# ULTRASOUND PREDICTORS OF ROTATOR CUFF TEARS IN PATIENTS WITH SUBACROMIAL IMPINGEMENT SYNDROME OF THE SHOULDER

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**Abstract**

The clinical value of measurement of qualitative and quantitative ultrasound parameters in patients with subacromial impingement syndrome in the diagnosis of rotator cuff tears of the shoulder was evaluated in 128 patients with age range 18 - 83. In all patients the length of coraco-acromial ligament, width of the supraspinatus tendon, structure, type of sonoelastography map in pathologically colored region of the supraspinatus tendon and strain ratio value in those regions, occupational ratio of the supraspinatus muscle to supraspinatus fosse were measured. The significance of the differences between the group of patients with tears and without was evaluated. The comparance of the diagnostic informativity of the main valuable ultrasound parameters in rotator cuff tear prognosis with calculation of the AUC ROC-analysis was performed. Results of the work showed the most optimal diagnostic model of the rotator cuff tendon's tear: width of the supraspinatus tendon more then 0,50 cm; structure – 2-nd и 3-rd type; colored map type of tendon sonoelastography – 3-rd; sonoelastography strain ratio – less than or equal 1,16. Using such criteria in complex study the sensitivity was 94% and specificity was 96% in detection of partial thickness rotator cuff tear of the supraspinatus tendon of the shoulder. The resume was conducted that sonoelastography should be included in all ultrasonographic studies of the shoulder; in this connection it increases diagnostic informativity of the partial thickness rotator cuff tears.

**Key words:** Ultrasound elastography, strain elastography, supraspinatus tendon partial tears, rotator cuff tears, MRI, CT-arthrography, shoulder arthroscopy

## Introduction

Impingement is a painful dysfunction of shoulder joint biomechanics resulting from compression of shoulder rotator tendons and/or bursa between coracoacromial arch and the tubercles of the humerus while abducting the arm upwards. With the rotator suffering most of the damage being the supraspinatus tendon [1]. The rotator tendon tears frequency in the population varies from 15 to 32 per cent, increasing with age, and doubles in the presence of subacromial impingement syndrome [2]. The risk group for developing the condition includes those leading an active lifestyle, professionals with overloading upper extremities and athletes. Impingement syndrome diagnostics during its early stages allows to halt progression of symptoms and prevent full rotator cuff tears.

Ultrasound examinations are widely used for examining shoulder pain patients for their fast, dynamic and highly informative nature. Latest publications involving high frequency ultrasound probes suggest comparable Ultrasound and MRT accuracy in detecting complete RC tears, while partial tears detection varying form 91.6% to 96.4% for Ultrasound and 92.8% to 96.1% for the MRT [3-5]. Recent research papers also show that musculoskeletal system ultrasound elastography allows for a new level of RC pathology diagnostics, differentially diagnose tenditis with degenerative changes, and more precise partial tears diagnostics [6-15]. Considering wide use of ultrasound in musculoskeletal system diagnostic practices further study of its new capabilities may be of considerable relevance.

The objective of this paper is to evaluate ultrasound predictors of the rotator cuff tears based on the new digital ultrasound technologies.

## Materials and Methods

A total of 128 patients with complaints of shoulder joint pain or dysfunction and lack of bone trauma in standard radiography, with positive tests for impingement syndrome during a clinical examination, or with positive tests of RC lesions, or with previously detected changes in the RC tendons using MRI or ultrasound, who had a short (5-7 days) course of nonsteroidal anti-inflammatory drugs that did not lead to pain reduction or range of motion recovery in the joint, were enrolled in a comprehensive prospective study based on the Federal State Budgetary Institution. «United hospital and policlinic» General Management department of the President of Russian Federation in 2015-2018 of 128 patients 67 (52%) were men and 61 (48%) women, the average age was 57.3 ± 12.8 years (from 18 to 83 years). Most of the patients (78.6%) were in the older age group (from 50 to 80 years). Acute shoulder injury leading to the onset of pain was observed in 14 patients (10.9% of cases): household injury - in 5 (4%) patients, non-sport related fall or impact injury - 4 (2.9% ), sport injury - in 5 (4%). The chronic trauma in patient history was present in 45 patients (35.2% of cases). The remaining 69 patients (53.9% of cases) did not have a connection between the onset of pain and the injury episode. All patients underwent a comprehensive clinical radiology examination, which included: clinical visual examination, assessment of pain level and functional limitations using test questionnaires, radiography of the shoulder joint, ultrasound with sonoelastography, MRI, MDCT or MR arthrography were performed if deemed necessary, therapeutic and diagnostic arthroscopy.

Ultrasounds examinations were performed using standard methodology by a certified ultrasound specialist trained in musculoskeletal examinations on the expert class devices MyLabClassC (ESAOTE), Preirus (HITACHI), EPIC (Philips), equipped with compression SEG. For the examinations high-frequency probes(10-18 MHz) were used. The ultrasound images were interpreted jointly by an orthopedic and ultrasound diagnostics traumatologist specialist.

The supraspinatus tendon structure was evaluated by using a method analogous to one proposed by H. Sugaya [16] for MRI use, but modified for ultrasound [16]:0 - tendon of sufficient thickness, homogeneous structure, normal echogenicity, comparable in echogenicity to the tendon of the subscapularis or infraspinatus muscles(with parallel linearly arranged fibers);

1- the tendon is thickened, without discontinuity, but the structure contains hypoechoic areas (uneven contours, partial disappearance of the fibrillar structure, local zones of reduced echogenicity that are less than 25% of the thickness of the entire tendon);

2 - decrease in echogenicity by 25% of the thickness of the tendon (complete disappearance of the fibrillar structure);

3 - tendon thinned (less than 0.4 cm), a possibility of a partial tear indicated by appearance of zones of discontinuous fibers and anechoic areas (signs of a partial tear);

4 - tendon missing. Tendinitis is diagnosed in the presence of 1st and 2nd degree of structural changes, a partial tear is diagnosed in the presence of the 3rd degree, a complete tear - in the presence of the 4th degree changes.

The qualitative analysis of supraspinatus tendon SEG images was controlled by the quality scale (QF) on the monitor screen. The SEG region of interest included the trapezoid muscle and a part of subcutaneous fat. The type of supraspinatus tendon SEG coloring was determined by using a 4-point density color scale, where: 0 - the tendon is evenly colored blue; 1 - the predominant color is blue, green zones are less than 25%; 2 - the predominant color is green; 3 - zone of red or yellow colors; 4 - linear red line.

The supraspinatus tendon tear was diagnosed at the 3rd degree as per the SEG, the absence of a tear at the 1st and 2nd degrees of SEG mapping, a complete tear was diagnosed with 4th type present. Strain ratio (SR) was used for SEG quantitative measurement, that compared the pathologically colored area of supraspinatus tendon to the deltoid muscle.

To assess the degree of supraspinatus atrophy the area of the main part of the muscle relative to the area of the supraspinous fossa – OR, was calculated using transverse oblique scans in the B-mode and in the SEG mode. The degree of supraspinatus atrophy was established with the use of ultrasound according to a 3-point scale developed by Thomazeau H. (1996) [17], where stage 1 related to OR values from 1 to 0.6 (normal or mild atrophy), stage 2 to OR values from 0.6 to 0.4 (moderate atrophy), stage 3 - to OR values less than 0.4 (severe atrophy).

Statistical analysis was carried out using the MEDCALC software. Quantitative results were presented in the form of arithmetic mean (M) and standard deviation (SD), in several cases median and the standard deviation of median were used.

Following data processing methods were used in this paper: - ROC analysis — to find a threshold value for a quantitative indicator at which the highest values of sensitivity and specificity are observed within the model under consideration. Scatter diagrams were plotted; - univariate regression analysis indicators with a significance level (p) less than or equal to 0.2 were included in a logistic regression analysis - to determine predictors of diagnosing supraspinatus tendon tears. Final model parameters were determined using backward elimination method. The identified results were considered statistically significant with p values <0.05. Sensitivity and specificity were calculated using the following formulas: sensitivity (%) = true-positive result / (true-positive result + false negative) x 100%; specificity (%) = true-negative result / (true-negative result + false positive) x 100%.

**Results**

RC tears were detected in 69 patients (53.9%): total - in 13, partial - in 56 patients: intra-articular type - 29, intratendinosis - 9, extra-articular - 8, full-thickness - 10, chronic tendinitis - in 59 (46.1%), of these 9 with calcific tendinitis.

Supraspinatus tendon thickness in 57 patients with partial tears ranged from 0.43 to 0.86 cm (and in 50 patients more than 0.54 cm). The structure of the tendon as examined in B-mode ultrasound in 31 patients was found to be of 3rd type, in 20 - of the 2nd type and in 6 - of the 1st type. The type of SEG mapping in 44 patients with tears corresponded to type 3, in 12 to type 2, and in one to type 1. In 51 tears patients SR in the pathologically colored coded area was less than or equal to 1.16, and in 57 patients was less than or equal to 1.9.

The mean values and standard deviation of ultrasound indicators analysis results, and significance of comparison of RC tear/non tear patients' groups differences are presented in Table 1.

**Table 1.**

The values of ultrasound parameters in the groups of comparance

| *US parameters* | *RCT N = 67* | *No RCT N = 61* | P-value |
|---|---|---|---|
| Thicknes of SST in sm | 0,58±0,14 | 0,49±0,12 | P = 0,0002 |
| Structure of SST (0-3) | 2,50±0,65 | 1,29±0,78 | P < 0,0001 |
| SEG type in RCT or SST local zone (0-3) | 2,79±0,44 | 1,29±0,69 | P < 0,0001 |
| Strain ratio value | 0,78±0,41 | 2,50±1,43 | P < 0,0001 |
| Acromio-coracal diameter in sm | 2,75±0,29 | 2,85±0,28 | P = 0,0498 |

The informativeness of each of the ultrasound parameters in diagnosing partial tears or absence thereof was assessed by evaluating the AUC area under the ROC curves. This determined the most significant predictors in creating an optimal supraspinatus tendon tears detection model using ultrasound (Table 2).

**Table 2.**

The value of ultrasound parameters in diagnosis of partial RCT.

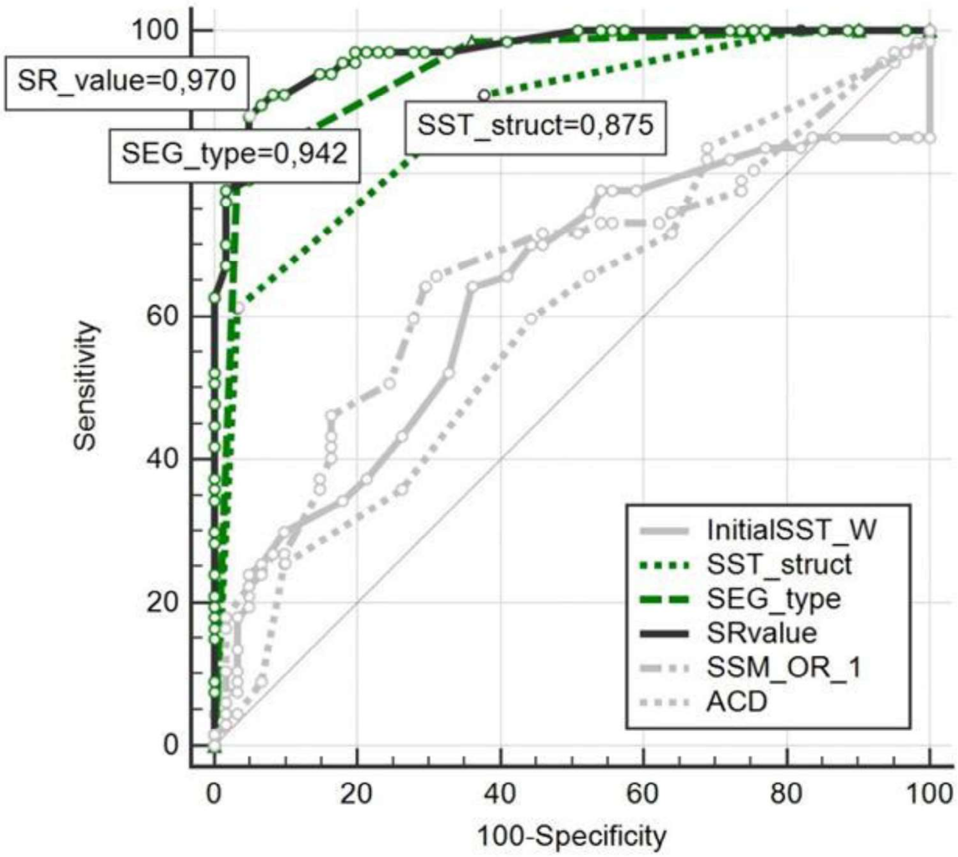
| ***Parameters N = 118*** | *Thicknes of SST* | *Structure of SST* | *SEG type* | *Strain ratio value* | *ACD* |
|---|---|---|---|---|---|
| AUC | 0,73 | 0,85 | 0,93 | 0,97 | 0,57 |
| 95%-CI | 0,63–0,80 | 0,77–0,91 | 0,87–0,97 | 0,92–0,99 | 0,47–0,66 |
| P-value | < 0,0001 | < 0,0001 | < 0,0001 | < 0,0001 | 0,1912 |
| Accuracy (Juden index) | 0,37 | 0,50 | 0,75 | 0,83 | 0,13 |
| Critical value | ≥ 0,50 | > 1 | > 2 | ≤1,16 | ≤2,7 |
| Sensitivity | 75,7 | 89,29 | 78,57 | 91,07 | 58,93 |
| Specificity | 62,5 | 61,02 | 96,61 | 91,53 | 54,24 |

The identified patters resulted in supraspinatus tendon partial tear diagnostic probability model that included 4 parameters: the thickness of the supraspinatus tendon of more than 0.50 cm; the structure of the supraspinatus tendon of 2nd and 3rd types; SEG supraspinatus tendon mapping of 3rd type; SEG strain ratio ≤ 1.16.

A comparative analysis of ROC curves showed high informativeness of the complex use of these supraspinatus tendon tears predictors data. The AUC area under the ROC curve is 0.99 (95% CI 0.95–1.00), the significance level is P <0.0001. Accuracy (Youden's index "J") - 0.91, sensitivity 94%, specificity 96%. A comparison of ROC curves for various ultrasound parameters is presented in Figure 1.

**Figure 1.**

ROC-curve comparance between different ultrasound parameters




Using a complex of predictors a diagnostic value of a model was evaluated for partial RCT (Table 3). Sonoelastography improved the diagnosis of partial RCT.

**Table 3.**

Informativeness of ultrasound predictors in the supraspinatus tendon partial tears diagnostics, in %

| *Parameters* | *SST thickness ≥0,50 sm* | *SST structure 2, 3* | *SEG type 3* | *Strain ratio ≤1,16* |
|---|---|---|---|---|
| Sensitivity | 75,7 | 89,4 | 78,3 | 91,4 |
| Specificity | 62,5 | 61,2 | 96,7 | 91,8 |
| AUC | 0,73 | 0,86 | 0,93 | 0,97 |
| Probability of positive finding | 1,6 | 2,3 | 22,0 | 10,9 |
| Probability of absence | 0,2 | 0,2 | 0,2 | 0,1 |
| Positive predictive value | 60,9 | 68,9 | 94,4 | 91,0 |
| Negative predictive value | 80,5 | 86,3 | 81,9 | 90,3 |

**Discussion**

The extent of the RC tear bears significant importance on the type of treatment and its outcome. Ultrasound examination methods provide informativeness that is comparable with MRI for the diagnosis of complete or partial RC tear. Given the low cost of the ultrasound and the wide availability of the method, it can be used in RC tears screening. The sensitivity and specificity of the basic ultrasound diagnostic method in the gray scale mode does not exceed 76%. This is due to the fact that with old-standing lesion to the tendon the defect can be filled with connective tissue that has a lower B-mode echogenicity, similar to low echogenicity in degenerative processes or tendinitis. Sensitivity and specificity of ultrasound during complete tears in the work of Cullen D.M. et al. (2007) accounted for 89% and 100% and 79% and 94% for partial ones [18]. A comparison made by Teefey S.A. et al. (2004) found the cumulative accuracy of ultrasound to be 87% [19], Fotiadou A.N. et al. (2008) showed an accuracy of 98% for complete and 87% for partial tears with ultrasound [20]. It has been proven that should an ultrasound examination be performed by an experienced orthopedic traumatologist, the sensitivity of detecting RC tears is comparable to that of an MRI scan performed by a radiologist [21]. In Europe and the United States there is a tendency for ultrasound to be carried out by a traumatologist as this reduces overall examination time for RC tears patients and shortens treatment planning [22]. A noted success and breakthrough in ultrasound diagnosis occurred with the advent of compression elastography technique based on the principle of comparing tissue compressibility resulting from a minor applied compression, first described by Ophir J. et al. (1999) [23]. It is based on the principle of color differentiation: the stiffed areas are mapped with one color and soft or elastic with a different color. Tissue stiffness is estimated in comparison to the reference tissue (eg, fatty tissue). The applicability of this method in shoulder joint examinations is made possible by superficial localization, the availability of rotational cuff tendons compression and the presence of the overlying muscle tissue (deltoid muscle) to compare compressibility. A wider use of sonoelastography in the musculoskeletal system examinations provides a new level of RC diagnosis, possibilities in differentiating tendinitis from degenerative changes and a more accurate diagnosis of partial RCT.

Inflammation and degenerative changes in the tendon are known to lead to a decrease in collagen fibers in the tendon, this is manifested by a local increase in its density and a decrease in the ability to stretch which ultimately leads to tears [11,14,24]. The echogenicity of the tendon with degenerative changes present is almost indistinguishable from unchanged tissue. It is this histopathological process that leads to an increase in compressibility and subsequent lower characteristics of the tissue density in tendinosis in the SEG mode [11, 14, 25].

In our earlier papers and as noted by other researchers, it was stated that a "healthy" supraspinatus tendon with SEG is much denser than a muscle and is, therefore, colored either blue or blue with green inclusions of up to 25%, "softening or tear zones in SEG are colored green or red" [ 11-15]. SEG, unlike MRI and standard gray scale ultrasound, allows to identify areas of partial tears against the background of degenerative tendon changes with identification of 3 types of SEG mapping and SR values of less than 1.1 with 85% accuracy ($p < 0.05$), which was already stated in our previous work [14]. Using MDCT arthrography and arthroscopy as reference methods, positive correlation of ultrasound, ultrasound with SEG and MRI data with the reference method results was observed in 62.3%, 82.9% and 78% of cases respectively [14].

In this paper we have additionally carried out a regression analysis of ultrasound predictors of supraspinatus tendon tears taking into account the SEG data. An analysis of the informativity of the ultrasound in identifying supraspinatus tendon partial tear was performed under this diagnostic model. The conclusion was made that ultrasound detected signs of supraspinatus tendon thickening of more than 0.5 cm should prompt on obligatory inclusion of SEG in the diagnostic algorithm to increases the detectability of the supraspinatus tendon partial tears. Statistically significant differences between all evaluated ultrasound indicators in the studied subgroups with and without supraspinatus tendon tears determine the importance of estimating the supraspinatus tendon thickness parameters, supraspinatus tendon structure, qualitative and quantitative SEG parameters as well as the supraspinatus muscle condition at SIS and RC tears.

Using the diagnostic model: supraspinatus tendon thickness of more than 0.50 cm; supraspinatus tendon structure of the 2nd and 3rd types; supraspinatus tendon SEG mapping of the 3rd type; SEG strain ratio of less than or equal to 1.16, it is possible to achieve a 94% sensitivity 96% specificity in detecting partial supraspinatus tendon tears.

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