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PII: S2666-6383(22)00019-6
Reference: JSEINT 548

To appear in: JSES International

Received Date: 30 November 2021
Accepted Date: 1 December 2021


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Evaluation of hypervascularity in synovitis of the shoulder using ultrasound: Comparison of preoperative ultrasound findings and intraoperative arthroscopic findings

Running title: Vascularity in shoulder synovitis by ultrasound

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Disclaimers
Funding: No funding was disclosed by the authors.
Conflicts of interest: The authors, their immediate families, and any research foundations with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

This study was approved by the Institutional Review Board of Keiyu Orthopaedic Hospital (#3012).
Abstract

Background: Synovitis of the shoulder causes pain; however, it is difficult to accurately determine the area and degree of synovitis from preoperative images. This study investigated the correlation between intraoperative arthroscopic findings and preoperative power Doppler ultrasonography (PDUS) findings for synovitis evaluation.

Methods: Forty patients (mean age 62.0 years; 24 males and 16 females) underwent arthroscopic surgery for partial rotator cuff tears. Three observation areas were evaluated: rotator interval (RI), subacromial bursa (SAB), and bicipital groove (BG). The Doppler flow areas and PDUS grade were measured one day before surgery. Arthroscopic findings were visualized intraoperatively and classified into three groups: pale, pink, and red. The correlation between the arthroscopic classification and PDUS findings was analyzed.

Results: The correlation between intraoperative arthroscopic classification and preoperative PDUS findings, Doppler flow area and PDUS grade, was high for the RI ($r = 0.82$, 0.70). There was no correlation for SAB ($r = 0.01$, -0.02) and BG ($r = -0.03$, 0.3).

Conclusion: Hypervascularity findings in the PDUS were highly correlated with arthroscopic color classification in the RI. Therefore, visualization of hypervascularity in the RI area could be a reliable measure for the assessment of glenohumeral synovitis in patients with partial-thickness rotator cuff tear.

Keywords: Ultrasound; power Doppler; rotator cuff tear; vascularity; arthroscopic color
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classification; synovitis

Level of evidence: Level III; Retrospective Design; Diagnostic Study

Shoulder pain and stiffness are common complications after arthroscopic rotator cuff repair (ARCR).

Although the pathology of shoulder pain is still controversial, several studies have reported subacromial and glenohumeral synovitis as being a source of pain in rotator cuff disease.\textsuperscript{1, 3, 12, 16, 20}

Being female, age less than 50 years old, workers compensation, diabetes, patients with partial tears, preoperative pain, and adhesive capsulitis have been reported as predictive factors for shoulder stiffness after ARCR.\textsuperscript{13, 14, 25, 30}

Glenohumeral synovitis would be associated with early postoperative shoulder stiffness after ARCR.\textsuperscript{29} Jo et al showed that there is excellent reliability between macroscopic and microscopic assessments of the glenohumeral and subacromial synovitis in rotator cuff disease.\textsuperscript{15}

A recent article has also proposed a macroscopic scoring system for glenohumeral synovitis.\textsuperscript{4} Davis et al proposed a validated intraoperative scoring system to classify the degree of glenohumeral synovitis based on the capsule characteristic during arthroscopy.\textsuperscript{4}

However, preoperative evaluation of the glenohumeral and subacromial synovitis has not been established.

Recent imaging studies have revealed that abnormal vascularization is associated with synovitis.

Several researchers have shown the relationship between hypervascularity and synovitis of the glenohumeral joint using digital subtraction angiography and dynamic magnetic resonance...
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Ultrasound has been widely used as another diagnostic modality to accurately detect soft tissue disorders, and vascularity in rotator cuff disease has been diagnosed using ultrasound (US) techniques. Several imaging studies have shown that evaluation of hypervascularity using power Doppler ultrasonography (PDUS) is feasible for determining the degree of synovitis. However, the reliability of PDUS evaluation of synovitis has not yet been determined. Consequently, this study investigated the correlation between preoperative PDUS findings and intraoperative arthroscopic findings.

Materials and Methods

Patient selection

We performed a retrospective review of data from 40 patients (24 males and 16 females) diagnosed with partial rotator cuff tear who underwent ARCR. In order to separately evaluate the inside and outside of the glenohumeral joint, partial rotator cuff tear was selected in this study. The mean age of the patients was 62.0 ± 10.9 years at the time of the operation. The exclusion criteria were complete rotator cuff tear, long head biceps rupture, collagen disease including rheumatoid arthritis, and history of fracture, dislocation, or previous shoulder surgery.

All patients underwent power Doppler ultrasonography (PDUS) one day before surgery. Subsequently, we investigated the correlation between the preoperative PDUS findings and the intraoperative arthroscopic findings. This study was approved by the relevant institutional review board.
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62 **Power Doppler ultrasonography**

63 Each patient underwent PDUS one day before surgery. All 40 examinations were performed by a single experienced sonographer using a SONIMAGE HS1 (Konica Minolta Corp., Tokyo, Japan) with an 18 MHz high-frequency transducer. For optimization of PDUS, each patient was comfortably seated and completely relaxed. A generous amount of scanning gel was applied between the transducer and skin for light pressure uniformity and good acoustic contact. The areas of the Doppler flow signals were quantified using a pixel counter (Fig. 1). We observed synovitis and hypervascularity in the ultrasound (US) in the rotator interval (RI), subacromial bursa (SAB), and bicipital groove (BG). Each area of investigation (RI, SAB, and BG) was evaluated with three measurements to avoid incorrect evaluation of the PDUS findings. The landmarks in the RI were the guides between the supraspinatus and subscapularis tendons of the coracoid process, humeral head, and acromion based on previous studies.\textsuperscript{17, 19, 28} For the observation of RI 1, the coracoacromial ligament was used as a landmark. In RI 2, the US probe was moved downward from RI 1 to the area where the long head of the biceps tendon (LHBT) was drawn on the short axis. For RI 3, the US probe was moved downward from RI 2 until the subscapularis tendon appeared (Fig. 2). The landmarks in the SAB were the superior facet of the greater tuberosity (denoted SAB 1), the middle facet (denoted SAB 2), and the inferior facet (denoted SAB 3). The landmarks in the BG were the greater tuberosity, lesser tuberosity, LHBT, and anterior deltoid muscle. For observation of BG 1, the trapezoidal shape of the lessor tuberosity was used as a
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landmark, and BG 2 and BG 3 were located in the downward direction of the probe width from BG 1.

Our original PDUS grading system was also used for evaluation of glenohumeral joint inflammation as follows: “hypovascularity” for no Doppler response, “moderate” for single or two areas out of three, and “hypervascularity” for all three areas (Fig. 3). The Doppler flow area and the original PDUS grade were compared with arthroscopic classification in the RI, SAB, and BG.

**Arthroscopic classification**

Standard anterior, lateral, and posterior portals in a lateral decubitus or beach chair position were used for the arthroscopic evaluation. Arthroscopic findings were classified by color classification (pale, pink, and red) based on a previous study by Davis et al (Fig. 4). The areas of investigation were the RI from the glenohumeral side, SAB from the subacromial side, and BG from both the glenohumeral side and the subacromial side.

**Statistical analysis**

The correlation between the Doppler flow area and intraoperative arthroscopic classification and that of the PDUS grade and arthroscopic classification were examined using Spearman's rank correlation coefficient. For the comparison of PDUS with the color classification, multiple comparison tests were performed using the Tukey–Kramer test. The correlations were denoted as high (>0.7), moderate (0.4–0.7), and weak (0–0.4). All analyses were performed using R (version 2.8.1), and the statistical significance was set at $P < 0.05$. 
Intraobserver reproducibility was calculated on the basis of two consecutive measurements. An intraclass correlation coefficient (ICC) of 1.0 represents perfect agreement, and ICC = 0 suggests that the measurements are entirely random. Appropriate reproducibility of intraobserver values depends on how one defines the clinical agreement for the analysis.

Results

The Doppler flow area of the RI, SAB, and BG was classified using the PDUS grade (Table I). The color classification of intraoperative arthroscopic findings was evaluated in the RI, SAB, and BG (Table II). The correlation between the Doppler flow area and intraoperative arthroscopic classification was $r = 0.82$ ($P < 0.001$) in the RI, $r = 0.01$ ($P = 0.91$) in the SAB, and $r = -0.03$ ($P = 0.85$) in the BG (Table 3, Fig. 5). The correlation between the PDUS grade and intraoperative arthroscopic classification was $r = 0.70$ ($P < 0.001$) in the RI, $r = -0.02$ ($P = 0.89$) in the SAB, and $r = 0.3$ ($P = 0.06$) in the BG (Table 3). The correlation between the Doppler flow area and arthroscopic classification and that between the original PDUS grade and arthroscopic classification in the RI were considered as high (Table 3).

The ICC for intraobserver reproducibility of the PDUS was 0.90 (95% confidence interval, 0.72–0.96). The agreement in intraobserver variations during the analysis of PDUS was acceptable.

Discussion
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The current study showed a high correlation between preoperative PDUS grade and intraoperative arthroscopic color classification in the RI. Therefore, we believe that the assessment of hypervascularity of the RI by PDUS can be used as a tool to predict intra-articular shoulder synovitis. The PDUS grade in RI was highly correlated with the arthroscopic findings, and can therefore be used as a semi-quantitative assessment for glenohumeral synovitis.

In patients with rotator cuff tears, synovitis is commonly observed during surgery. Previous studies have identified subacromial and glenohumeral synovitis as being a source of pain in rotator cuff disease. Moreover, glenohumeral synovitis would be associated with early postoperative shoulder stiffness after ARCR. Management of synovitis in the shoulder joint is one of the most important factors in the treatment of the shoulder joint. Preoperative evaluation of synovitis in the shoulder joint would therefore be invaluable for determining appropriate surgical indication. However, its evaluation remains challenging. Davis et al reported the classification of arthroscopic findings based on color classification, with pale, pink, and red intensity of synovitis in that order. Jo et al reported a correlation between arthroscopic findings and microscopic observations of synovitis tissue in patients with rotator cuff tears. Arthroscopic color classification would indicate the degree of microscopic synovitis. The results of the current study indicate that vascularity evaluation using non-invasive PDUS provides important information on synovitis in the shoulder joint.

In clinical practice, less-invasive and more convenient tools would be an ideal diagnostic modality. Simultaneously, the reliability and reproducibility should be considered. Non-invasive
evaluation of the Doppler flow area in the RI showed a high correlation with intraoperative
arthroscopic findings \( r = 0.82, P < 0.001 \), whereas there was no correlation in the SAB \( r = 0.001, P = 0.91 \) and BG \( r = -0.03, P = 0.85 \). The agreement in intraobserver variations during the
analysis of PDUS was acceptable \( 0.90 \). Our PDUS grade system—“hypovascularity” with no
Doppler response, “moderate” with one or two sites, and “hypervascularity” with three sites—
would be more convenient for clinical practice compared to calculation of the Doppler flow area.

Although there was a high correlation between the PDUS and intraoperative findings in the RI,
we consider that anatomical factors should be considered for correct diagnosis. Several vascular
supplies for inflammation of the RI in cadaveric studies are the thoracoacromial artery, anterior
brachial circumflex artery, and suprascapular artery.\(^2,24\) Okuno et al reported that hypervascularity
to the RI originated from the coracoid branch of the thoracoacromial and axillary arteries in a
digital subtraction angiography study of a frozen shoulder.\(^23\) The thoracoacromial and axillary
arteries have a cranial, caudal, and medial blood supply to the RI.\(^2,24\) Therefore, measurement at a
single site may lead to incorrect evaluation in the RI. We consider that measurement at three sites,
as in the current study, improves the reliability of hypervascularity evaluation of the RI. The reason
for the lack of correlation in the SAB may be the evaluating position. In the current study, it was
performed in the shoulder extension position for visualization of the SAB. In the extension
position, the SAB is subjected to a strong compression force and the micro-vessels disappear;
however, when evaluating the rotator cuff and SAB, it is recommended that the rotator cuff be
examined in the shoulder extension position.\(^7\) Therefore, we should consider the observation
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position and area for the evaluation of hypervascularity of the SAB by US. The reason for the lack of correlation in the BG may be the fact that US evaluates the arcual artery that branches from the anterior circumflex humeral artery. The arcual artery supplies blood to the humeral head and is located about 10 mm inferiorly from the most cranial part of the greater tuberosity and 3 to 4 mm medially from the medial wall of the greater tuberosity. Therefore, the measurement of the BG in PDUS may be anatomically observing the arcual artery and not synovitis. In addition, although arthroscopic findings in the BG were evaluated from the articular side and bursal side, the observation area in arthroscopic findings in the BG may be different from the area in PDUS.

The current results would support the determination of the timing of surgical intervention and the content of rehabilitation. Synovectomy is the treatment of choice in patients with severe pain, but imaging evaluation to confirm synovitis before surgery has not yet been established. It would be beneficial for clinicians to establish imaging evaluations that provide a preoperative view of the intra-articular condition. Rehabilitation after ARCR is commonly performed with range of motion exercises, rotator cuff muscle strengthening, and mobilization. However, the assessment of inflammation after ARCR is not objective because it is based on the patient's chief complaint and swelling, making it difficult to unify the content of rehabilitation. A recent study reported that US is a more sensitive tool for assessing joint inflammatory activity in rheumatoid arthritis compared to clinical evaluation. The current study results indicate that hypervascularity in the RI can be used as an objective evaluation of the glenohumeral synovitis at preoperative evaluation or during rehabilitation after ARCR.
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Our study has several limitations. First, the PDUS grade and intraoperative arthroscopic findings were semi-quantitative evaluations. Recent ultrasound imaging technologies have been shown to be more accurate and sensitive for micro blood flows in connective tissues. In previous reports, contrast-enhanced US\(^8,9,21\) and superb microvascular imaging\(^17,19\) have been used to evaluate hypervascularity via US. Conventional PDUS imaging suffers from technical limitations associated with the visualization and quantitative evaluation of fine vessels or low-velocity blood flow.

Moreover, the position and pressure of the probe may affect the current results. For optimization of the PDUS, we conducted the evaluation in the same position, with a generous amount of scanning gel, and in several scanning areas. Although the current study showed high agreement in intraobserver variations during the analysis of PDUS, inter-rater reliability has not been studied.

Because US and arthroscopic findings are inherently technically demanding, a new system for quantitative evaluation of synovitis in the shoulder joint may provide high inter-rater reliability.

Second, we selected partial-thickness rotator cuff tear in the current study because we separately evaluated the inside and outside of the glenohumeral joint. In clinical practice, subacromial and glenohumeral synovitis should be considered in small or middle rotator cuff tears compared to large or massive rotator cuff tears. However, differences between partial and full-thickness rotator cuff tear were not evaluated in this study.

Third, the discrepancy of the evaluated areas between PDUS and arthroscopic findings may affect the results. The RI was evaluated by PDUS from the subacromial side and by arthroscopy from the glenohumeral side. Because an RI lesion is a thin tissue, we consider that this different
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observation side would not be significant. However, this indirect evaluation may actually be considerable.

Conclusion

We investigated the correlation between preoperative Doppler flow area, our original PDUS grade, and intraoperative arthroscopic classification in the RI, SAB, and BG. The Doppler flow area and the PDUS grade showed a high correlation of arthroscopic synovitis for RI. Therefore, visualization of hypervascularity in the RI area could be a reliable measure for the assessment of glenohumeral synovitis in patients with partial-thickness rotator cuff tear.

References

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Vascularity in shoulder synovitis by ultrasound


doi:10.1136/ard.2004.023929


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Figure Legends

Figure 1 Pixel counter was used to quantify the flow signal area of the power Doppler ultrasound.

Figure 2 Rotator interval (RI) ultrasound measurement.

(A) Performed in neutral limb position. (B) The bony landmarks are the coracoid process (CP), humeral head (HH), and acromion. (C) The soft tissue landmarks are the coracoacromial ligament (CAL) for RI 1, (D) long head of the biceps tendon (LHBT) for RI 2, (E) until the subscapularis tendon appeared for RI 3.

Figure 3 The PDUS grade system in RI.

The original PDUS grade images, “hypovascularity” group (A), (B), (C) with no Doppler response in three sites. In “moderate” group (D), (E), (F) with single or two site Doppler response. In “hypervascularity” group (G), (H), (I), all three sites have Doppler response.

Figure 4 Arthroscopic images of the rotator interval.

Arthroscopic images, (A) pale, (B) pink, and (C) red.

Figure 5 Correlation between hypervascularity area and arthroscopic classification.
Table III. Correlation between Doppler findings and arthroscopic classification

<table>
<thead>
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<th></th>
<th>hypervascularity area</th>
<th>PDUS grading system</th>
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<tr>
<td></td>
<td>Correlation</td>
<td>p value</td>
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<tr>
<td>RI</td>
<td>0.82</td>
<td>.001*</td>
</tr>
<tr>
<td>SAB</td>
<td>0.01</td>
<td>.91</td>
</tr>
<tr>
<td>BG</td>
<td>-0.03</td>
<td>.85</td>
</tr>
</tbody>
</table>

* Statistically significant (p < .001).

CI, confidence interval.

RI, rotator interval; SAB, subacromial bursa; BG, bicipital groove.
Table I. Power Doppler ultrasonography grading system

<table>
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<th>hypovascularity</th>
<th>moderate</th>
<th>hypervascularity</th>
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<tbody>
<tr>
<td>RI</td>
<td>11 (27.5)</td>
<td>16 (40.0)</td>
<td>13 (32.5)</td>
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<tr>
<td>SAB</td>
<td>23 (57.5)</td>
<td>16 (40.0)</td>
<td>1 (2.5)</td>
</tr>
<tr>
<td>BG</td>
<td>0 (0)</td>
<td>11 (27.5)</td>
<td>29 (72.5)</td>
</tr>
</tbody>
</table>

RI, rotator interval; SAB, subacromial bursa; BG, bicipital groove.
Table II. Classification of intraoperative arthroscopic findings

<table>
<thead>
<tr>
<th></th>
<th>n (%)</th>
<th>pale</th>
<th>pink</th>
<th>red</th>
</tr>
</thead>
<tbody>
<tr>
<td>RI</td>
<td>14 (35.0)</td>
<td>13 (32.5)</td>
<td>13 (32.5)</td>
<td></td>
</tr>
<tr>
<td>SAB</td>
<td>7 (17.5)</td>
<td>18 (45.0)</td>
<td>15 (37.5)</td>
<td></td>
</tr>
<tr>
<td>BG</td>
<td>21 (52.5)</td>
<td>11 (27.5)</td>
<td>8 (20.0)</td>
<td></td>
</tr>
</tbody>
</table>

RI, rotator interval; SAB, subacromial bursa; BG, bicipital groove.