	55 [26]	45 [31]	**<0.001**
VAS[a]	55 [27]	49 [33]	**<0.001**
Positive shoulder tests			
Jobe	55/71 (77)	50/71 (70)	0.38
Neer	34/71 (48)	33/71 (46)	0.50
Palm-up	47/72 (65)	27/72 (38)	**0.002**
Range of motion, total degrees lost[a]	30 [145]	40 [80]	0.93

Note: Unless otherwise indicated, data are numerators and data in parentheses are percentages, compared using McNemar test; denominator was omitted when equal to the number of participants in first row. Significant *p*-values are highlighted in bold.

Abbreviations: DASH, disabilities of the arm, shoulder and hand outcome measure; VAS, visual analog scale for pain.

[a]Data are median and data in brackets are interquartile range, compared using the Wilcoxon test.

The US findings on baseline and follow-up examinations are shown in Table 2. On follow-up, the number of calcifications on shoulder tendons was lower and less patients had hypoechogenic tendons. The Doppler signal was found mostly outside the calcifications and the frequency of twinkling artifacts was low.

3.2 | Prognostic factors on baseline ultrasound examination

A positive color Doppler signal on tendons at baseline was more frequent in patients who self-reported improvement ($p = 0.002$). Patients who self-reported improvement also showed fewer tendons with heterogeneity on the first examination ($p = 0.01$). A comparison between initial US features in patients who self-reported improvement versus non-improvement is depicted in Table 3. Those differences were not present when a comparison was done between patients with positive and negative variations of DASH and VAS scores.

A total of 160 calcifications were found in the initial evaluations. A comparison between the characteristics of the individual calcifications found in the initial exam of patients with or without an improvement in VAS score is shown in Table 4. Patients who showed a decrease in VAS score on follow-up had more calcifications with poorly defined contours ($p = 0.03$) and more sparse calcifications ($p = 0.001$). No significant differences were found when DASH or self-reported improvement were considered (Supplementary Data, Tables S1 and S2).

TABLE 2 Ultrasound findings on initial and follow-up examinations.

Findings	Initial	Follow-up	*p* value
Number of calcifications[a]	1.0 [2.0]	1.0 [3.0]	**0.02**
Diameter of largest calcification, millimeters[a]	3.1 [4.6]	2.4 [5.2]	0.23
Tendon heterogeneity	38 (48)	27 (34)	0.07
Tendon hypoechogenicity	39 (49)	27 (34)	**0.02**
Tendon insertional thickening	24 (30)	14 (18)	0.08
Supraspinatus thickness, millimeters[a]	5.5 [1.4]	5.4 [1.7]	0.15
Glenohumeral effusion	22 (28)	19 (24)	0.58
Subacromial effusion	10 (13)	6 (8)	0.42
Color Doppler	18 (23)	11 (14)	0.12

Note: Unless otherwise indicated, data are numerators and data in parentheses are percentages, compared using McNemar test; the denominator used to calculate the percentages was the number of participants (79). Significant *p*-values are highlighted in bold.
[a]Data are median and data in brackets are interquartile range, compared using the Wilcoxon test.

TABLE 3 Initial ultrasound findings on self-reported improving and non-improving participants.

Findings	Improving	Non-improving	*p* value
Number of participants	31	48	
Number of calcifications[a]	2.0 [3.0]	1.0 [3.0]	0.23
Diameter of largest calcification, millimeters[a]	3.5 [5.2]	2.5 [5.2]	0.21
Largest distance of calcification to insertion, millimeters[a]	2.6 [2.8]	1.8 [4.1]	0.47
Tendon heterogeneity	9 (29)	29 (60)	**0.01**
Tendon hypoechogenicity	18 (15)	21 (44)	0.25
Tendon insertional thickening	11 (36)	13 (27)	0.46
Humeral tuberosity cortical irregularity	18 (58)	27 (56)	1.00
Rotator cuff tear	8 (26)	7 (15)	0.25
Supraspinatus thickness, millimeters[a]	5.3 [1.2]	5.6 [1.7]	0.83
Glenohumeral effusion	9 (29)	13 (27)	1.00
Subacromial effusion	4 (13)	6 (13)	1.00
Color Doppler	13 (42)	5 (10)	**0.002**

Note: Unless otherwise indicated, data are numerators and data in parentheses are percentages, compared using Fisher's exact test; the denominator used to calculate the percentages was the number of participants in first row. Significant *p*-values are highlighted in bold.
[a]Data are median and data in brackets are interquartile range, compared using the Mann–Whitney *U* test.

TABLE 4 Characteristics of individual calcifications and VAS outcome.

Characteristics	ΔVAS < 0	ΔVAS ≥ 0	*p* value
Total number of calcifications described	118	42	
Diameter, greater axis in millimeters[a]	2.9 [3.2]	2.7 [2.9]	0.66
Distance to insertion, millimeters[a]	1.8 [1.7]	2.0 [1.5]	0.61
Location			0.87
Supraspinatus	33 (28)	14 (33)	
Infraspinatus	30 (25)	9 (21)	
Subscapularis	43 (36)	14 (33)	
Geometry			0.19
Linear	14 (12)	3 (7)	
Oval	67 (57)	19 (45)	
Polyhedral	37 (31)	20 (48)	
Irregular contour	53 (45)	18 (43)	0.86
Poorly defined contour	23 (20)	2 (5)	**0.03**
Acoustic shadow			0.85
Absent	102 (86)	36 (86)	
Mild	15 (13)	6 (14)	
Strong	1 (1)	0	
Grouped	10 (9)	13 (31)	**0.001**

Note: Unless otherwise indicated, data are numerators and data in parentheses are percentages, compared using Fisher's exact test; the denominator used to calculate the percentages was the number of calcifications in first row. Significant *p*-values are highlighted in bold.
Abbreviation: VAS, visual analog scale for pain.
[a]Data are median and data in brackets are interquartile range, compared using the Mann–Whitney *U* test.

TABLE 5 Evolution of ultrasound findings on patients with improved DASH outcome.

Findings	No. patients	Initial	Follow-up	Variation	*p* value
Number of calcifications	45	2.0 [2.0]	2.0 [2.0]	−1.0 [1.0]	**0.004**
Diameter of largest calcification, millimeters	45	3.8 [4.8]	3.1 [4.2]	−0.2 [2.4]	0.20
Supraspinatus thickness, millimeters	54	5.7 [1.5]	5.4 [1.6]	−0.5 [1.2]	**0.005**
Subacromial effusion, millimeters	6	4.3 [4.6]	0.0 [0.8]	−4.3 [3.8]	**0.03**
Color Doppler grade	15	2.0 [2.0]	0.0 [1.0]	−1.0 [3.0]	**0.02**

Note: Data are median and data in brackets are interquartile range, compared using the Wilcoxon test. Only patients with positive findings on initial exam were considered. Significant *p*-values are highlighted in bold.
Abbreviation: DASH, disabilities of the arm, shoulder and hand outcome measure.

3.3 | Ultrasound features evolution and clinical outcomes

Significant differences were found in the ultrasound features evolution, according to the outcomes. In the subgroup of patients who improved the DASH score, a decrease in color Doppler grade ($p = 0.02$), in the number of calcifications ($p = 0.004$), in the supraspinatus tendon thickness ($p = 0.005$), and in subacromial effusions ($p = 0.03$) was detected (Table 5). In the subgroup of patients who improved their VAS score, there was a reduction in the number of calcifications ($p = 0.002$) and in subacromial effusion thickness ($p = 0.02$) and in the subgroup of patients with a self-reported symptomatic improvement a decrease in the number of calcifications ($p < 0.001$) and a reduction in color Doppler grade ($p = 0.046$) was also found (Supplementary Data, Tables S3 and S4).

Images from a patient with a decrease in the subacromial effusion and an improved DASH (75 to 70 over a period of 9 months) are depicted in Figure 1. Figure 2 illustrates a case with a reduction in Doppler signal grade on the supraspinatus tendon and an improved DASH score (from 40 to 26 after 10 months).

3.4 | Potential confounders

When comparing different outcomes, there was no difference in age, sex, dominancy of the examined shoulder or in the number of days between evaluations. No differences in study outcomes (DASH, VAS, and self-reported improvement) were found between the various therapies and between patients who received any treatment and those who did not. A binary logistic regression model, displayed in

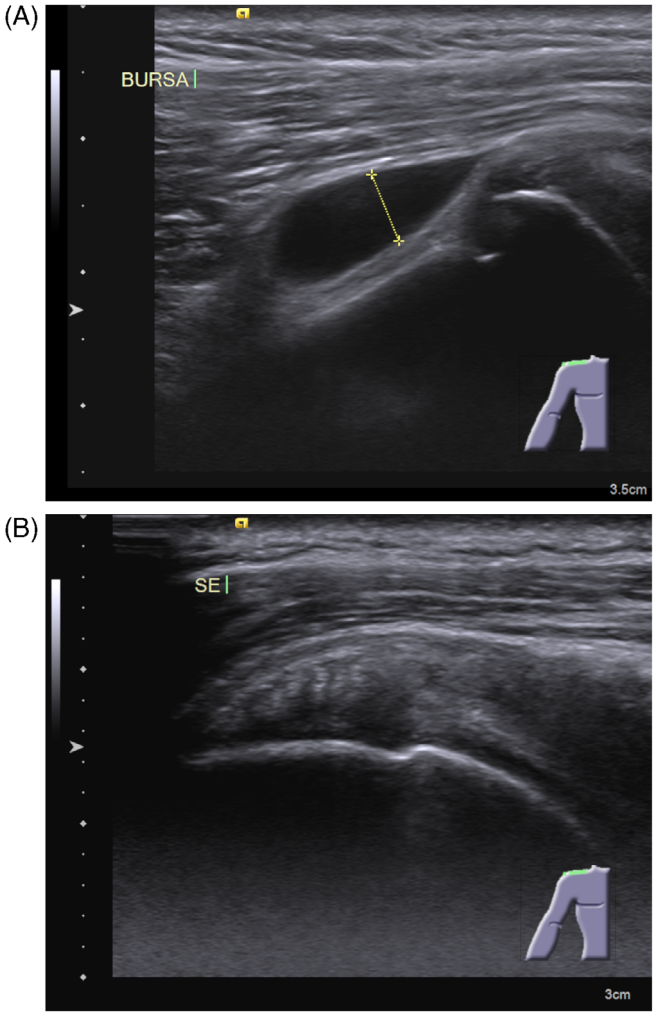

FIGURE 1 Ultrasound images of a patient with a subacromial effusion on first exam (A) and no effusion found after 9 months (B); this patient showed a slight reduction on DASH score between examinations.

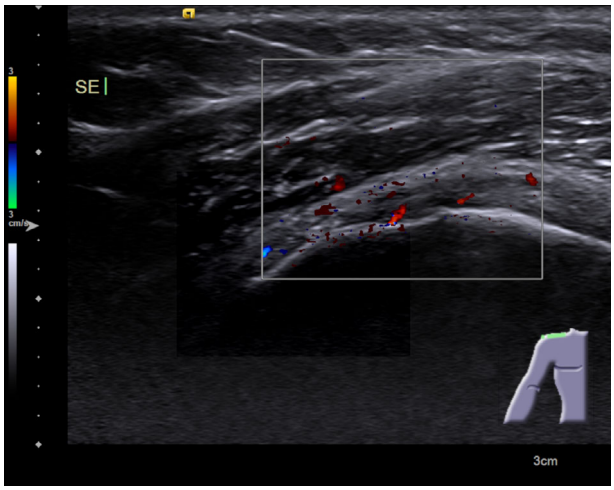

FIGURE 2 Ultrasound image of a patient's first exam, with several bars of Doppler signal present in the supraspinatus tendon; 10 months later no Doppler signal was found, and the DASH score had improved from 40 to 26. A pulse repetition frequency (PRF) of 488 Hz was used.

TABLE 6 Binary logistic regression model for self-reported improving outcome.

Variable	*B*	*p* value
Color Doppler present	−2.149	0.002
Tendon heterogeneity	1.551	0.007
Anti-inflammatory drugs	0.863	0.17
Any treatment received	0.472	0.61
Number of days between evaluations	−0.002	0.43

Note: Nagelkerke $R^2 = 0.348$.

Table 6, confirmed the independence of the effects of color Doppler signal and tendon heterogeneity regarding therapy and time elapsed between evaluations.

In the subgroup of patients who improved the DASH score, variation in the supraspinatus thickness (Spearman correlation coefficient, $\rho = -0.270$, $p = 0.049$) and variation in the number of calcifications ($\rho = 0.313$, $p = 0.04$) showed a little, yet significant, association with the use of anti-inflammatory drugs; no other significant association was found between the evolution of ultrasound findings and the medication used or with the time elapsed between evaluations.

4 | DISCUSSION

Most of the factors known to influence shoulder pain prognosis are clinical or sociodemographic. In this study, we compared the clinical and ultrasonographic evolution of patients presenting with shoulder pain. Patients with a self-reported improvement of symptoms had on a baseline US evaluation less tendon heterogeneity ($p = 0.01$) and more frequent Doppler signal on tendons ($p = 0.002$). Baseline tendon calcifications with a poorly defined contour ($p = 0.03$) and with a sparse distribution ($p = 0.001$) were associated with a better evolution of pain, as evaluated by VAS. In patients with a positive outcome, as depicted by a diminishing DASH score, a reduction was found in the number of US calcifications ($p = 0.004$), in the supraspinatus tendon thickness ($p = 0.005$), in subacromial effusions ($p = 0.03$) and in color Doppler grade ($p = 0.02$), between initial and follow-up exams.

An association between outcome and calcification size and location was not observed in our results, but calcifications with an indistinct contour were associated with improving pain, in agreement with the study from Ogon et al.[16] Furthermore, a diminishing number of calcifications was found in patients who had a positive outcome. Previously, de Witte et al.[31] reported that multiple calcifications on baseline were associated with an inferior long-term outcome.

The presence of color Doppler signal in the rotator cuff or in the long head of biceps tendons on initial evaluation, and the reduction in Doppler grade on follow-up noted in patients with a positive outcome supports the results found by Chiou et al.[17]; those authors found a better prognosis, with an increased frequency of spontaneous

resorption, in calcifications with hypervascularity on color Doppler ultrasound. However, we found Doppler signal not only related to but also unrelated to calcifications, suggesting that a vascularity increase associated with a reparative process can also occur besides calcific tendinitis. Le Goff et al.[28] also depicted an association between pain and hypervascularity within or close to calcifications, potentially corresponding to the reabsorption phase of calcific tendinitis as described by Uhtoff et al.[32]

A decrease in subacromial effusion, seen in patients with improving pain and disability scores, suggests that the presence of liquid in the subacromial bursa may have a role in the genesis of pain. A better response to treatment with corticosteroid injections when patients first presented with a subacromial effusion was earlier found by Le Goff et al.[28]

Heterogeneous tendons, with a variable echogenicity along their length, seem to be associated with sustained symptoms, pointing to irreversibility of the lesions. Supraspinatus thickness decreased in our patients in association with better outcomes; this is in accordance with the association previously described between supraspinatus thickness and tendinopathy.[33]

This study had several limitations. As an observational study, medication was not controlled. However, from the analysis of the reported treatments, there is no indication that medication led to any significant bias. The time elapsed between evaluations was variable, but no correlation was found with outcomes or with the evolution of ultrasound findings. The outcome variables are subjective and dependent on the patient's answers, and the correlation between them was only low to moderate; this aspect is particularly relevant for self-reported improvement, which was based on just one, not previously validated, question. The results were not homogeneous regarding the different outcome variables, restricting the interpretation and generalization of the results. Ultrasound variables concerning tendon echotexture changes and insertional thickening are defined in several publications but have always a subjective component.

In conclusion, there is no obvious and irrefutable ultrasound marker for a good prognosis. The presence of a positive Doppler signal on shoulder tendons might be a marker for a better prognosis of shoulder pain. Poorly defined, sparsely distributed calcifications seem also to be associated with a better course of shoulder pain.

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no conflict of interest.

DATA AVAILABILITY STATEMENT

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

ETHICS STATEMENT

This project was approved by the Ethics Committee of our institution (Approval Letter Ref. n. 413/17) and have therefore been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments. Written consent was obtained from all individual participants included in the study.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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