Chronicity is associated with the glenohumeral synovitis in patients with a rotator cuff tear

Du-Han Kim¹ | Ki-Cheor Bae¹ | Jung-Hoon Choi¹ | Sang-Soo Na¹ | Ilseon Hwang² | Chul-Hyun Cho¹

¹Department of Orthopedic Surgery, Keimyung University Dongsan Hospital, Keimyung University School of Medicine, Daegu, South Korea
²Department of Pathology, Keimyung University Dongsan Hospital, Keimyung University School of Medicine, Daegu, South Korea

Correspondence
Chul-Hyun Cho, Department of Orthopedic Surgery, Keimyung University Dongsan Hospital, Keimyung University School of Medicine, 1035, Dalgubeol-daero, Dalseo-gu, Daegu 42601, South Korea.
Email: oscho5382@dsmc.or.kr

Funding information
National Research Foundation of Korea, Grant/Award Numbers: 2014R1A5A2010008, 2017R1D1A1B03035113

Abstract
Synovitis of the glenohumeral joint (GHJ) and subacromial space (SAS) is one of the most common findings during arthroscopic rotator cuff repair (RCR). The purpose of this study is to determine clinical factors associated with the degree of synovitis in patients with a rotator cuff tear and whether macroscopic synovitis affects early clinical outcomes following arthroscopic RCR. Arthroscopic videos of 230 patients treated with arthroscopic RCR were randomly reviewed by two experienced shoulder surgeons. The synovitis scores of the GHJ using Davis’s grading system and the SAS using Jo’s grading system were rated with a consensus. Univariate and multivariate analyses were used to identify the associations between the synovitis scores and various parameters, including demographics, preoperative, and postoperative clinical outcomes. Univariate analyses revealed that age, side, body mass index, duration of symptoms, preoperative stiffness, diabetes, muscle atrophy, fatty infiltration, tear size, preoperative clinical scores, and preoperative range of motion were significantly associated with the GHJ synovitis score (all $p < 0.05$). Multivariate analyses revealed that the duration of symptoms, tear size, and diabetes was significantly associated with the GHJ synovitis score ($p = 0.048$, $p = 0.025$, $p = 0.011$, respectively). Longer duration of symptoms, larger tear size, and the presence of diabetes was independently associated with increased GHJ synovitis in patients with a rotator cuff tear. These results suggest that GHJ synovitis might be more involved in the pathogenesis for pain and tear progression of rotator cuff disease compared with SAS synovitis.

KEYWORDS
glenohumeral joint, rotator cuff disease, subacromial space, synovitis

1 | INTRODUCTION

Rotator cuff disease, the most common cause of shoulder pain and dysfunction, represents a spectrum of rotator cuff pathologies from tendinosis, partial-thickness tear, full-thickness tear, and rotator cuff tear arthropathy.¹⁻³ The proposed etiology of rotator cuff disease includes degeneration, subacromial impingement, hypoxia, inflammation, and trauma.³⁻⁵ And its clinical manifestation and natural course vary widely among patients. While some patients experience rapid progression of tears with pain or functional disability, some have little or no...
The rotator cuff is interposed between the glenohumeral joint (GHJ) and subacromial space (SAS) as a mover and stabilizer of the shoulder joint. It is generally recognized that rotator cuff disease involves not only the tendons but also tissues in the GHJ and SAS, including bursa, synovium, ligament, and joint fluid. Jo et al. suggested that rotator cuff disease, like osteoarthritis, is regarded and treated as a "pan-joint disease" of the shoulder.

It is widely accepted that subacromial synovitis is a source of pain in rotator cuff disease. The subacromial bursa is anatomically vulnerable to friction with the undersurface of the acromion during the range of motion (ROM) and synovitis occurs subsequently into the SAS. Several basic studies reported that overexpression of inflammatory cytokines, enzymes, and proteinases was observed in the subacromial bursa of patients with a rotator cuff tear. These studies highlighted the important role that subacromial synovitis plays in the development of shoulder pain in patients with a rotator cuff tear and noted that its severity is associated with the pain intensity.

A growing body of evidence exists for the role of GHJ synovitis in rotator cuff disease, however, it has not fully elucidated as of yet. Gotth et al. noted increased expression of interleukin (IL)-1β in synovial tissue in patients with a full-thickness rotator cuff tear. Subsequently, several laboratory studies revealed that increased synovial inflammation and angiogenesis of the GHJ correlates with the tear size of the supraspinatus tendon and suggested that GHJ synovitis might be involved in the pathogenesis of rotator cuff tear.

Synovial inflammation of the GHJ and SAS is one of the most common findings during arthroscopic surgery for a rotator cuff tear. Until now, most basic studies have characterized the biochemical and histologic findings of specimens including rotator cuff, synovium, joint fluid, or subacromial bursa. Few studies have examined the macroscopic appearance of the synovial tissue of the GHJ and SAS. Furthermore, no prior studies evaluated the potential association between macroscopic synovitis and various clinical factors in patients with a rotator cuff tear.

The primary aim of this study was to determine clinical factors associated with the degree of GHJ and SAS synovitis in patients with a rotator cuff tear. The secondary aim was to determine whether macroscopic synovitis affects early clinical outcomes following arthroscopic rotator cuff repair (RCR). This study was conducted to prove the hypothesis that the degree of macroscopic synovitis would correlate with clinical findings in patients with rotator cuff tear.

2 METHODS

This study was approved by the institutional review board of our hospital (IRB No:2020-04-026), and informed consent was obtained from all patients. Two-hundred thirty patients who underwent arthroscopic RCR by a single surgeon at a single institution between October 2013 and February 2018 were included in this study. Inclusion criteria were as follows: (1) patients with arthroscopic RCR; (2) available medical records and arthroscopic findings; (3) available data for serial follow-up periods including 3, 6, and 12 months after surgery. Exclusion criteria included: (1) a history of previous shoulder surgery or major trauma; (2) a history of inflammatory arthritis; (3) corticosteroid injection within 4 weeks before surgery; and (4) anti-inflammator medication within 2 weeks before surgery.

2.1 Macroscopic assessment for synovitis

With patients in the lateral decubitus position, a standard arthroscopic GHJ examination through the posterior and anterior portals to evaluate intra-articular pathology was performed. Next, the arthroscope was placed in the SAS, and RCR was conducted. Using an arthroscopic shaver and radiofrequency device, arthroscopic debridement and ablation for the synovitis of the GHJ and SAS were performed as thoroughly as possible.

Arthroscopic videos of 230 patients treated with arthroscopic RCR were randomly presented to two shoulder surgeons for macroscopic assessment of synovitis. Before the independent assessment, the consensus for synovitis grading of the GHJ and SAS between two observers were generated through a detailed review of the studies reported by Davis et al. and Jo et al. with 30 samples of arthroscopic video. To evaluate intraobserver reliability, this same procedure was repeated 2 weeks after the first round of assessment.

According to the grading system proposed by Davis et al., GHJ synovitis was graded as follows: color of capsule (pale [0], pink [1], or red [2]); villous projections [none (0), few (1), or extensive (2)]; capillaries in capsule [scattered (0) or hypertrophied (1)]; and axillary recess [normal (0) or contracted (1)] (Figure 1). Total GHJ synovitis scores thus ranged from 0 to 6.

According to the grading system proposed by Jo et al., SAS synovitis was graded as follows: hypertrophy based on the size of the synovial villi (<2 mm (0), 2–5 mm (1), >5 mm (2)); hyperemia based on the redness of the villi [pale and transparent (0), slightly reddish (1), definitely red (2)]; and density assessed by the coverage of synovial villi [≥1/3 (0), ≥1/3 (1)] (Figure 2). Total SAS synovitis scores thus ranged from 0 to 5.

2.2 Clinical parameters

Available demographic and clinical parameters included age, sex, side, body mass index (BMI), occupation, duration of symptoms, history of trauma, preoperative stiffness, diabetes, muscle atrophy, fatty infiltration, tear size, preoperative and postoperative clinical scores, and ROMs. The occupation was divided into four categories for analysis (heavy work, light work, unemployed, others: refuse to reveal their occupation). We defined criteria for shoulder stiffness as follows: (1) passive forward flexion < 120°; (2) external rotation at side <30°; or (3) internal rotation at the back <third lumbar level according to the definition of Oh et al. Preoperative muscle atrophy was evaluated according to the Thomazeau classification.

Fatty infiltration of muscle was evaluated according to the Goutallier
classification. Tear size of the rotator cuff was classified according to DeOrio and Cofield. Clinical evaluations included the visual analog scale (VAS) pain score (0 = no pain; 10 = unbearable pain), the American Shoulder and Elbow Surgeons' (ASES) score, and ROM assessment before surgery and at 3, 6, and 12 months after surgery.

For statistical analysis of internal rotation, we converted values into contiguously numbered groups: 1–12 for T1–T12, 13–17 for L1–L5, 18 for the sacrum, and 19 for buttock.

### 2.3 Statistical methods

The SPSS statistical package (version 20.0; IBM) was used for data analysis. Intraobserver and interobserver reliability were assessed by calculating the κ correlation coefficient. To identify clinical parameters associated with the degree of synovitis, univariate analysis was conducted using the Pearson correlation test, Spearman correlation test, independent t-test, and one-way ANOVA.

![Figure 1](image1.png) **FIGURE 1** Macroscopic findings of the synovitis in the glenohumeral joint according to David's grading system. Color of the capsule: pale (A), pink (B), red (C). Villous projections: none (D), few (E), extensive (F). Capillaries in capsule: scattered (G), hypertrophied (H). Axillary recess: normal (I), contracted (J)

![Figure 2](image2.png) **FIGURE 2** Macroscopic findings of the synovitis in the subacromial space according to Jo's grading system. Hypertrophy based on the size of the synovial villi: <2 mm (A), 2–5 mm (B), >5 mm (C). Hyperemia based on the redness of the villi: pale and transparent (D), slightly reddish (E), definitely red (F). Density assessed by the coverage of synovial villi: <1/3 (G), ≥1/3 (H)
analysis of variance test. Significant associations observed in univariate analysis were included in the multivariate analysis. 95% confidence intervals were reported to provide the magnitude of the association. Statistical significance was accepted for $p$ values of less than 0.05.

### RESULTS

The mean age of patients was $60.4 \pm 7.2$ years (range, 42–76 years), and there were 132 women (57.4%) and 98 men (42.6%). The dominant side was involved in 172 patients (74.8%) and the

|                      | $N$ (%) or mean ± SD | GHJ synovitis score | SAS synovitis score |
|----------------------|----------------------|---------------------|---------------------|
|                      |                      | Mean ± SD           | $p$                 | Mean ± SD           | $p$                 |
| **Age**              | 60.4 ± 7.2           | 0.008*              | 0.395               |
| **Sex**              |                      |                     |                     |
| Man                  | 98 (42.6%)           | 4.0 ± 1.5           | 0.400               | 1.9 ± 1.2           | 0.656               |
| Woman                | 132 (57.4%)          | 3.8 ± 1.5           | 1.8 ± 1.2           |
| **Side**             |                      |                     |                     |
| Dominant             | 172 (74.8%)          | 3.7 ± 1.5           | 0.011*              | 1.8 ± 1.2           | 0.360               |
| Nondominant          | 58 (25.2%)           | 4.3 ± 1.2           | 2.0 ± 1.3           |
| **Body mass index**  | 25.0 ± 3.0           | 0.019*              | 0.105               |
| **Occupation**       |                      |                     |                     |
| Heavy work           | 98 (42.6%)           | 4.0 ± 1.4           | 0.425               | 1.8 ± 1.6           | 0.675               |
| Light work           | 49 (21.3%)           | 4.0 ± 1.6           | 2.0 ± 1.2           |
| Unemployed           | 81 (35.2%)           | 3.7 ± 1.5           | 1.8 ± 1.3           |
| Others               | 2 (0.9%)             | 3.0 ± 4.2           | 2.5 ± 0.7           |
| **Sx duration**      | 30.0 ± 35.5          | 0.027*              | 0.473               |
| **History of trauma**|                      |                     |                     |
| No                   | 191 (83.0%)          | 3.9 ± 1.4           | 0.471               | 1.8 ± 1.2           | 0.708               |
| Yes (minor)          | 39 (17.0%)           | 3.7 ± 1.7           | 1.9 ± 1.1           |
| **Preop stiffness**  |                      |                     |                     |
| No                   | 190 (82.6%)          | 3.6 ± 1.5           | 0.006*              | 1.8 ± 1.2           | 0.334               |
| Yes                  | 40 (17.4%)           | 4.5 ± 1.4           | 2.0 ± 1.1           |
| **Diabetes**         |                      |                     |                     |
| No                   | 198 (86.1%)          | 3.7 ± 1.5           | 0.001*              | 1.8 ± 1.2           | 0.803               |
| Yes                  | 32 (13.9%)           | 4.7 ± 1.2           | 1.9 ± 1.2           |
| **Muscle atrophy**   |                      |                     |                     |
| No - mild            | 187 (81.3%)          | 3.7 ± 1.5           | 0.002*              | 1.8 ± 1.2           | 0.424               |
| Moderate             | 39 (17.0%)           | 4.4 ± 1.4           | 1.9 ± 1.2           |
| Severe               | 4 (1.7%)             | 4.8 ± 1.0           | 2.5 ± 1.9           |
| **Fatty infiltration**|                      |                     |                     |
| No                   | 1 (0.4%)             | NA                  | 0.022*              | NA                  | 0.839               |
| Some                 | 87 (37.8%)           | 3.7 ± 1.5           | 1.9 ± 1.1           |
| Evident              | 114 (49.6%)          | 3.9 ± 1.4           | 1.7 ± 1.2           |
| Fat = muscle         | 25 (10.9%)           | 4.3 ± 1.6           | 2.0 ± 1.4           |
| Fat > muscle         | 3 (1.3%)             | 5.0 ± 1.0           | 3.3 ± 1.2           |
| **Tear size**        |                      |                     |                     |
| Partial              | 33 (14.3%)           | 3.2 ± 1.3           | <0.001*             | 1.7 ± 1.0           | 0.641               |
| Small                | 33 (14.3%)           | 3.5 ± 1.8           | 1.8 ± 1.3           |
| Medium               | 74 (32.2%)           | 4.0 ± 1.4           | 1.9 ± 1.3           |
| Large                | 54 (23.5%)           | 4.1 ± 1.4           | 2.0 ± 1.2           |
| Massive              | 36 (15.7%)           | 4.4 ± 1.3           | 1.7 ± 1.2           |

Abbreviations: GHJ, glenohumeral joint; NA, not applicable; Preop, preoperative; SAS, subacromial space; SD, standard deviation; Sx, symptoms.

*Statistically significant.
nondominant side in the remaining 58 (25.2%). The mean BMI was 25.0 ± 3.0 kg/m² (range, 17.0–32.9 kg/m²). The mean duration of symptoms was 30.0 ± 35.5 months (range, 1–168 months). Preoperative stiffness was observed in 40 patients (17.4%) and 32 (13.9%) had diabetes. Tear sizes were classified as partial-thickness tear in 33 patients (14.3%), small tear in 33 (14.3%), medium tear in 74 (32.2%), large tear in 54 (23.5%), and massive tear in 36 (15.7%; Table 1).

The mean total GHJ synovitis score was 3.9 ± 1.5. For subitems, the mean score of color of capsule was 1.2 ± 0.6, villous projections 1.2 ± 0.6, capillaries in capsule 0.9 ± 0.3, and axillary recess 0.6 ± 0.5. The mean total SAS synovitis score was 1.9 ± 1.2. For subitems, the mean score of color of capsule was 1.2 ± 0.6, hyperemia 1.1 ± 0.5, and density 0.2 ± 0.4. The intraobserver and interobserver reliability of GHJ synovitis grading system was color of the capsule (κ = 0.781 and 0.593), villous projections (κ = 0.615 and 0.694), capillaries in the capsule (κ = 0.694 and 0.530), and axillary recess (κ = 0.862 and 0.673; Tables 2 and 3). The intraobserver and interobserver reliability of the SAS synovitis grading system was hypertrophy (κ = 0.701 and 0.520), hyperemia (κ = 0.699 and 0.518), and density (κ = 0.773 and 0.666).

Univariate analyses revealed that age, side, BMI, duration of symptoms, preoperative stiffness, diabetes, muscle atrophy, fatty infiltration, and tear size were significantly associated with the GHJ synovitis score (all p < 0.05). Preoperative VAS pain score, ASES score, forward flexion, external rotation, and internal rotation were also significantly associated with the GHJ synovitis score (all p < 0.05). However, there were no associations between the SAS synovitis score and all parameters including demographics, preoperative, and postoperative clinical outcomes (all p > 0.05). There were no associations between the GHJ and SAS synovitis score and clinical outcomes at 3, 6, 12 months after surgery including VAS pain score, ASES score, and forward flexion, external rotation, and internal rotation (all p > 0.05; Table 4).

Multivariate analyses revealed that the duration of symptoms, diabetes, and tear size was significantly associated with the GHJ synovitis score (p = 0.048, p = 0.025, p = 0.011, respectively; Table 5).

### TABLE 2 Intraobserver reliability of the grading systems

| GHJ synovitis grading | Observer 1 | Observer 2 | Mean κ-value |
|-----------------------|------------|------------|--------------|
| Color of capsule      | 0.807      | 0.755      | 0.781        |
| Villous projections   | 0.604      | 0.625      | 0.615        |
| Capillaries in capsule| 0.682      | 0.706      | 0.694        |
| Axillary recess       | 0.848      | 0.876      | 0.862        |

| SAS synovitis grading | GHJ synovitis grading |
|-----------------------|-----------------------|
| Hypertrophy           | 0.729                 |
| Hyperemia             | 0.701                 |
| Density               | 0.763                 |

Abbreviations: GHJ, glenohumeral joint; SAS, subacromial space.

### TABLE 3 Interobserver reliability of the grading systems

| GHJ synovitis grading | First-round | Second-round | Mean κ-value |
|-----------------------|-------------|--------------|--------------|
| Color of capsule      | 0.603       | 0.582        | 0.593        |
| Villous projections   | 0.520       | 0.547        | 0.534        |
| Capillaries in capsule| 0.501       | 0.558        | 0.530        |
| Axillary recess       | 0.689       | 0.657        | 0.673        |

| SAS synovitis grading | GHJ synovitis grading |
|-----------------------|-----------------------|
| Hypertrophy           | 0.495                 |
| Hyperemia             | 0.512                 |
| Density               | 0.672                 |

Abbreviations: GHJ, glenohumeral joint; SAS, subacromial space.

## DISCUSSION

The present study was conducted to identify clinical factors that may be associated with the degree of macroscopic synovitis in patients with a rotator cuff tear. The main findings were: (1) longer duration of symptoms, larger tear size, and the presence of diabetes were independently associated with increased GHJ synovitis; (2) SAS synovitis was not associated with any demographic and clinical parameters; (3) GHJ and SAS synovitis was not associated with postoperative clinical outcomes. These results suggest that GHJ synovitis might be more involved in the pathogenesis for pain and tear progression of rotator cuff disease compared with SAS synovitis.

Although significant biochemical and microscopic evidence of synovial inflammation of the GHJ and SAS in patients with a rotator cuff tear exists, few studies have examined the macroscopic appearance of the synovial tissue of the GHJ and SAS. The absence of macroscopic studies may largely be due to the lack of a standardized grading system for synovitis as observed during arthroscopic surgery. Hence, Jo et al. proposed a macroscopic grading system for synovitis in the GHJ and SAS in patients with a rotator cuff tear and found that macroscopic findings were reliably correlated with microscopic findings. Subsequently, Davis et al. reported that the reliability of Jo’s grading system may be low and proposed a new grading system for macroscopic synovitis of the GHJ with excellent reliability. Using these grading systems, it is possible to systematically score the degree of synovitis and to identify associations between macroscopic synovitis and various clinical factors. In the present study, considering the pros and cons of each system, we rated synovitis scores of the GHJ according to Davis’s grading system and the SAS according to Jo’s grading system.

It is generally recognized that synovial inflammation of the SAS is associated with the pathophysiology of rotator cuff disease. Gotoh et al. reported that IL-1-induced subacromial synovitis may play a role in shoulder pain. Blaine et al. reported that tumor necrotic factor (TNF)-α, IL-1α, IL-1β, IL-6, cyclooxygenase (COX)-1, COX-2, matrix metalloprotease (MMP)-1, and MMP-9 are overexpressed in the subacromial bursa in patients with a rotator cuff tear. SAS synovitis was associated with...
overexpression of proinflammatory cytokines, enzymes, and MMPs, which may have an important role in the pain mechanism and pathophysiology of rotator cuff tear. Meanwhile, Gotoh et al. noted that overexpression of IL-1β in the GHJ synovium in patients with a rotator cuff tear and emphasized the pivotal role of synovial inflammation in modulating rotator cuff degeneration. IL-1β is well known to stimulate a cascade of catabolic responses by upregulating degradative enzymes including MMP-1, MMP-9, and MMP-13. Indeed, recent studies reported an overexpression of MMP-1 and MMP-13 genes, involving cell-mediated tendon degeneration, in the torn supraspinatus tendon and synovial fluid. Shindle et al. reported that IL-1β, IL-6, COX-2, MMP-9, and vascular endothelial growth factor (VEGF) were overexpressed in the synovium of patients with a rotator cuff tear and suggested that chronic GHJ synovitis may be associated with rotator cuff tears. Abrams et al. reported increased synovial inflammation and angiogenesis, and upregulation of MMP-3 in patients with a full-thickness rotator cuff tear and found that expression of MMP-3 correlates with the degree of synovitis.

Jo et al. found that the degree of macroscopic synovitis was significantly greater in the GHJ compared with the SAS. They reported this finding is unexpected and counter to conventional thinking since SAS synovitis was long considered a primary source of pain and pathophysiology of rotator cuff disease. In the present study, our results were consistent with those reported by Jo et al. Preoperative VAS pain score, ASES score, and all ROMs were significantly associated with the GHJ synovitis scores, not the SAS synovitis scores. Multivariate analyses revealed that longer duration of symptoms, larger tear size, and the presence of diabetes were independently associated with increased GHJ synovitis. However, the SAS synovitis was not associated with any tested parameters including demographics, preoperative clinical scores, and ROMs. Because there is little study to compare the expression of biochemical markers between SAS and GHJ, it is difficult to define the main contributing site associated with the pathophysiology of rotator cuff tear. However, very recently, biochemical studies have reported that overexpression of inflammatory cytokines, growth factors, enzymes, and MMPs in GHJ capsule and synovial fluid are associated with

|                | GHJ synovitis grading | SAS synovitis grading |
|----------------|-----------------------|-----------------------|
| VAS pain score |                       |                       |
| Preoperative   | 6.0 ± 2.2             | 0.133                 |
| PO 3 months    | 3.6 ± 1.8             | -0.029                |
| PO 6 months    | 2.5 ± 1.8             | 0.028                 |
| PO 12 months   | 1.5 ± 1.5             | -0.052                |
| ASES score     |                       |                       |
| Preoperative   | 44.3 ± 18.7           | -0.251                |
| PO 3 months    | 59.4 ± 14.4           | 0.026                 |
| PO 6 months    | 72.8 ± 14.8           | -0.006                |
| PO 12 months   | 84.9 ± 11.8           | 0.113                 |
| Forward flexion|                       |                       |
| Preoperative   | 145.9° ± 31.4°        | -0.229                |
| PO 3 months    | 143.1° ± 18.6°        | 0.028                 |
| PO 6 months    | 158.3° ± 13.5°        | 0.007                 |
| PO 12 months   | 166.5° ± 8.3°         | 0.012                 |
| External rotation |               |                       |
| Preoperative   | 53.4° ± 23.4°         | -0.180                |
| PO 3 months    | 51.9° ± 12.6°         | -0.021                |
| PO 6 months    | 64.0° ± 12.8°         | -0.028                |
| PO 12 months   | 72.2° ± 9.8°          | -0.020                |
| Internal Rotation |                  |                       |
| Preoperative   | 12.4 ± 3.6            | 0.267                 |
| PO 3 months    | 13.4 ± 2.5            | 0.048                 |
| PO 6 months    | 10.6 ± 3.3            | 0.051                 |
| PO 12 months   | 8.2 ± 3.0             | 0.079                 |

Abbreviations: ASES, American Shoulder and Elbow Surgeons; GHJ, glenohumeral joint; PO, postoperative; SAS, subacromial space; SD, standard deviation; VAS, visual analog scale.

*Statistically significant.
TABLE 5 Multivariate analysis between synovitis scores and clinical parameters

|                  | t    | p    | Lower bound | Upper bound |
|------------------|------|------|-------------|-------------|
| Age              | 1.389| 0.166| -0.007      | 0.043       |
| Side             | 0.936| 0.350| -0.214      | 0.600       |
| Body mass index  | 0.531| 0.596| -0.044      | 0.076       |
| Duration of symptoms | 1.990  | 0.048\* | 0.000       | 0.010       |
| Preoperative stiffness | 0.427  | 0.670 | -0.461      | 0.715       |
| Diabetes         | 2.258| 0.025\*| 0.076       | 1.125       |
| Muscle atrophy   | 1.833| 0.068| -0.039      | 1.064       |
| Fatty infiltration | -1.254 | 0.211 | -0.617      | 0.137       |
| Tear size        | 2.564| 0.011\*| 0.052       | 0.394       |
| Preoperative VAS pain score | -0.668 | 0.505 | -0.245      | 0.121       |
| Preoperative ASES score | -0.702 | 0.483 | -0.038      | 0.018       |
| Preoperative forward flexion | -0.721 | 0.472 | -0.010      | 0.005       |
| Preoperative external rotation | -0.912 | 0.363 | -0.012      | 0.005       |
| Preoperative internal rotation | 1.482 | 0.140 | -0.014      | 0.102       |

Abbreviations: ASES, American Shoulder and Elbow Surgeons; VAS, visual analog scale.
*Statistically significant.

rotator cuff degeneration and tear progression as well as pain generation in patients with rotator cuff tear.\cite{4,12,14} Based on the results from our study, we do not deny that synovial inflammation of the SAS is associated with the pathophysiology of rotator cuff disease. We think that the pathogenesis for pain in patients with rotator cuff tear may originate from the GHJ synovitis rather than the SAS synovitis.

Gotoh et al.\cite{6} observed that full-thickness rotator cuff tears were associated with greater degrees of synovitis than partial-thickness tears. Shindle et al.\cite{11} reported that increased synovial inflammation and tissue degeneration correlates with the tear size of the supraspinatus tendon. Tajana et al.\cite{15} reported that the total protein concentration of synovial fluid increased with the loss of integrity of the rotator cuff, reaching the highest levels in rotator cuff tear arthropathy. The absolute enzymatic activity of gelatinases was greater in full-thickness tears compared with partial-thickness tears.\cite{15} VEGF, a well-known angiogenic factor, plays an important role in the inflammation of synovial tissue.\cite{11,22,23} Yanagisawa et al.\cite{11} reported that VEGF expression was associated with vascularity, synovial proliferation, and pain in rotator cuff disease. VEGF expression was closely correlated with synovial proliferation and with neovascularization in Type II diabetics with rotator cuff disease.\cite{22} Our study also found that larger tear size and the presence of diabetes were independently correlated with increased GHJ synovitis. These findings suggest that the GHJ synovitis may be involved in degeneration and tear progression of the rotator cuff tendon. Further studies to characterize this relationship may help guide the development of effective treatments to reduce pain and prevent tear progression in patients with rotator cuff disease.

The potential effects of macroscopic synovitis on early clinical outcomes following arthroscopic RCR are not well understood. In the present study, arthroscopic debridement and ablation for the GHJ and SAS synovitis was performed as thoroughly as possible using an arthroscopic shaver and radiofrequency device. We found no associations between the GHJ and SAS synovitis score and clinical outcomes at 3, 6, 12 months after surgery including VAS pain score, ASES score, and all ROMs. However, this is a retrospective study without standard management guideline for synovitis. Further prospective randomized studies to determine whether macroscopic synovitis affects early clinical outcomes following arthroscopic RCR are warranted.

This study has several limitations. First, the synovitis score was only rated at the time of arthroscopic surgery, therefore, it was not possible to evaluate the serial effects of synovial inflammation on clinical symptoms and tear progression. Second, a potential correlation between macroscopic and microscopic evaluations was not characterized. Third, the degree of synovitis can vary with respect to location and grading of synovitis according to the location was not conducted. However, it is of note that this is the first study, to the best of our knowledge, to determine clinical factors associated with the severity of synovitis in a relatively large set of patients with a rotator cuff tear.

5 CONCLUSION

Longer duration of symptoms, larger tear size, and the presence of diabetes mellitus was independently associated with increased GHJ synovitis in patients with a rotator cuff tear. These results suggest that GHJ synovitis might be more involved in the pathogenesis for pain and tear progression of rotator cuff disease compared with SAS synovitis.

ACKNOWLEDGMENTS

The authors would like to thank Ye-Ji Kim and Eun-Ji Jeon for their support with data collection. This study was supported by the National Research Foundation of Korea, funded by the Korean government (Grant nos. 2017R1D1A1B03035113 and 2014R1A5A2010008).

AUTHOR CONTRIBUTIONS

Du-Han Kim analyzed the data and reviewed the manuscript. Ki-Cher Bae reviewed the manuscript and supervision. Jung-Hoon Choi gathered and analyzed the data and reviewed the manuscript. Sang-Soo Na gathered and analyzed the data. Ilseon Hwang conceived the idea and analyzed the data. Chul-Hyun Cho conceived the idea and wrote the manuscript.
REFERENCES
1. Jo CH, Shin JS, Kim JE, Oh S. Macroscopic and microscopic assessments of the glenohumeral and subacromial synovitis in rotator cuff disease. BMC Musculoskelet Disord. 2015;16:272.
2. Liu XN, Yang CJ, Kim JE, et al. Enhanced tendon-to-bone healing of chronic rotator cuff tears by bone marrow aspirate concentrate in a rabbit model. Clin Orthop Surg. 2018;10:99-110.
3. Shindle MK, Chen CCT, Robertson C, et al. Full-thickness supraspinatus tears are associated with more synovial inflammation and tissue degeneration than partial-thickness tears. J Shoulder Elbow Surg. 2011;20:917-927.
4. Abrams GD, Luria A, Carr RA, Rhodes C, Robinson WH, Sokolove J. Association of synovial inflammation and inflammatory mediators with glenohumeral rotator cuff pathology. J Shoulder Elbow Surg. 2016;25:989-997.
5. Bedi A, Maak T, Walsh C, et al. Cytokines in rotator cuff degeneration and repair. J Shoulder Elbow Surg. 2012;21:218-227.
6. Gotelo M, Hamada K, Yamakawa H, et al. Interleukin-1 induced subacromial synovitis and shoulder pain in rotator cuff diseases. Rheumatology. 2001;40:995-1001.
7. Blaine TA, Kim YS, Voloshin I, et al. The molecular pathophysiology of subacromial bursitis in rotator cuff disease. J Shoulder Elbow Surg. 2005;14:84s-89s.
8. Lo IKY, Boorman R, Marchuk L, Hollinshead R, Hart DA, Frank CB. Matrix molecule mRNA levels in the bursa and rotator cuff of patients with full-thickness rotator cuff tears. Arthroscopy. 2005;21:645-651.
9. Santavirta S, Konttinen YT, Antti-Poika I, Nordstrom D. Inflammation of the subacromial bursa in chronic shoulder pain. Arch Orthop Trauma Surg. 1992;111:336-340.
10. Voloshin I, Gelines J, Maloney MD, O’Keefe RJ, Bigliani LU, Blaine TA. Proinflammatory cytokines and metalloproteases are expressed in the subacromial bursa in patients with rotator cuff disease. Arthroscopy. 2005;21(1076:e11071-e1076).
11. Yanagisawa K, Hamada K, Gotelo M, et al. Vascular endothelial growth factor (VEGF) expression in the subacromial bursa is increased in patients with impingement syndrome. J Orthop Res. 2001;19:448-455.
12. Gotelo M, Hamada K, Yamakawa H, et al. Interleukin-1 induced glenohumeral synovitis and shoulder pain in rotator cuff diseases. J Orthop Res. 2002;20:1365-1371.
13. Kim SK, Kim HN, Moon ES, Lim KY, Cho NY, Kim MS. Inflammatory cytokine expressions of the subacromial bursitis and glenohumeral joint synovitis in the patients with full thickness rotator cuff tear. Clin Should Elbow. 2011;14:172-178.
14. Osawa T, Shinozaki T, Takagishi K. Multivariate analysis of biochemical markers in synovial fluid from the shoulder joint for diagnosis of rotator cuff tears. Rheumatol Int. 2005;25:436-441.
15. Tajana MS, Murena L, Valli F, Passi A, Grassi FA. Correlations between biochemical markers in the synovial fluid and severity of rotator cuff disease. Chir Organi Mov. 2009;93(suppl 1):S41-S48.
16. Davis DE, Maltenfort M, Abboud JA, Getz C. Classifying glenohumeral synovitis: a novel intraoperative scoring system. J Shoulder Elbow Surg. 2017;26:2047-2053.
17. Oh JH, Kim SH, Lee HK, Jo KH, Bin SW, Gong HS. Moderate preoperative shoulder stiffness does not alter the clinical outcome of rotator cuff repair with arthroscopic release and manipulation. Arthroscopy. 2008;24:983-991.
18. Thomazeau H, Boukobza E, Morcret N, Chaperon J, Langlais F. Prediction of rotator cuff repair results by magnetic resonance imaging. Clin Orthop Relat Res. 1997;344:275-283.
19. Goutallier D, Postel JM, Gleyze P, Leguilloux P, Van Driessche S. Influence of cuff muscle fatty degeneration on anatomic and functional outcomes after simple suture of full-thickness tears. J Shoulder Elbow Surg. 2003;12:550-554.
20. DeOrio JK, Cofield RH. Results of a second attempt at surgical repair of a failed initial rotator-cuff repair. J Bone Joint Surg Am. 1984;66:563-567.
21. Tonotuka H, Sugaya H, Takahashi N, Kawai N, Sugiyama H, Marumo K. Preoperative pain control in arthroscopic rotator cuff repair: does it matter? Clin Orthop Surg. 2019;11:192-199.
22. Handa A, Gotelo M, Hamada K, et al. Vascular endothelial growth factor 121 and 165 in the subacromial bursa are involved in shoulder joint contracture in type II diabetics with rotator cuff disease. J Orthop Res. 2003;21:1138-1144.
23. Ryu JD, Kirpalani PA, Kim JM, Nam KH, Han CW, Han SH. Expression of vascular endothelial growth factor and angiogenesis in the diabetic frozen shoulder. J Shoulder Elbow Surg. 2006;15:679-685.