Editorial
The efficacy of repeated needling for calcific tendinitis of the rotator cuff

Original Articles
Ultrasound-guided needle decompression and steroid injection for calcific tendinitis of the shoulder: risk factors for repeat procedures and outcome analysis

Anatomic fit of precontoured extra-articular distal humeral locking plates: a cadaveric study

Refracture after locking compression plate removal in displaced midshaft clavicle fractures after bony union: a retrospective study

Clinical outcome in patients with hand lesions associated with complex regional pain syndrome after arthroscopic rotator cuff repair

Investigation of the range of motion of the shoulder joint in subjects with rotator cuff arthropathy while performing daily activities

Distal biceps tendon injection

Interobserver agreement for detecting Hill-Sachs lesions on magnetic resonance imaging

Case Reports
Unusual and nondescript type of distal clavicular fracture

Metastasis of renal cell carcinoma around suture anchor implants

Review
The best options in superior capsular reconstruction

www.cisejournal.org
Aims and Scope

Clinics in Shoulder and Elbow (Clin Shoulder Elbow, CiSE; eISSN: 2288-8721) (pISSN: 2383-8337 till 2018) is an international, peer-reviewed journal and the official journal of Korean Shoulder and Elbow Society. It was first launched in 1998 (from March 1998 to June 2010: Journal of the Korean Shoulder and Elbow Society). It is published quarterly in the first day of March, June, September, and December, with articles in English, and has been published as an online-only journal since 2019. The purposes of CiSE are: first, to contribute in the management and education of shoulder and elbow topics; second, to share latest scientific informations among international societies; and finally, to promote communications on shoulder/elbow problems and patient care. It can cover all fields of clinical and basic researches in shoulder and elbow. CiSE publishs papers on basic and clinical researches, focusing on areas such as the etiology and epidemiology, biomechanics and pathogenesis, management and surgery, complication and prognosis for disease of shoulder and elbow. The manuscripts in the following categories can be submitted: original articles, case reports, invited review articles, editorials and letters to the editor. All submissions are processed online (www.cisejournal.org). The publication is determined by the editors and peer reviewers, who are experts in their specific fields of shoulder and elbow.

Articles published in this journal can be obtained from the official website of CiSE (www.cisejournal.org) as contents, abstracts and full-text PDF files.

Clinics in Shoulder and Elbow is indexed/tracked/covered by PubMed, Pubmed Central (PMC), Korea Citation Index (KCI), KoreaMed, KoMCI, CrossRef, and Google Scholar.

For subscription, submission, or any other information, please contact the editorial office below.

Open Access

This is an Open Access article distributed under the terms of the Creative Commons Attribution Non-Commercial License (http://creativecommons.org/licenses/by-nc/4.0/) which permits unrestricted non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.
Editorial Board

Editor-In-Chief
Young-Kyu Kim  
*Gachon University, Korea*

Assistant Editor-In-Chief
Hyung-Bin Park  
*Gyeongsang National University, Korea*

Deputy Editor
Yong-Min Chun  
*Yonsei University, Korea*

Associate Editors
Sang-Hun Ko  
*University of Ulsan, Korea*
Joong-Bae Seo  
*Dankook University, Korea*
Jae Chul Yoo  
*Sungkyunkwan University, Korea*

Editorial Board
Kerem Bilsel  
*Bezmialem Vakif Universitesi, Turkey*
Chul-Hyun Cho  
*Keimyung University, Korea*
Nam-Su Cho  
*Kyung Hee University, Korea*
Moustafa Ismail Ibrahim Elsayed  
*Sohag Faculty of Medicine, Egypt*
Michael Hantes  
*University of Thessaly, Greece*
Jung-Taek Hwang  
*Hallym University, Korea*
Jong-Hun Ji  
*The Catholic University of Korea, Korea*
Chunyan Jiang  
*Beijing Jishuitan Hospital, China*
Chris H. Jo  
*Seoul National University, Korea*
Kyu-Hak Jung  
*Gachon University, Korea*
Sae-Hoon Kim  
*Seoul National University, Korea*
Doo-Sup Kim  
*Yonsei University, Korea*
Myung-Sun Kim  
*Chonnam National University, Korea*
William Levine  
*Columbia University, USA*
Andri Maruli Tua Lubis  
*University of Indonesia, Indonesia*
Edward McFarland  
*Johns-Hopkins University, USA*
Teruhisa Mihata  
*Osaka Medical College, Japan*
Tomoyuki Mochizuki  
*Tokyo Medical and Dental University, Japan*
Hyun-Seok Song  
*The Catholic University of Korea, Korea*
W. Jaap Willems  
*Lairesse Kliniek, Netherlands*

Manuscript Editor
Mi-Joo Chung  
*Infolumi, Korea*
Contents

Editorial

53 The efficacy of repeated needling for calcific tendinitis of the rotator cuff
Hyun Seok Song

Original Articles

55 Ultrasound-guided needle decompression and steroid injection for calcific tendinitis of the shoulder: risk factors for repeat procedures and outcome analysis
Su Cheol Kim, Sang Min Lee, Gun Tae Park, Min Chang Jang, Jae Chul Yoo

66 Anatomic fit of precontoured extra-articular distal humeral locking plates: a cadaveric study
Joon-Ryul Lim, Tae-Hwan Yoon, Hwan-Mo Lee, Yong-Min Chun

72 Refracture after locking compression plate removal in displaced midshaft clavicle fractures after bony union: a retrospective study
Ho-Youn Park, Seok-Jung Kim, Yoo-Joon Sur, Jae-Woong Jung, Chae-Gwan Kong

80 Clinical outcome in patients with hand lesions associated with complex regional pain syndrome after arthroscopic rotator cuff repair
Takaki Imai, Masafumi Gotoh, Keiji Fukuda, Misa Ogino, Hidehiro Nakamura, Hiroki Ohzono, Naoto Shiba, Takahiro Okawa

88 Investigation of the range of motion of the shoulder joint in subjects with rotator cuff arthropathy while performing daily activities
Mohammad Taghi Karimi, Sahar Khademi

93 Distal biceps tendon injection
Jacqueline van der Vis, Stein J. Janssen, Ronald L.A.W. Bleys, Denise Eygendaal, Michel P.J. van den Bekerom; on behalf of Elbow Study Collaborative

98 Interobserver agreement for detecting Hill-Sachs lesions on magnetic resonance imaging
Hassanin Alkaduhimi, Aïmane Saarig, Ihsan Amajjar, Just A. van der Linde, Marieke F. van Wier, Nienke W. Willigenburg, Michel P.J. van den Bekerom; Shoulder and Elbow Center

Case Reports

106 Unusual and nondescript type of distal clavicular fracture
Alberto Izquierdo Fernández, José Carlos Minarro

110 Metastasis of renal cell carcinoma around suture anchor implants
Samuel Baek, Myung Ho Shin, Tae Min Kim, Kyung-Soo Oh, Dong Ryun Lee, Seok Won Chung

Review

114 The best options in superior capsular reconstruction
Dong Hyun Kim, Young Soo Jung, Kyung-Rock Kim, Jong Pil Yoon
Treatment calcific tendinitis of the shoulder remains controversial, with continued debate on whether ultrasound-guided needling and/or lavage, subacromial corticosteroid injection, radial or focused extracorporeal shockwave therapy (ESWT) [1], or arthroscopic removal [2,3] provides optimal outcomes. A prospective randomized trial in 25 patients compared the effectiveness of ultrasound-guided needling and radial shockwave therapy [4]. Ultrasound needling resulted in less pain and faster resorption of calcifications after 6 weeks. However, no significant differences were found after 1 year. A systematic review compared ESWT, ultrasound-guided percutaneous lavage, subacromial corticosteroid injection, and combined treatments for calcific tendinitis of the shoulder [5]. This meta-analysis suggested that combined ultrasound-guided needling and subacromial corticosteroid injection significantly decreased shoulder pain visual analog scale, improved Constant-Murley score and decreased the size of calcium deposits. Another systematic review concluded that high-energy focused ESWT was the best therapy in terms of functional recovery [6].

There is little evidence regarding the prognostic factors of each modality. Chou et al. [1] reported that a poor prognosis of ESWT for calcific tendinitis was significantly related to Gartner type I calcification, calcification extent $> 15$ mm and a duration of symptoms $> 11$ months.

Kim et al. [7] reported the clinical outcomes of single (84 cases) and multiple (14 cases) ultrasound-guided injection for calcific tendinitis. All functional scores were significantly improved at the final visit. The group with repeated ultrasound-guided needle decompression of calcific deposits showed worse pain and subjective satisfaction compared to the group that received a single ultrasound-guided needle decompression. At 2 months after the initial needling and injection, ultrasound-guided needling was repeated up to three times if the patient had persistent symptoms and calcific deposits on plain radiography. However, the authors could not determine which poor prognostic factors were associated with repeated needling and injection. These repeated lavage and injections could not be appropriate for these poor prognostic cases. What would the outcome have been at final follow-up if repeated injections had not been undertaken 2 months after the initial injection?

Ultrasound-guided lavage and corticosteroid injection can relieve symptoms and have a role in decreasing calcific deposits. However, multiple needling of the calcific tendinitis can also cause complications. Complications of needling of calcific deposits include injury or tear of the tendon and infection. There are no strict indications for repeated injection. Repeating lavage and
corticosteroid injections until the calcific deposits resolve completely is not recommended. Because of the lack of evidence regarding the efficacy, the risks and benefits of repeated needling (lavage) and injection should be carefully considered.

ORCID

Hyun Seok Song https://orcid.org/0000-0002-7844-2293

REFERENCES


https://doi.org/10.5397/cise.2021.00269
Background: Although ultrasound-guided needle decompression (US-GND) can treat calcific tendinitis of the shoulder effectively, repeat procedures might be required for unresolved symptoms. We evaluated the overall clinical outcomes of US-GND with subacromial steroid injection and the final results and factors predisposing toward repeat procedures.

Methods: Ninety-eight patients who underwent US-GND for calcific tendinitis of the supraspinatus/infraspinatus were analyzed between March 2017 and December 2018. The clinical outcomes (pain visual analog scale, functional visual analog scale [FVAS], and American Shoulder and Elbow Surgeons [ASES] score) and final subjective satisfaction were compared between groups A (single US-GND) and B (repeat US-GND). The factors predisposing toward repeated US-GNDs were analyzed.

Results: We found that 59.3% (58/98) of patient ASES scores were ≥80, and 73.5% of patients (72/98) were satisfied with the outcome. Group B (n=14) demonstrated a significantly higher rate of dominant-arm involvement compared to group A (78.6% vs. 48.8%, p=0.046). However, initial calcification size, shape, number, density, subscapularis involvement, lavage, and procedure time did not differ significantly between the groups. Group B showed poorer final FVAS (7 [interquartile range, 6–8] vs. 8 [interquartile range, 7–9], p=0.036) and subjective satisfaction compared to group A (satisfied: 5 [35.7%] vs. 67 [79.8%], p<0.001).

Conclusions: US-GND with subacromial steroid injection is a viable treatment option for calcific tendinitis of the shoulder. Dominant-arm involvement was the only independent factor for repeated US-GND. Final outcome of repeated US-GND for unimproved patients was promising; however, these outcomes were poor compared to those of the patients who improved after the first procedure.

Keywords: Calcification, physiologic; Tendinopathy; Shoulder pain; Ultrasonography, interventional; Decompression; Rotator cuff

INTRODUCTION

Calcific tendinitis is the most common pathology identified in patients with shoulder pain, with a prevalence that ranges from 6.8% to 54% [1-4]. Although calcific tendinitis is a self-limiting disease, it sometimes can require intervention because of severe
pain [3,5]. The initial treatment options for calcific tendinitis include pain control with oral medications, such as nonsteroidal anti-inflammatory drugs (NSAIDs), and injection of corticosteroids into the shoulder joint [3]. However, calcific deposits can be removed using real-time ultrasound-guided needle decompression (US-GND) if patients have persistent pain with prominent calcific deposits on plain radiography [6].

US-GND possesses several advantages. US-GND can be used to directly remove the calcific deposits without surgery. The procedure is convenient and not burdensome for either clinician or patient since US-GND can be performed under local anesthesia, enabling faster recovery [7]. Numerous studies have reported good clinical outcomes after US-GND [3,8,9]. The success rate for US-GND is approximately 70% [8,10-12]. Moreover, US-GND is the most effective treatment for calcific tendinitis of the shoulder among the various treatments (extracorporeal shock wave therapy [ESWT], US-GND, corticosteroid injection, and combined treatment) according to a systematic review by Arirachakaran et al. [13]. However, some studies reported that up to 42% of patients had persistent shoulder complaints after undergoing US-GND [4,14,15]. Therefore, the outcome of US-GND for calcific tendinitis is being debated.

Previously, repeat procedure is among the commonly reported factors predisposing toward poor clinical outcomes after US-GND [4,14-16]. Farin et al. [10] reported that repeated US-GND resulted in poor final outcomes compared to single US-GND. However, the predisposing factors associated with reluctance to undergo single US-GND requiring repeat procedure and the detailed outcomes of repeated US-GND such as pain, function, results of additional magnetic resonance imaging (MRI), and the need for surgical removal have not been explored.

Hence, this study aimed to analyze clinical and radiologic outcomes of US-GND at our institution, predisposing factors for repeated US-GND, and final outcome of repeated US-GND compared to that of single US-GND. The hypotheses were that US-GND would show good clinical and radiologic outcomes (comparable to previous studies), repeat US-GND would induce poor clinical and radiologic outcomes compared to single US-GND, and there are predisposing factors associated with repeated US-GND.

METHODS

This study was approved by the Institutional Review Board of Samsung Medical Center (IRB No. 2020-02-121-001). The need for informed consent was waived owing to the retrospective study design, which posed minimal risk to the patients during data acquisition.

Patients with painful calcific tendinitis refractory to conservative treatment, including medication, steroid injection, and ESWT, exceeding 6 months who underwent US-GND between March 2017 and December 2018, were assessed retrospectively. During this period, a total of 125 patients underwent US-GND for calcific tendinitis of the shoulder at our institution. Patients who had calcific deposits larger than 3 mm on the supraspinatus (SSP) or infraspinatus (ISP) tendon on any radiographic view and who underwent US-GND were included in this study.

Patients with the following conditions were excluded: (1) calcific deposits only in the subscapularis (SSC) tendon (n = 6); (2) dystrophic calcification according to the French Society of Arthroscopy (FAS) classification [17] (n = 4); (3) combined full-thickness rotator cuff tear on US imaging (n = 2); (4) history of previous US-GND (n = 1), surgery (n = 1), fracture (n = 2), or inflammatory arthritis including osteoarthritis (n = 3), rheumatoid arthritis (n = 1), and infectious arthritis (n = 0) of the affected shoulder; and (5) less than 6 months of follow-up (n = 7). After exclusions, 98 patients met the criteria and were involved in this study.

Clinical and Radiologic Evaluation

The shoulder range of motion (ROM), visual analog scale for pain (PV AS), VAS for function (FV AS), and American Shoulder and Elbow Surgeons (ASES) scores [18] were evaluated to assess the clinical outcome. The shoulder ROM included active forward elevation (FE), external rotation (ER) to the side, and behind-the-back internal rotation (IR). The FE and ER were measured using a goniometer. A 10-point scale was used to measure the IR based on the following anatomic levels described by Levy et al. [19]: greater trochanter to the buttocks (2 points), sacrum to L4 (4 points), L3 to L1 (6 points), T12 to T8 (8 points), and T7 to T1 (10 points). All functional scores were recorded by a single athletics shoulder trainer (SML) blinded to the study, and the ROM was assessed by five shoulder fellows trained at our institution.

Radiologic evaluation was performed using plain radiography (anteroposterior, true anteroposterior, cephalic tilt, axillary lateral, and arch view), which was obtained with the patient shoulders in neutral rotation. The maximum length of the deposit was measured on any plain radiograph. The number of calcific deposits was designated as single or multiple. Clustered lobular calcifications consisting of one clump were designated as a single deposit (Fig. 1). The morphology of the calcific deposits was assessed using the FAS classification: type A (sharply delineated, dense, and homogenous deposits); type B (sharply delineated, dense appearance, with multiple fragments); and type C (hetero-
geneous appearance, fluffy deposit). Patients with type D deposits were excluded (Fig. 2) [17]. The qualitative reduction in the calcific deposits was assessed after the procedure based on comparison with baseline: 1, no change; 2, less than half removed (<50%); 3, approximately half removed (about 50%); 4, more than half removed (>50%); and 5, completely removed (Fig. 3).

All radiologic measurements were performed by two trained shoulder fellows (SCK and KSC) who were blinded to the result of the study, and the inter-observer reproducibility was calculated.

Clinical and radiologic evaluations were performed before and after the procedure at each outpatient visit. The patients were followed up for 2 months after the US-GND; the number of subsequent outpatient visits varied depending on improvement in symptoms. US-GND was repeated up to three times if the patient had persistent symptoms and calcific deposits on plain radiography. At the last outpatient visit, the patients were asked final questions about subjective satisfaction, additional MRI, and whether operated or not. Subjective satisfaction was divided into four categories: very satisfied, satisfied, the same, and poor. If the patients did not visit the outpatient clinic for more than 6 months, a telephone survey was conducted to ascertain the PVAS, FVAS, ASES scores, and the answers to final questions.

**Ultrasound-Guided Needle Decompression**

All procedures were performed at our institution by five first-year shoulder fellows during the study period. The patients were required to sit on a bed with a 70° backrest, and the affected shoulder was exposed for diagnostic US for calcific tendinitis and rotator cuff pathology. The arm was positioned in IR if the calcific deposit was located in the SSP/ISP tendons. For SSC calcifications, the arm was positioned in ER.

The skin over the lesion was sterilized using betadine and alcohol, and a sterile O-hole drape was placed. Sterile US gel and film were used. Local anesthesia (2% lidocaine hydrochloride [400 mg/4 mL, Daihan Pharm, Seoul, Korea]) was injected into the skin and around the calcific deposit under real-time U.S. guidance to reduce pain during the procedure. The calcific deposits were punctured repeatedly with an 18-G needle until all hard sections of the calcific deposit were softened and lost any definitive shape. During the US-GND, density of calcification, possibility of lavage, and operative time were recorded. When the cal-

---

**Fig. 1.** Number of calcific deposits: (A) single, (B) multiple; (C) clustered lobular-shaped deposits were regarded as a single entity.

**Fig. 2.** French Society of Arthroscopy classification (A) type A (sharply delineated, dense, and homogenous appearance of deposits), (B) type B (sharply delineated, dense appearance, and multiple fragments), (C) type C (heterogeneous appearance, fluffy deposit).
move their shoulder immediately after the procedure without any restriction in motion.

Statistical Analysis

All initial and final clinical and radiologic outcomes were analyzed using paired comparisons. Patients were divided into two groups depending on whether they received one (group A) or more than one (group B) procedure, and the variables of Groups A and B were compared. Moreover, patients were divided into “satisfied vs. dissatisfied” and “no calcific deposit vs. remnant calcific deposit” groups at the final examination, and their variables were compared.

All statistical analyses were performed using SAS ver. 9.4 (SAS Institute, Cary, NC, USA). Continuous variables (age, symptom duration, follow-up duration, calcific deposit size, operative time, ROM, and functional scores) were analyzed using Student t-test or Mann-Whitney-Wilcoxon test. Categorical variables (sex, site of involvement, dominant-arm involvement, diabetes, smoking status, SSC involvement, number of deposits, FAS classification, lavage, density, decrease in calcific deposit, and final questionnaires) were analyzed using the chi-square test or Fisher’s exact test. Multivariable logistic regression analysis for repeated US-GND was performed. An alpha value of 0.05 was used.

Interobserver reproducibility for the radiologic measurements was calculated using Cohen’s kappa coefficient (κ) for categorical variables (FAS classification, qualitative reduction in the calcifications) and the intraclass correlation coefficient (ICC) for continuous variables (size). If the ICC or κ was > 0.75, 0.4–0.75, or < 0.4, the reliability was considered excellent, fair to good, or poor, respectively. The interobserver reproducibility for the radiologic variables was: the ICCs for initial and final calcification size were good (0.90, 0.95), κ for final reduction in calcification size was good (0.80), and κ for the initial and final FAS classification was fair to good (0.51 and 0.62).

Post hoc power analysis was performed to determine the statistical power for comparison between groups A and B. The ASES score at the final follow-up was the primary outcome of this study. A minimal clinically important difference of 12 [20] and standard deviation of 15 [6,8] in ASES scores were determined as per prior studies, and the significance level was set to an alpha value of 0.05. The comparison between group A (n = 84) and group B (n = 14) yielded a statistical power of 79.2%.

RESULTS

Ninety-eight patients (mean age, 52.9 ± 10.3 years) with 29.4 ± 10.4 months follow-up were analyzed. Initial calcific deposit size was firm and difficult to fragment, we recorded the finding as “hard.” When there was no resistance when passing the needling through the calcific deposit, we recorded the finding as “soft.” The density between these was recorded as “intermediate.” After puncture, the calcific debris were aspirated using a 10-mL syringe with a new 18-G needle, if possible.

After the procedure, a mixture of 4 mL of 1% lidocaine and 1 mL of triamcinolone acetonide (40 mg/1 mL; Hanall Pharm, Seoul, Korea) was injected into the subacromial space, and oral NSAIDs were prescribed for 1 month. Patients were instructed to
13.3 ± 6.6 mm, and FAS type B (42.9%) was the most commonly observed. The demographic and initial characteristics of the calcific deposits of the consecutive patients are presented in Table 1.

During the first US-GND, 36 dense, 39 intermediate, and 23 soft calcific deposits were observed. Saline lavage was possible in 55 patients, and the mean procedure time was 29.1 ± 11.3 minutes (range, 13–47 minutes). After the first US-GND, 14 patients (14.3%) underwent repeated US-GND (group B), and 1 patient underwent US-GND three times. The mean period between initial and second US-GND was 4.2 ± 2.2 months (range, 1.4–9.7 months), and the procedure time for the repeat procedure was 16.5 minutes (interquartile range, 12.8–28.0 minutes).

The overall clinical and radiologic outcomes are presented in Table 2. All functional scores improved significantly in the final follow-up compared to the initial. The calcific deposits were removed completely in 45 patients (45.9%), and 72 patients (73.5%) were very satisfied or satisfied. Nine patients (9.2%) underwent additional MRI, and all patients showed more severe than grade two partial tears of the SSP tendon [21]. Among these nine patients, four (4.1%) underwent arthroscopic calcific material removal and rotator cuff repair.

### Comparison between Needling Once and Repeated Needling

The patients’ demographics and initial characteristics, including the ROM and functional scores, did not differ significantly between groups A and B with the exception of dominant-arm involvement (Table 3).

The initial size of the calcific deposit, shape according to the FAS classification, number of deposits, SSC involvement, density (group A: 30 dense, 33 intermediate, 21 soft; group B: 6 dense, 6 intermediate, 2 soft; p = 0.761), saline lavage (group A: 48, group B: 7, p = 0.835), and procedure time (group A: 29.0 minutes [interquartile range, 19.8–35.3]; group B: 29.5 minutes [interquartile range, 18.0–45.8], p = 0.583) did not differ significantly between groups A and B.

In multivariable regression analysis of repeated needling, dom-

### Table 1. Patient demographics and initial characteristics of the calcific deposits

<table>
<thead>
<tr>
<th>Variable</th>
<th>Total (n = 98)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>52.9 ± 10.3 (31–87)</td>
</tr>
<tr>
<td>Sex (male:female)</td>
<td>24:74</td>
</tr>
<tr>
<td>Site (right:left)</td>
<td>55:43</td>
</tr>
<tr>
<td>Dominant-arm involvement</td>
<td>52 (53.1)</td>
</tr>
<tr>
<td>Diabetes</td>
<td>11 (11.2)</td>
</tr>
<tr>
<td>Smoking</td>
<td>3 (3.1)</td>
</tr>
<tr>
<td>Symptom duration (mo)</td>
<td>13.7 ± 13.0 (1–60)</td>
</tr>
<tr>
<td>Follow-up duration (mo)</td>
<td>29.4 ± 10.4 (6.2–42.9)</td>
</tr>
<tr>
<td>Calcific deposit</td>
<td></td>
</tr>
<tr>
<td>Size (mm)</td>
<td>13.3 ± 6.6 (3.7–35.9)</td>
</tr>
<tr>
<td>FAS classification (type A:B:C)</td>
<td>30:42:26:0</td>
</tr>
<tr>
<td>Subscapularis calcific deposit</td>
<td>9 (9.2)</td>
</tr>
<tr>
<td>Number (single:multiple)</td>
<td>62:36</td>
</tr>
</tbody>
</table>

Values are presented as mean ± standard deviation (range), number, or number (%).

FAS: French Society of Arthroscopy.
*Type A (dense homogenous calcification with clear contours), type B (dense fragmented calcification with clear contours), type C (heterogeneous appearance, fluffy deposit).

### Table 2. Initial and final outcomes of the study population

<table>
<thead>
<tr>
<th>Variable</th>
<th>Initial</th>
<th>Final</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forward elevation (°)</td>
<td>160.0 (150.0–160.0)</td>
<td>160.0 (1500–160.0.)</td>
<td>0.162</td>
</tr>
<tr>
<td>External rotation (°)</td>
<td>60.0 (50.0–70.0)</td>
<td>60.0 (50.0–70.0)</td>
<td>0.936</td>
</tr>
<tr>
<td>Internal rotation*</td>
<td>10.0 (8.0–10.0)</td>
<td>100 (8.0–10.0)</td>
<td>0.109</td>
</tr>
<tr>
<td>PVAS</td>
<td>6.0 (5.0–7.0)</td>
<td>2.0 (1.0–3.0)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>FVAS</td>
<td>6.0 (5.0–7.0)</td>
<td>8.0 (7.0–9.0)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>ASES score</td>
<td>45.0 (36.0–57.0)</td>
<td>85.0 (72.0–90.0)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Calcific deposit</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Size (mm)</td>
<td>11.9 (8.4–16.5)</td>
<td>3.0 (0–5.8)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>FAS classification (type A:B:C:none)</td>
<td>30:42:26:0</td>
<td>1:20:32:45</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Subjective satisfaction (a:b:c:d)</td>
<td>-</td>
<td>39:33:13:13</td>
<td>-</td>
</tr>
</tbody>
</table>

Values are presented as median (interquartile range).

*Behind vertebral levels: greater trochanter to the buttocks (2 points), sacrum to L4 (4 points), L3 to L1 (6 points), T12 to T8 (8 points), and T7 to T1 (10 points); †Type A (sharply delineated, dense, and homogenous appearing deposits), type B (sharply delineated, dense appearance, with multiple fragments), type C (heterogeneous appearance, fluffy deposit); ‡1: no change, 2: <50% decrease, 3: about 50% decrease, 4: >50% decrease, 5: complete removal; §a: very satisfied, b: satisfied, c: rather the same, d: poor; ††Statistically significant.
inherent arm involvement was an independent predisposition factor (odds ratio, 4.075; 95% confidence interval, 1.033–16.078, p = 0.045), but symptom duration was not (odds ratio, 1.031; 95% confidence interval, 0.991–1.074, p = 0.130).

The clinical outcomes of groups A and B are presented in Table 4. Final FV AS scores and subjective satisfaction were significantly better in group A (50% satisfied) than in group B (35.7% satisfied). The frequency of additional MRI was significantly higher in group B. The reason for the MRI scan of four patients in group A was that SSP partial tear was suspected on the ultrasound during US-GND. However, persistent pain in the affected shoulder in five group B patients resulted in performance of MRI scans. However, the rate of

| Table 3. Patient demographics and baseline characteristics of two groups |
|-----------------------------|-----------------------------|-----------------------------|
| Variable                    | Group A (n = 84)            | Group B (n = 14)            | p-value          |
| Age (yr)                    | 52.0 (46.8–60.0)            | 54.5 (47.3–58.0)            | 0.919            |
| Sex (male:female)           | 22:62                      | 2:12                      | 0.507            |
| Site (right:left)           | 44:40                      | 11:3                      | 0.985            |
| Dominant-arm involvement    | 41 (48.8)                  | 11 (78.6)                 | 0.046†           |
| Diabetes                    | 11 (13.1)                  | 0                          | 0.356            |
| Smoking                     | 3 (3.6)                    | 0                          | 1.000            |
| Symptom duration (mo)       | 12.0 (3.0–18.0)             | 12.5 (7.5–24.0)            | 0.196            |
| Follow-up duration (mo)     | 33.81 (26.3–38.1)           | 30.77 (22.0–34.7)          | 0.243            |
| Calcific deposit            |                            |                            |                  |
| Size (mm)                   | 12.1 (8.4–16.3)             | 11.3 (8.7–15.8)            | 0.670            |
| FAS classification (type A/B/C*) | 26:22:36                | 4:4:6                     | 0.976            |
| Subscapularis calcific deposit | 7                          | 2                          | 0.612            |
| Number (single/multiple)    | 54:30                      | 8:6                        | 0.831            |

Values are presented as median (interquartile range), number, or number (%).


| Type A (sharply delineated, dense, and homogenous appearing deposits), type B (sharply delineated, dense appearance, with multiple fragments), type C (heterogeneous appearance, fluffy deposit); †Statistically significant. |

| Table 4. Clinical outcomes of two groups |
|-----------------------------|-----------------------------|-----------------------------|
| Variable                    | Group A (n = 84)            | Group B (n = 14)            | p-value          |
| Initial                     |                            |                            |                  |
| Forward elevation (°)       | 160.0 (150.0–160.0)         | 160.0 (142.5–160.0)        | 0.897            |
| External rotation (°)       | 60.0 (50.0–70.0)            | 60.0 (60.0–67.5)           | 0.479            |
| Internal rotation*          | 10.0 (8.0–10.0)             | 10.0 (8.5–10.0)            | 0.757            |
| PVAS                        | 5.0 (5.0–7.0)               | 6.0 (4.0–8.0)              | 0.510            |
| FVAS                        | 6.0 (5.0–7.0)               | 5.5 (3.5–7.3)              | 0.917            |
| ASES score                  | 46.3 ± 15.3                | 43.7 ± 19.5               | 0.614            |
| Final                       |                            |                            |                  |
| Forward elevation (°)       | 160.0 (150.0–160.0)         | 160.0 (150.0–160.0)        | 0.318            |
| External rotation (°)       | 60.0 (50.0–70.0)            | 65.0 (50.0–70.0)           | 0.773            |
| Internal rotation*          | 10.0 (10.0–10.0)            | 10.0 (8.0–10.0)            | 0.296            |
| PVAS                        | 1.0 (1.0–3.0)               | 2.0 (1.0–4.0)              | 0.140            |
| FVAS                        | 8.0 (7.0–9.0)               | 7.0 (6.0–8.0)              | 0.036‡           |
| ASES score                  | 85.0 (74.0–89.5)            | 78.5 (63.0–90.0)           | 0.267            |
| Subjective satisfaction (a:b:c:d†) | 36:31:11:6                | 9:3:2:2                    | 0.001†           |
| Additional MRI              | 4 (4.8)                    | 5 (35.7)                   | 0.003‡           |
| Surgical removal            | 2 (2.4)                    | 2 (14.3)                   | 0.097            |

Values are presented as median (interquartile range), mean±standard deviation, or number.


*Behind vertebral levels: greater trochanter to the buttocks (2 points), sacrum to L4 (4 points), L3 to L1 (6 points), T12 to T8 (8 points), and T7 to T1 (10 points); †: a: very satisfied, b: satisfied, c: rather the same, d: poor; ‡Statistically significant.
surgical removal did not differ significantly between the two groups.

**Change in Calcific Deposits**

The change in size of the calcific deposits according to number of needling procedures in groups A and B is described in Fig. 4. The size of the calcification after the first needling procedure was $4.1 \pm 4.7$ mm and $9.5 \pm 4.7$ mm in groups A and B ($p<0.001$), respectively. After the second needling procedure, the size of the calcific deposits decreased to $5.5 \pm 4.7$ mm in group B, which did not differ from the post-procedural size of group A ($p = 0.207$). The final deposit size did not differ between the groups ($p = 0.274$).

The changes in the FAS classification in groups A and B are shown in Fig. 5. Initially, type B was most common in groups A and B. After the needling procedure in group A, 36 patients had no calcification; and type C calcifications were observed most commonly. Complete removal of the calcific deposits after the first procedure was not observed in any patient in group B. Finally, type B was most commonly observed ($n = 6$) and complete removal of calcification was observed in three patients in group B. The final FAS classification differed significantly between the two groups ($p = 0.039$).

The reduction in calcific deposits is presented in Fig. 6. After the first procedure, 36 patients in group A showed no calcification and 12 patients showed greater than 50% calcification reduction. After final removal, 42 patients in group A showed no calcification and 21 patients showed greater than 50% calcification reduction. In group B, one patient showed a reduction exceeding 50% after the first procedure, and eight showed a reduction exceeding 50% after the second procedure.

**Comparison According to Final Subjective Satisfaction**

At the final follow-up, 72 patients were very satisfied or satisfied, while 26 patients were not satisfied (Table 5). The initial calcification size was significantly larger and the final functional scores were better in the satisfied patients compared to the dissatisfied patients.

**Comparison According to Residual Calcific Deposit**

The calcific deposits were completely removed in 45 patients (group CR), while 53 patients had residual deposits (group RD). The initial characteristics did not differ between groups CR and RD, and only initial shape according to the FAS classification differed significantly between the groups (group CR vs. RD: type A:B:C, 17:13:15 vs. 13:29:11; $p = 0.036$). However, final ROM and functional scores were not different between the groups.

**DISCUSSION**

This study analyzed the overall clinical and radiologic outcomes of US-GND for calcific tendinitis of the shoulder over a minimum follow-up period of six months. Repeated US-GND was performed in 14.3% of patients; overall, 73.5% of patients were satisfied at final follow-up. Patients who underwent repeated US-GND showed a significantly higher rate of dominant-arm involvement, poor final FVAS and subjective satisfaction, and a

---

**Fig. 4.** Mean change in the size of the calcific deposit. *Significantly different ($p<0.001$).

**Fig. 5.** Change in French Society of Arthroscopic classification. *Significantly different ($p<0.001$).
After 1st procedure  |  Final  
---|---
Group A | Group B  
|  |  
No change | <50% | 50% | >50% | Complete removal  
|  |  |  |  |  
36 | 12 | 11 | 12 | 13  
42 | 21 | 9 | 6 | 6  

After 1st procedure  |  After 2nd procedure  |  Final  
---|---|---
Group A | Group B  
|  |  
No change | <50% | 50% | >50% | Complete removal  
|  |  |  |  |  
1 | 3 | 4 | 5 | 3  
3 | 6 | 5 | 4 | 6  

*Significantly different (p=0.008); †Significantly different (p=0.039).

Fig. 6. Qualitative reduction in calcific deposit.

Table 5. Comparison according to the final subjective satisfaction

<table>
<thead>
<tr>
<th>Variable</th>
<th>Satisfied (n = 72)</th>
<th>Dissatisfied (n = 26)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calcific deposit</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Size (mm)</td>
<td>13.1 (9.7–18.7)</td>
<td>8.9 (7.3–11.9)</td>
<td>0.003†</td>
</tr>
<tr>
<td>FAS classification (type A:B:C*)</td>
<td>25:28:19</td>
<td>5:14:7</td>
<td>0.287</td>
</tr>
<tr>
<td>Forward elevation (°)</td>
<td>160.0 (150.0–160.0)</td>
<td>160.0 (150.0–167.5)</td>
<td>0.345</td>
</tr>
<tr>
<td>External rotation (°)</td>
<td>60.0 (50.0–70.0)</td>
<td>60.0 (60.0–67.5)</td>
<td>0.410</td>
</tr>
<tr>
<td>Internal rotation†</td>
<td>10.0 (8.0–10.0)</td>
<td>10.0 (8.0–10.0)</td>
<td>0.850</td>
</tr>
<tr>
<td>PVAS</td>
<td>5.0 (4.5–7.0)</td>
<td>5.50 (5.00–6.8)</td>
<td>0.896</td>
</tr>
<tr>
<td>ASES score</td>
<td>44.5±15.2</td>
<td>48.6±17.4</td>
<td>0.329</td>
</tr>
<tr>
<td>During procedure</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Procedure time (min)</td>
<td>29.5 (19.00–39.25)</td>
<td>28.50 (18.50–35.00)</td>
<td>0.974</td>
</tr>
<tr>
<td>Lavage</td>
<td>41</td>
<td>14</td>
<td>0.966</td>
</tr>
<tr>
<td>Density (dense:intermediate:soft)</td>
<td>26:28:18</td>
<td>10:11:5</td>
<td>0.837</td>
</tr>
<tr>
<td>Final</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calcific deposit</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Size (mm)</td>
<td>1.9 (0.0–5.4)</td>
<td>3.6 (0.0–6.0)</td>
<td>0.480</td>
</tr>
<tr>
<td>FAS classification (A:B:C:none*)</td>
<td>1:12:24:35</td>
<td>0:8:8:10</td>
<td>0.463</td>
</tr>
<tr>
<td>Remnant deposit (Y:N)</td>
<td>37:35</td>
<td>16:10</td>
<td>0.509</td>
</tr>
<tr>
<td>Forward elevation (°)</td>
<td>160.0 (150.0–160.0)</td>
<td>155.0 (150.0–160.0)</td>
<td>0.205</td>
</tr>
<tr>
<td>External rotation (°)</td>
<td>60.0 (50.0–70.0)</td>
<td>60.0 (50.0–70.0)</td>
<td>0.895</td>
</tr>
<tr>
<td>Internal rotation†</td>
<td>10.0 (10.0–10.0)</td>
<td>10.0 (8.0–10.0)</td>
<td>0.071</td>
</tr>
<tr>
<td>PVAS</td>
<td>1.0 (1.0–2.0)</td>
<td>3.5 (2.8–4.0)</td>
<td>&lt; 0.001†</td>
</tr>
<tr>
<td>FVAS</td>
<td>8.0 (7.8–9.0)</td>
<td>7.0 (6.8–7.3)</td>
<td>&lt; 0.001†</td>
</tr>
<tr>
<td>ASES score</td>
<td>86.0 (80.0–90.5)</td>
<td>66.0 (62.0–74.5)</td>
<td>&lt; 0.001†</td>
</tr>
</tbody>
</table>

Values are presented as median (interquartile range), number, or mean±standard deviation.
*Type A (sharply delineated, dense, and homogenous appearing deposits), type B (sharply delineated, dense appearance, with multiple fragments), type C (heterogeneous appearance, fluffy deposit); †Behind vertebral levels: greater trochanter to the buttocks (2 points), sacrum to L4 (4 points), L3 to L1 (6 points), T12 to T8 (8 points), and T7 to T1 (10 points); ‡Statistically significant.

https://doi.org/10.5397/cise.2021.00101
higher frequency of additional MRI evaluation for rotator cuff pathology compared to those who underwent US-GND once. Based on final subjective satisfaction, dissatisfied patients had smaller calcifications compared to satisfied patients. However, the presence of residual calcific deposits on final plain radiograph was not associated with clinical outcome.

Although the specific methodology differed by clinician, the previously reported clinical success rate after US-GND was approximately 70% [8,10-12], and US-GND was a good treatment modality for calcific tendinitis of the shoulder compared to other options [3,13,22]. Kim et al. [3] reported that US-GND elicited superior clinical and radiologic outcomes for treatment of calcific tendinitis of the shoulder compared to ESWT. Oudelaar et al. [22] reported that 74% of patients experienced complete symptomatic relief at 6 months. Moreover, a recent meta-analysis reported that the needling procedure was the most efficient treatment method according to the clinical outcomes obtained after 2 years’ follow-up [13].

However, some studies have shown that US-GND does not guarantee good outcomes for calcific tendinitis of the shoulder [14,15,22,23]. The improvement in pain at one year after US-GND reportedly ranged from 51% to 69% according to a systematic review [24], and more than 42% of patients complained of recurrent shoulder pain after the procedure [14,22]. Moreover, 18%-45% of patients underwent repeat US-GND owing to persistent pain in the affected shoulder after the first procedure [10,23], de Witte et al. [15] compared the clinical and radiologic outcomes between US-GND and subacromial steroid injection alone and reported no difference between the two treatment modalities.

In our study, the mean size of the calcific deposit decreased significantly after US-GND, and 67.3% of patients had PVAS score ≤ 2, 59.3% had ASES score ≥ 80, and 73.5% were satisfied to very satisfied. Thus, the success rate of US-GND in our study is comparable to that of previous studies, which was approximately 70% [6,8,10,11]. Repeated US-GND was performed in 14.3% patients in our study, which was slightly lower than that reported in previous studies (18%-45%) [10,23].

Previously, repeat procedures have been reported as a common poor prognostic factor for US-GND. [4,25]. Ogon et al. [25] reported that small deposit size and repeated needling procedures were associated with poor outcomes; and Oudelaar et al. [4] reported that long symptom duration, repetitive procedures, and smaller calcific deposits were poor prognostic factors for US-GND.

In our study, only dominant-arm involvement was an independent risk factor for repeat needling, consistent with de Witte et al. [14]. Other factors such as initial calcific deposit size, shape, number, density, possibility of lavage during the procedure, and procedure time were not associated. The reason for this observation was not revealed by our study. However, we assumed that the relatively greater use of the dominant arm might be the cause of persistent symptoms and consequent requirement for repeated needling procedures.

Patients who underwent repeated US-GND showed low ROM and functional scores similar to those of previous studies, even though only FVAS was statistically significant [4,10]. However, as mentioned by Oudelaar et al. [4], the reason for the poor level of satisfaction could not be clearly identified; it was unclear whether the repeat needling procedure rendered the patients unhappy or if dissatisfied patients underwent repeated needling procedures.

Although the initial calcification size was not associated with repeat US-GND, there was a significant difference of initial calcification size between the satisfied and dissatisfied patients. Dissatisfied patients showed smaller initial calcifications compared to their satisfied counterparts. However, the relationship between initial calcification size and result of the needling procedure is inconclusive [4,25]. Oudelaar et al. [4] asserted that large calcifications exert a predominantly space-occupying effect; however, small calcifications seem to have more inflammatory symptoms than space-occupying effects. Moreover, patients with small calcifications had fewer complaints than those with large calcifications; thus, the effect of the needling procedure was smaller than that for large deposits.

Furthermore, complete removal of calcific deposits is associated with US-GND outcomes [15,26]. Krasny et al. [26] reported that patients with gradual radiologic improvement showed better clinical outcomes. Further analysis was conducted to determine if the final residual calcification was related to the final outcome; however, no association was observed in this study. Therefore, complete removal of the calcific deposit seems unnecessary, and the decision to repeat US-GND should not be based solely on radiographs.

In the early period at our institution, radiologists performed the US-GND by consultation. However, since 2012, first-year orthopedic shoulder fellows have been performing the US-GND. We had concerns over the outcomes when the practitioner changed; however, this study revealed no great difficulty in learning the US-GND procedure for orthopedic doctors. These doctors achieved good outcomes.

Moreover, the mean procedure time was 29.1 minutes, which is fairly long for US-GND. Although none of the previous studies have reported on the association between procedure time and US-GND outcomes and no association was observed in our
study, we opine that puncturing the calcific deposit for a sufficient duration is vital to achieving good results.

This study has several limitations. First, there were limitations inherent to the retrospective study design. The number of patients requiring repeat needling was insufficient because the frequency of the repeated needling procedure is relatively low. Although the inclusion of 14 patients with repeated US-GND yielded a statistical power of 79.2%, a larger sample is required to obtain clearer outcomes for repeated US-GND. Second, the follow-up duration was short, with a minimum period of six months. Some difficulties were encountered in motivating the patients to revisit the outpatient clinic for long-term follow-ups since some patients experienced marked improvements in pain and function after the procedure. Patients whose symptoms improved after the first needling could not be assessed regularly at the outpatient clinic. However, the mean follow-up period was 29.4 months, which is sufficient to assess the results of US-GND. Third, the final follow-up duration ranged widely from 6 to 42 months after the needling procedure. Calcific deposits usually dissolve and disappear over time after needling, and the patients' symptoms also change over time [22]. Hence, comparing the radiologic and clinical outcomes of the needling procedure with different follow-up durations could have been fallacious. Fourth, other treatment after US-GND was not analyzed. In particular, NSAIDs were prescribed for 1 month after the procedure, but drug compliance was not recorded due to the retrospective research design. Drug compliance and additional treatment might have affected clinical results; therefore, these are potential confounding factors. Finally, the criteria for calcific density evaluation might have been subjective for practitioners.

US-GND with subacromial steroid injection is a good treatment option for calcific tendinitis of the shoulder. Dominant-arm involvement was the only factor associated with repeated US-GND, while the size, shape, number, and density of the calcifications and possibility of lavage were not associated factors. The final outcome of repeated US-GND for unimproved patients was also promising; however, the function and subjective satisfaction were poor compared to those of the patients who improved after the first procedure.

REFERENCES


Anatomic fit of precontoured extra-articular distal humeral locking plates: a cadaveric study

Joon-Ryul Lim¹, Tae-Hwan Yoon¹, Hwan-Mo Lee², Yong-Min Chun¹

¹Department of Orthopedic Surgery, Arthroscopy and Joint Research Institute, Severance Hospital, Yonsei University College of Medicine, Seoul, Korea
²Department of Orthopedic Surgery, Severance Hospital, Yonsei University College of Medicine, Seoul, Korea

**Background:** Extra-articular distal humerus locking plates (EADHPs) are precontoured anatomical plates widely used to repair distal humeral extra-articular diaphyseal fractures. However, EADHPs frequently cause distal protrusion and resulting skin discomfort. The purpose of this study was to predict the occurrence of anatomic fit mismatch. We hypothesized that the smaller the humerus size, the greater the anatomic fit mismatch with EADHP.

**Methods:** Twenty humeri were analyzed in this study. Humeral length and distal humeral width were used as parameters of humeral size. Plate protrusion was measured between the EADHP distal tip and the distal humerus. We set the level of unacceptable EADHP anatomic fit mismatch as ≥10 mm plate protrusion.

**Results:** A significant negative linear correlation was also confirmed between humeral size and plate protrusion, with a coefficient of determination of 0.477 for humeral length and 0.814 for distal humeral width. The cutoff value of humeral length to avoid ≥10 mm plate protrusion was 293.6 mm (sensitivity, 88.9%; specificity, 81.8%) and for distal humeral width was 60.5 mm (sensitivity, 100%; specificity, 81.8%).

**Conclusions:** Anatomic fit mismatch in distal humeral fractures after EADHP fixation has a negative linear correlation with humeral length and distal humeral width. For patients with a distal humeral width <60.5 mm, ≥10 mm plate protrusion will occur when an EADHP is used, and an alternative implant or approach should be considered.

**Keywords:** Bone plates; Humeral fractures; Prostheses and implants; Humerus

---

**INTRODUCTION**

Distal-third humeral fractures account for up to 2% of all adult fractures [1], and they are challenging to surgically correct [2-4]. Various anatomical precontoured locking plates have recently been developed and are used for surgical treatment of distal humerus fractures [5-7]. Extra-articular distal humerus locking plates (EADHPs; DePuy Synthes, Oberdorf, Switzerland) are anatomical precontoured plates widely used in distal humeral extra-articular diaphyseal fractures [8-12]. The posterolateral elbow column is used to fix the EADHP with a posterior approach. Despite the distally tapered design of the plate, it causes plate protrusion and skin discomfort after surgery (Fig. 1). Implant prominence after EADHP fixation was

**Received:** April 7, 2021  
**Revised:** April 26, 2021  
**Accepted:** April 28, 2021

**Correspondence to:** Yong-Min Chun  
Department of Orthopedic Surgery, Arthroscopy and Joint Research Institute, Severance Hospital, Yonsei University College of Medicine, 50-1 Yongsei-ro, Seodaemun-gu, Seoul 03722, Korea  
Tel: +82-2-2228-5679, Fax: +82-2-363-6248, E-mail: min1201@hanmail.net, ORCID: https://orcid.org/0000-0002-8147-6136

**IRB approval:** None.  
**Financial support:** None.  
**Conflict of interest:** None.

Copyright © 2021 Korean Shoulder and Elbow Society.  
This is an Open Access article distributed under the terms of the Creative Commons Attribution Non-Commercial License (http://creativecommons.org/licenses/by-nc/4.0/) which permits unrestricted non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.
noted in up to 59.5% of cases [13]. This problem requires implant removal after fracture union [11,12]. However, in most distal humeral fracture cases, EADHPs should be placed beneath the radial nerve (Fig. 2). Thus, iatrogenic radial nerve palsy is likely to result from EADHP removal surgery.

Zhou et al. [14] reported that EADHP caused approximately 8° of anatomic fit mismatch in the shafts of adult Chinese bodies in a cadaveric humeri study, which can be resolved by bending the plate. However, anatomic fit mismatch with plate protrusion occurring at the EADHP distal tip is likely to occur when the humerus is small, and anatomic fit mismatch is difficult to resolve through plate bending. Therefore, it is necessary to predict the plate protrusion occurrence and resulting skin discomfort that leads to risk of iatrogenic radial nerve palsy to better inform treatment planning and implant selection. However, the humeral size at which EADHP distal tip protrusion occurs due to anatomic fit mismatch has not been established.

The purpose of this study was to determine the humeral size cutoff for plate protrusion despite proper plate positioning through a cadaveric study. We hypothesized that the smaller the size of the humerus, the greater the anatomic fit mismatch of EADHP that would occur, and that the relationship between humeral size and mismatch will have a negative linear correlation.

**METHODS**

Because this study is a cadaveric study, there is no Institutional Review Board approval and informed consent for this study.

**Specimens**

A total of 20 humeri of various sizes were used. All soft tissue was removed, and the lack of any gross deformities of the humerus was confirmed. Humeral length and distal humeral width were used as parameters of humeral size. Humeral length was measured along the anatomical axis, and the distance between the humeral head tip and the trochlear tip with a perpendicular line on the axis was measured using digital tape (BL-DM; Bluetec, Daejeon, Korea). Distal humeral width was measured as the medial-to-lateral length between the medial and lateral epicondyles along the perpendicular plane of the anatomical axis using a digital caliper (SD500-150PRO; Sincon, Busan, Korea) (Fig. 3).
Measurement of Anatomic Fit Mismatch
A six-hole EADHP was positioned sufficiently laterally to not encroach on the olecranon fossa. EADHP mismatch caused by humeral posterior angulation in the shaft area as well as in the distal part was due to the plate’s distal five holes being longer than that of the distal humeral posterolateral column. The shaft mismatch could be resolved through proper EADHP bending [14], so the middle portion of the EADHP was bent using a plate bending press (Plate Bending Press 329.3; DePuy Synthes) to fit the contour of posterior angulation of the humerus. Additionally, mismatch occurring at the plate distal tip may be improved by proximal plate positioning, but in such cases, plate-bone mismatches occurred at the posterolateral column even if the plate was modified by the plate bending press. Therefore, we first fitted the EADHP to the posterolateral column, the mismatch occurring in the humeral shaft was resolved by the plate bending press, and the mismatch occurring in the plate distal tip was measured. The amount of mismatch between the plate and distal humerus was assessed by measuring the distance between the center point of the EADHP distal tip and the distal humeral bone point. The distal humeral bone point was set as a perpendicular line drawn from the plate distal tip center point to the humeral bone (Fig. 4).

There have been no previous studies of EADHP anatomic fit mismatch and symptom occurrence. We defined unacceptable EADHP anatomic fit mismatch as plate protrusion ≥ 10 mm.

Statistical Analysis
Simple linear regression was performed to estimate how humeral length and humeral width predicted protrusion distance. Receiver operating characteristic curve analysis was used to determine the appropriate cutoff value for plate protrusion, and the value with the largest Youden index (J) was defined as the optimal cutoff value [15]. Statistical power was set to 0.9 and the threshold for significance was set to p ≥ 0.05. All statistical analyses and tests were performed using IBM SPSS ver. 25.0 (IBM Corp., Armonk, NY, USA).

RESULTS
Mean humeral length was 301.13 ± 23.3 mm and mean distal humeral width was 60.9 ± 5.0 mm. Mean plate protrusion distance was 9.1 ± 2.7 mm. In total, 45% (9/20) of humeri showed ≥10 mm plate protrusion. A significant linear correlation was observed between humeral length and plate protrusion (p = 0.001) and the coefficient of determination value (R²) was 0.477. The best-fit linear equation was Y = 32.85–0.08X (Fig. 5A). A significant linear correlation was also confirmed between distal humeral width and plate protrusion (p < 0.001), and the R² was 0.814 and the best-fit linear equation was Y = 38.57–0.48X (Fig. 5B).

The area under the curve for humeral length was 0.879 and for distal humeral width was 0.944. The maximal J value for humeral length was 0.707; thus, the cutoff value for humeral length to avoid ≥10 mm plate protrusion was 293.6 mm (sensitivity,

![Fig. 4](https://doi.org/10.5397/cise.2021.00227)

**Fig. 4.** The distal humeral bone point was set based on a perpendicular line drawn from the center point of the extra-articular distal humerus locking plate (EADHP) tip to the humeral bone. Plate protrusion was measured between the center point of the EADHP distal tip and the distal humeral bone point.

![Fig. 5](https://doi.org/10.5397/cise.2021.00227)

**Fig. 5.** (A) Scattergram of distal plate protrusion for humeral length: the best-fit linear equation is calculated as Y=32.85–0.08X, where Y represents the protrusion and X represents the humeral length. (B) Scattergram of distal plate protrusion for distal humeral width: the best-fit linear equation is calculated as Y=38.57–0.48X, where Y represents the protrusion and X represents the distal humeral width.
eters for humeral size in this study. Distal humeral width was decreased.

If the gap is greater than 5mm, biomechanical stability is significantly decreased by 1 mm, plate protrusion decreased by 0.48 mm. Additionally, when humeral length was < 293.6 mm or distal humeral width was < 60.5 mm, plate protrusion was at least 10 mm at the distal humerus.

Despite the tapered design of the EADHP for the distal humerus, anatomic fit mismatch frequently occurred at the distal tip of the EADHP. The EADHP was designed to allow distal fixation with five locking screws (three bicortical screws proximally on the lateral column and two unicortical screws at the end toward the capitellum and trochlea) [11]. If EADHPs are proximally fixed to avoid distal tip protrusion in small-sized humeri, mismatch at the distal tip of the plate can be reduced to some degree, but a gap between the bone and plate occurs at the lateral column where the three bicortical screws are supposed to be fixed. If the gap is greater than 5mm, biomechanical stability is significantly decreased [16]. Therefore, these mismatches should be considered in preoperative planning.

Humerus length and distal humeral width were used as parameters for humeral size in this study. Distal humeral width was the most relevant measure, and it had approximately twice the $R^2$ value of humerus length. In a previous cadaveric humeral estimation study, the $R^2$ between the distance from the olecranon fossa upper margin to the trochlear tip and humeral length was 0.47 [17]. This $R^2$ suggests that humeral length is not highly predictive of the size of the distal humeral region. Additionally, the $R^2$ between humeral length and plate protrusion as measured in this study was 0.477, which was similar to previous values observed between the distal humerus region and humeral length. Interestingly, the $R^2$ between distal humeral width and protrusion was 0.814, suggesting that distal humeral width is a better predictor of plate protrusion than humeral length.

Zhou et al. [14] reported a mismatch issue for EADHPs in the distal humerus posterolateral column and shaft in a Chinese cadaveric study. They found that 75% (33/44) of humeri were longer than 293.6 mm, which is the cutoff value for plate protrusion in this study. However, they focused on mismatch at the shaft, not at the distal tip of the EADHP. Furthermore, plate-bone mismatch due to angulation of the shaft area can be resolved through plate bending, but distal plate protrusion is difficult to resolve, so it is necessary to predict whether the patient is an EADHP candidate before surgery.

EADHP anatomic fit mismatch should be predicted preoperatively to prevent implant removal and potential iatrogenic radial nerve damage. Trikha et al. [13] reported that approximately 59.5% (22/37) of patients treated using an EADHP exhibited prominence on the elbow posterolateral side. Among them, only one patient underwent implant removal. Although implant mismatch occurred, not all patients developed skin discomfort requiring implant removal. However, in the majority of cases, the EADHP is placed beneath the radial nerve in a posterior approach to distal humeral fractures, and no matter how cautious we are, iatrogenic radial nerve palsy can occur during implant removal. Thus, when skin protrusion due to EADHP anatomic fit mismatch at the distal tip and resulting discomfort are expected, alternative treatments should be considered.

As an alternative treatment, a lower profile plate for the distal medial tibia can be employed for distal humerus fractures through the same posterior approach [18]. This locking plate does not use the posterolateral column of the distal humerus and seems to be less affected by protrusion; however, whether the biomechanical properties of the plate are comparable to conventional EADHPs should be investigated. As another alternative, a locking compression plate used for the proximal humerus was suggested via an anterolateral approach [19,20]. A previous biomechanical study showed that modified use of a proximal humeral locking plate has comparable mechanical stability com-

Fig. 6. Receiver operative characteristic curve analysis. The area under the curve for humeral length, 0.879; 90% confidence interval (CI), 0.74–1.0; p=0.004. The cutoff value was 293.6 mm for humeral length, which corresponds to a sensitivity of 88.9% and a specificity of 81.8%. The area under the curve for distal humeral width, 0.944; 90% CI, 0.86–1.0; p=0.001. The cutoff value was 60.5 mm for distal humeral width, which corresponds to a sensitivity of 100% and a specificity of 81.8%.

DISCUSSION

The purpose of this study was to investigate whether anatomic fit mismatch between EADHP and the distal humerus increases as humeral size decreases when an EADHP is used to repair a distal humeral fracture. EADHP protrusion decreased by 0.08 mm per 1-mm increase in humeral length. As distal humeral width increased by 1 mm, plate protrusion decreased by 0.48 mm. Additionally, when humeral length was < 293.6 mm or distal humeral width was < 60.5 mm, plate protrusion was at least 10 mm at the distal humerus.

Despite the tapered design of the EADHP for the distal humerus, anatomic fit mismatch frequently occurred at the distal tip of the EADHP. The EADHP was designed to allow distal fixation with five locking screws (three bicortical screws proximally on the lateral column and two unicortical screws at the end toward the capitellum and trochlea) [11]. If EADHPs are proximally fixed to avoid distal tip protrusion in small-sized humeri, mismatch at the distal tip of the plate can be reduced to some degree, but a gap between the bone and plate occurs at the lateral column where the three bicortical screws are supposed to be fixed. If the gap is greater than 5mm, biomechanical stability is significantly decreased [16]. Therefore, these mismatches should be considered in preoperative planning.

Humerus length and distal humeral width were used as parameters for humeral size in this study. Distal humeral width was the
pared to EADHP [21]. Yin et al. [22] suggested both an anterolateral approach and a lateral approach to distal humeral extra-articular fractures as alternative surgical methods. Unlike EADHP, plate irritation was not reported in the clinical outcomes of the anterolateral approach or the lateral approach.

There are several limitations to this study. First, cadaveric studies have some important differences from in vivo studies. In this cadaveric research, the soft tissue was completely removed, but soft tissue dissection is limited during in vivo surgery. Second, the definition or threshold value for EADHP anatomic fit mismatch leading to skin protrusion and related discomfort was determined arbitrarily, because research on this topic is sparse. The threshold leading to protrusion and discomfort in patients may not be consistent with this value. Third, the sample size was small.

In conclusion, anatomic fit mismatch in distal humeral fractures after EADHP fixation has a negative linear correlation with humeral length and distal humeral width. In particular, for patients whose distal humeral width is less than 60.5 mm, 10 mm or greater plate protrusion is predicted when an EADHP is applied, and an alternative implant or approach should be considered during treatment planning.

**ORCID**

Joon-Ryul Lim https://orcid.org/0000-0002-0123-7136  
Tae-Hwan Yoon https://orcid.org/0000-0002-2859-5240  
Yong-Min Chun https://orcid.org/0000-0002-8147-6136

**REFERENCES**

19. Park JH, Kim JW, Oh CH, Choi KS, Hong JY, Kim JG. PHILOS plate osteosynthesis in metaphyseal fractures of the distal hu-


Background: A midshaft clavicle fracture is a common fracture that typically responds well to open reduction and internal fixation (ORIF). However, refracture can occur after implant removal (IR). This study aimed to analyze the rate of refracture and related factors after removal of the locking compression plate (LCP) for displaced midshaft clavicle fractures.

Methods: We retrospectively reviewed the medical records of 201 patients who had undergone ORIF with LCP for midshaft clavicle fractures after IR after bony union from January 2011 to May 2018 at our institute. We evaluated basic demographic characteristics and radiographic parameters. All patients were treated with an LCP for primary fracture. The patients were divided into two groups: a refracture group that experienced a second fracture within 1 year after IR and a no-fracture group.

Results: There were four cases (1.99%) of refracture; three were treated conservatively, while one was treated surgically. All patients achieved bony union. The average interval between refracture and IR was 64 days (range, 6–210 days). There was a significant difference in classification of fractures (AO Foundation/Orthopaedic Trauma Association [AO/OTA] classification) between the two groups. However, other patient demographics and radiographic measurements between refracture and IR, such as bone diameter, showed no significant difference between the two groups.

Conclusions: This study showed that one in 50 patients suffered from refracture after removal of the LCP. Thus, if patients desire IR, the surgeon should explain that there is a relatively higher possibility of refracture for cases with simple or segmental fractures than for other types of fracture.

Keywords: Clavicle; Shaft; Locking compression plate; Removal; Refracture

INTRODUCTION

Clavicle fracture is a common injury, with an incidence ranging from 29–54 per 100,000; it generally occurs in younger, active individuals [1,2]. The peak age of clavicle fracture is between 32 and 34 years [3]. Midshaft fractures account for about 80% of clavicle fractures, and non-surgical treatments have been recommended in the past. However, the non-surgical treatments de-
scribed by Neer [4] and Rowe [5] in the 1960s have been demonstrated to be clinically and radiologically inferior for displaced midshaft clavicle fractures to surgical treatments like open reduction and internal fixation (ORIF), which show excellent results [6-8]. Commonly used ORIF techniques for midshaft clavicle fractures are plate fixation and intramedullary (IM) nail fixation [1,8-10].

Since the frequency of ORIF increases with clavicle fracture, some studies have reported the issue of implant removal (IR) [11-13]. In some cases, IR is inevitable due to infection, nonunion, or implant breakage. However, in most cases, the decision for IR is based on patient needs or surgeon preference, and the reasons are minor, such as implant-related irritation, discomfort, pain, or limited range of motion. Among these, the most common cause of IR is implant-related irritation due to multifactorial causes, including anatomical location characteristics of the fracture, pain sensitivity, bone quality, surgeon experience, and type of implant used [6,12,14]. The rates of irritation range from 9% to 44% after plate fixation and from 9% to 62% after IM nailing [6,8,15].

A recent prospective study has reported that patients with this kind of discomfort show improved functional outcomes and decreased irritation after IR [16]. However, there is a risk of refracture after IR in patients with midshaft clavicle fracture. The incidence of refracture after IR ranges from 1% to 7.5% [9,10,13,17]. The purpose of this study was to identify the incidence rate and other factors related to refracture after locking compression plate (LCP) removal for midshaft clavicle fracture after bony union. The results of this study might help surgeons make decisions about IR and prevent refractures.

METHODS

This study was a retrospective, single-center clinical case series approved by the Institutional Review Board of Uijeongbu St. Mary’s Hospital (IRB No. UC21RASI0002). Data were collected from January 2011 to May 2018. We reviewed the medical records of patients who had undergone ORIF with LCP (Synthes, Oberdorf, Switzerland) for midshaft clavicle fracture and an IR procedure after bony union. A simple radiographic examination confirmed union of the fracture. IR was performed upon patient request. Patients who underwent IR for other reasons, such as infection, nonunion, implant loosening, and periprosthetic fracture, were excluded. As no such patients were noted in the present study, none were excluded, and 201 patients were enrolled. The patients were divided into two groups based on refracture after IR surgery: a refracture group (n = 4) of patients diagnosed with refracture at the original site within 1 year after IR and a no-fracture group (n = 197) of patients who did not show refracture after IR.

Variables were collected by retrospectively reviewing the medical records of all patients enrolled in this study. Data included age, sex, height, body weight, body mass index (BMI), smoking status, interval between initial plate fixation and removal, and characteristics of the refraction. Clavicle anteroposterior (AP) and axial X-rays obtained from the initial fractures until the final follow-up were used for serial radiographic assessments. Bony union of the previous fracture site was confirmed by plain radiographs. The criteria for bony union were as follows: (1) bridging callus formation or complete obliteration of the gap between fracture fragments on AP and axial views, (2) no further migration of implants and no displacement of fracture fragments, and (3) no pain. IR was carried out as follows. Under general anesthesia, the superior approach to the clavicle was used in all cases. Patients were allowed unlimited daily activities from the first day after IR. However, sports activities and lifting of heavy objects were prohibited until 6 weeks postoperatively. The surgery was performed by one orthopedic shoulder surgeon (CGK). Immediate IR postoperative radiography was reviewed to measure clavicle length and diameter at the fracture site. Clavicle length was defined as the length of the virtual line connecting the midpoints of the two ends. Clavicle diameter was measured at the thinnest part of the fracture site. In addition, callus formation at the fracture site was evaluated.

Statistical Analysis

The baseline characteristics of patients are presented as mean and range or number and percentage. Continuous variables are shown as mean ± standard deviation (range). Categorical variables are presented as number and percentage. To compare characteristics between groups, a Mann-Whitney U-test was used for continuous variables, and a Fisher’s exact test was used for categorical variables. Logistic regression analysis was not carried out because there were only four cases of refracture in this case series. The p-values <0.05 were considered significant. All statistical analyses were performed using the SPSS ver. 14.0 (SPSS Inc., Chicago, IL, USA).

RESULTS

The patient demographics are shown in Table 1. The mean age at IR was 37.8 ± 15.5 years (range, 14–67 years). There were 176 males (87.6%) and 25 females (13.4%). The mean time interval between plate fixation and removal was 14.2 ± 7.3 months (range,
The mean height, weight, and BMI were 169.7 ± 7.6 cm (range, 146–188 cm), 69.5 ± 12.0 kg (range, 37–115 kg), and 24.0 ± 3.3 kg/m$^2$ (range, 13.4–36.7 kg/m$^2$), respectively. The mean age was 38.0 ± 15.5 years (range, 12–67 years) for the no-fracture group and 27.8 ± 15.0 years (range, 17–50 years) for the refracture group (p = 0.194). The refracture group included more women than the no-fracture group (25% vs. 12.2%). The mean time interval between fixation and removal was 14.3 ± 7.3 months (range, 6–66 months) for the no-fracture group and 10.1 ± 2.3 months (range, 7–12 months) for the refracture group (p = 0.261). The mean height, weight, and BMI for the no-fracture group and the refracture group were 169.6 ± 7.6 cm (range, 146–188 cm) and 171.8 ± 2.1 cm (range, 169–174 cm) (p = 0.577), 69.5 ± 11.9 kg (range, 37–115 kg) and 65.8 ± 14.7 kg (range, 46–80 kg) (p = 0.532), and 24.1 ± 3.3 kg/m$^2$ (range, 13.4–36.7 kg/m$^2$) and 22.2 ± 4.8 kg/m$^2$ (range, 16.1–27.0 kg/m$^2$) (p = 0.269), respectively. Age, sex, interval between fixation and removal, height, weight, BMI, and smoking status were not significantly different between the two groups (Table 1).

The rate of refracture was 1.99% (n = 4). The characteristics of patients in the refracture group are shown in Table 2 and Figs. 1-4. These patients demonstrated a wide range of traumatic injuries after IR. Three had trauma history and developed abrupt onset pain and refracture after lifting a heavy object (patient 1) (Fig. 1), falling while playing soccer (patient 2) (Fig. 2), or rising from the floor using the hand (patient 4) (Fig. 4). One of these participants (patient 3) (Fig. 3) had suffered gradual pain for the week before presenting without trauma and being diagnosed with a refracture. One patient (patient 3) experienced a refracture at the previous site, while the others had refractures at the empty screw hole. Three patients were treated conservatively with an arm sling. All of them achieved solid bony union by the last follow-up visit. In one patient, the refracture was displaced, and the patient (patient 4) wanted rapid recovery. As a result, re-fixation surgery was performed with an LCP, and bony union was achieved. Repeat removal surgery was performed at 1 year after re-fixation. There has been no refracture after the second IR.

Radiographic measurements, operative procedures, and fracture classifications are shown in Table 3. The mean clavicular length was 160.0 ± 11.2 mm for the no-fracture group and 158.0 ± 7.4 mm for the refracture group (p = 0.853). The mean bone diameter was 12.4 ± 2.1 mm for the no-fracture group and

### Table 1. Demography of the patients

<table>
<thead>
<tr>
<th>Variable</th>
<th>Total (n = 201)</th>
<th>No fracture (n = 197)</th>
<th>Refracture (n = 4)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>37.8 ± 15.5</td>
<td>38.0 ± 15.5</td>
<td>27.8 ± 15.0</td>
<td>0.194</td>
</tr>
<tr>
<td>Sex (male:female)</td>
<td>176:25</td>
<td>173:24</td>
<td>3:1</td>
<td>0.415</td>
</tr>
<tr>
<td>Interval* (mo)</td>
<td>14.2 ± 7.3</td>
<td>14.3 ± 7.3</td>
<td>10.1 ± 2.3</td>
<td>0.261</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>169.7 ± 7.6</td>
<td>169.6 ± 7.6</td>
<td>171.8 ± 2.1</td>
<td>0.577</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>69.5 ± 12.0</td>
<td>69.5 ± 11.9</td>
<td>65.8 ± 14.7</td>
<td>0.532</td>
</tr>
<tr>
<td>Body mass index (kg/m²)</td>
<td>24.0 ± 3.3</td>
<td>24.1 ± 3.3</td>
<td>22.2 ± 4.8</td>
<td>0.269</td>
</tr>
<tr>
<td>Smoking</td>
<td>131</td>
<td>128</td>
<td>3</td>
<td>0.566</td>
</tr>
<tr>
<td>No</td>
<td>70</td>
<td>69</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Values are presented as mean ± standard deviation. *Duration between initial operation and removal operation.

### Table 2. Series of four patients in refracture group

<table>
<thead>
<tr>
<th>Patient no.</th>
<th>Sex</th>
<th>Age at refracture (yr)</th>
<th>AO/OTA classification</th>
<th>Interval fixation to IR (mo)</th>
<th>Refracture time after IR (day)</th>
<th>Mechanism of injury (refracture)</th>
<th>Refracture site</th>
<th>Refracture treatment</th>
<th>After refracture follow-up (mo)</th>
<th>Final follow-up result</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>M</td>
<td>50</td>
<td>C2</td>
<td>12</td>
<td>11</td>
<td>Heavy object lifting</td>
<td>Screw hole</td>
<td>Conservative</td>
<td>67</td>
<td>Bone union</td>
</tr>
<tr>
<td>2</td>
<td>M</td>
<td>17</td>
<td>A2</td>
<td>7</td>
<td>210</td>
<td>Fall down in soccer</td>
<td>Screw hole</td>
<td>Conservative</td>
<td>2</td>
<td>Bone union</td>
</tr>
<tr>
<td>3</td>
<td>F</td>
<td>22</td>
<td>A2</td>
<td>10</td>
<td>29</td>
<td>None</td>
<td>Previous fracture site</td>
<td>Screw hole</td>
<td>Conservative</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>M</td>
<td>22</td>
<td>A3</td>
<td>11.5</td>
<td>6</td>
<td>Get up with hand on the floor</td>
<td>Screw hole</td>
<td>ORIF</td>
<td>22</td>
<td>Bone union</td>
</tr>
</tbody>
</table>

11.2 ± 2.2 mm in the refracture group (p = 0.229). These differences were not statistically significant. Wires were used in 132 patients (65.7%), and interfragmentary screws were used in 40 patients (20%). The frequency rates for use of wire or interfragmentary screws and the presence of callus were not significantly different between the two groups. All patients underwent initial fracture surgery using LCP. After analyzing the two groups based on fracture classification, the most common fracture pattern was AO Foundation/Orthopaedic Trauma Association (AO/OTA) 15.2B (wedge fracture: n = 141, 70.1%). There were no patients in

![Fig. 1. Imaging of patient 1. X-rays of preoperative (A), three-dimensional computed tomography (B), primary fracture postoperative (C), implant removal (D), refracture at the screw hole (white arrow) (E), refracture fixation postoperative and refracture union (yellow arrow) at the last follow-up (F).](https://doi.org/10.5397/cise.2021.00059)

![Fig. 2. Imaging of patient 2. X-rays of preoperative (A), three-dimensional computed tomography (B), primary fracture postoperative (C), implant removal (D), refracture at the screw hole (white arrow) (E), refracture fixation postoperative and refracture union (yellow arrow) at the last follow-up (F).](https://doi.org/10.5397/cise.2021.00059)
the refracture group with AO type B fracture (three type A fractures and one type C fracture). The difference between the two groups was statistically significant (p = 0.005).

**DISCUSSION**

This study aimed to analyze the rate of refracture after LCP re-
moval for midshaft clavicle fracture following bony union. The overall refracture rate was 1.99% (4/201) in this study. Only one factor, AO/OTA fracture classification, had a statistically significant difference between the refracture group and the no-fracture group. A previous study [13] reported an overall refracture rate of 7.2%, with female and lower BMI as risk factors for refracture. However, we did not identify differences in these factors between the two groups in this study. According to our analysis, patient demographics were similar in these two groups. The main differences between the present study and the previous were number of included participants (201 in the present study vs. 278 in the previous) and surgical techniques (for example, plate type and requirement for wire or interfragmentary screws) used in the initial surgery. Due to our small number of patients and very low rate of refracture (1.99%), we could not analyze the risk factors statistically (logistic regression analysis). Further studies are needed to determine whether differences in rate of refractures might have been caused by factors other than those mentioned above.

In this study, the only difference between the two groups was classification of the initial fracture. Fractures were classified using the AO/OTA classification, of which the wedge type fracture (B type) was most common. However, no patient in the refracture group had this fracture type but showed one segmental fracture (C2 fracture, in patient 2) and three simple fractures (two A2 and one A1 fractures). In patient 2, a relatively severe trauma occurred 210 days after IR. We hesitated to include this case in the present study, but it was included after confirming that the area of refracture was the previous screw hole. Wedge-type fractures have a separate fragment and required additional wiring or interfragmentary screw fixation was required in 87.9% of patients in this study. As a result, it was estimated that the broad fracture area would have been newly healed at the wedge or fragment location. In the case of a simple or segmental fracture, we anticipated that the fracture sites might be narrow or vertical and vulnerable to impacts or shear forces if complete union was not achieved. For this reason, we concluded that the two groups differed in classification of fractures.

Patients who underwent IR surgery in this study had various reasons for requesting IR. This surgery was performed if a simple X-ray confirmed bony union. As in general cases, this procedure was performed around 1 year after the initial fracture surgery depending on patient circumstances. In one patient (patient 3) with refracture at the fracture site and who had experienced no minor trauma, X-rays after removal surgery showed complete bony union. However, refracture occurred 10 months after IR. Although a simple radiographic examination indicated that the fracture site was healed, IR might have been performed before complete bony union. In addition, the strength of the bony union might not have been sufficiently determined using simple radiography.

The average removal interval in the refracture group was shorter than in the no-fracture group, although the difference was not significant. Therefore, it cannot be recommended to remove the plate before the fracture site is completely healed. Patients need sufficient attention and postoperative care if removal

<table>
<thead>
<tr>
<th>Variable</th>
<th>Total (n = 201)</th>
<th>No fracture (n = 197)</th>
<th>Refracture (n = 4)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length (mm)</td>
<td>157.0 ± 11.1</td>
<td>160.0 ± 11.2</td>
<td>158.0 ± 7.4</td>
<td>0.853</td>
</tr>
<tr>
<td>Diameter (mm)</td>
<td>12.4 ± 2.1</td>
<td>12.4 ± 2.1</td>
<td>11.2 ± 2.2</td>
<td>0.229</td>
</tr>
<tr>
<td>Callus</td>
<td></td>
<td></td>
<td></td>
<td>0.299</td>
</tr>
<tr>
<td>None</td>
<td>149</td>
<td>145</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Callus</td>
<td>52</td>
<td>52</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Wire</td>
<td></td>
<td></td>
<td></td>
<td>0.425</td>
</tr>
<tr>
<td>None</td>
<td>69</td>
<td>67</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Wiring</td>
<td>132</td>
<td>130</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Interfragmentary screw</td>
<td></td>
<td></td>
<td></td>
<td>0.409</td>
</tr>
<tr>
<td>None</td>
<td>161</td>
<td>157</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Fixation</td>
<td>40</td>
<td>40</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>AO/OTA classification type</td>
<td></td>
<td></td>
<td></td>
<td>0.005*</td>
</tr>
<tr>
<td>A</td>
<td>55</td>
<td>52</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>141</td>
<td>141</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>5</td>
<td>4</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

Values are presented as mean±standard deviation. AO/OTA: AO Foundation/Orthopaedic Trauma Association. *Statistically significant.

https://doi.org/10.5397/cise.2021.00059
surgery is scheduled within 1 year of the initial fracture surgery. One study [18] reported that upper extremity fracture IR should be performed no less than 18 months after the primary surgery. Our study showed that average removal time was shorter in the refracture group, although this difference was not significant. Thus, if removal time is delayed for more than 1 year, the possibility of refracture or characteristics after IR could be different. Further studies will be needed to confirm our findings.

In this study, three patients with refracture obtained bony union with conservative treatments. One patient underwent surgical treatment with an autologous iliac bone graft due to displacement of the refracture site, with repeat removal surgery performed at one 1 year after revision surgery. No refracture occurred after the second removal surgery. In patients who developed refracture, bony union had been confirmed before IR. Therefore, we thought that the refracture site might have had biological potential for bone healing, as in treatment of primary midshaft clavicle fractures. Thus, the degree of displacement should be used to decide whether to perform revision surgery. In this type of revision, there is no clear guideline for bone grafting. Fixation alone without a bone graft could result in bony union of the fracture. However, bone grafting should be considered as a procedure that allows definite bony union. One patient (patient 4) in this study underwent an autogenous iliac bone graft during refixation surgery. Further study is needed to determine whether bone graft is required for all refractures of the midshaft clavicle after IR.

This study had several weaknesses. First, the reason for the IR procedure was not studied, though the most common reason for reoperation after mid-clavicle shaft fracture was isolated IR. According to a recent systematic review, 0%–53% of all clavicle ORIF plates are removed eventually [7]. In the present study, 51.8% of patients who underwent primary clavicle fracture procedure underwent IR during the same period. The reasons for the IR were not investigated in this study, although no IR was due to major complications such as infection, nonunion, metallic failure, or loosening. Second, radiographic parameters were evaluated using only simple X-rays. Since the shape of the clavicle is not perfectly cylindrical on plain radiographs, more accurate thickness measurements would have been possible if additional computed tomographic tests had been conducted. Finally, the number of patients included in the study was small. Refracture was not a common complication, occurring in only 1.99% of all patients. Four refracture cases were not enough to statistically analyze the risk factors. Therefore, further studies with more participants and other statistical methods are needed to reduce the chance of bias, increase statistical confidence, and analyze the characteristics of refractures following midshaft clavicle fracture after bony union.

This study showed that one in 50 patients suffered refracture after removal of LCP following ORIF of midshaft clavicle fracture. Before performing IR, surgeons should explain the relatively higher possibility of refracture in cases with simple or segmental fracture than in those with other types of fractures.

**REFERENCES**

Clinical outcome in patients with hand lesions associated with complex regional pain syndrome after arthroscopic rotator cuff repair

Takaki Imai\textsuperscript{1}, Masafumi Gotoh\textsuperscript{2}, Keiji Fukuda\textsuperscript{3}, Misa Ogino\textsuperscript{3}, Hidehiro Nakamura\textsuperscript{2}, Hiroki Ohzono\textsuperscript{4}, Naoto Shiba\textsuperscript{4}, Takahiro Okawa\textsuperscript{2}

\textsuperscript{1}Department of Rehabilitation, Kyushu University of Nursing and Social Welfare, Kumamoto, Japan
\textsuperscript{2}Department of Orthopedic Surgery, Kurume University Medical Center, Fukuoka, Japan
\textsuperscript{3}Department of Orthopedic Surgery, Keishinkai Hospital, Saga, Japan
\textsuperscript{4}Department of Orthopedic Surgery, Kurume University, Kurume, Japan

Background: Complex regional pain syndrome (CRPS)-related hand lesions are one of the complications following arthroscopic rotator cuff repair (ARCR). This study aimed to investigate the clinical outcomes of patients with CRPS-related hand lesions following ARCR.

Methods: Altogether, 103 patients with ARCR were included in this study (mean age, 63.6±8.2 years; 66 males and 37 females; follow-up period, preoperative to 12 months postoperative). Clinical assessment included the Japanese Orthopaedic Association (JOA) score, University of California, Los Angeles (UCLA) score, Constant score, 36-item short form health survey (SF-36) score, and Quick Disabilities of the Arm, Shoulder, and Hand (QuickDASH) score from preoperative to 12 months postoperatively. The patients were either assigned to the CRPS group or non-CRPS group depending on CRPS diagnosis until the final follow-up, and clinical outcomes were then compared between the groups.

Results: Of 103 patients, 20 (19.4%) had CRPS-related hand lesions that developed entirely within 2 months postoperatively. Both groups showed significant improvement in JOA, UCLA, and Constant scores preoperatively to 12 months postoperatively (p<0.001). Comparisons between the two groups were not significantly different, except for SF-36 “general health perception” (p<0.05) at 12 months postoperatively. At final follow-up, three patients had residual CRPS-related hand lesions with limited range of motion and finger edema.

Conclusions: CRPS-related hand lesions developed in 19.4% of patients following ARCR. Shoulder or upper-limb function improved in most cases at 12 months, with satisfactory SF-36 patient-based evaluation results. Patients with residual CRPS-related hand lesions at the last follow-up require long-term follow-up.

Keywords: Shoulder; Rotator cuff injuries; Complex regional pain syndrome; Treatment outcome

INTRODUCTION

Rotator cuff tears commonly develop in middle-aged and elderly individuals [1]. Arthroscopic rotator cuff repair (ARCR) is a treatment option for patients with cuff tears [2,3] and is comparable in clinical outcome to open repair [4,5]. Additionally, the
risk of postoperative complications is low due to decreased incisions in the skin and soft tissues [6]. However, vascular and neurologic injury, fluid extravasation, stiffness, and iatrogenic tendon injury may develop postoperatively [6,7].

Complex regional pain syndrome (CRPS) has various etiologic factors, including minor traumas, fractures, sprains, immobilization, and surgical interventions [8,9]. CRPS-related hand lesions are also a complication after ARCR, leading to atrophic changes, range of motion (ROM) limitation, hyperalgesia, paridrosis, and edema [10,11]. The incidence of CRPS-related hand lesions after ARCR is 11.0%–24.4% in the Japanese literature, which typically develops within 3 months postoperatively [12-16]. The reported incidence rate of CRPS varies according to the diagnostic criteria used, with an incidence rate of 24.2% based on the Ministry of Health, Labour and Welfare CRPS study team in the Japan (MHLWJ) evaluation system for “clinical purposes,” 11% in the MHLWJ evaluation system for “research purposes,” 6% in the International Association for the Study of Pain (IASP) 2005 for “clinical purposes,” and 0.5% in the IASP 2005 for “research purposes” [11].

It has been reported in Japanese literature that CRPS-related hand lesions do not affect postoperative outcomes after ARCR [13,14]; however, a few English studies have been evaluated regarding these outcomes. Therefore, the present study aimed to investigate the clinical outcomes of patients with CRPS-related hand lesions after ARCR in a retrospective manner. We hypothesized that upper extremity function, including the shoulder joint, would not be affected by CRPS-related hand lesions after ARCR.

METHODS

The Institutional Review Board of Kurume University approved the study protocol, and all subjects provided informed consent for participation.

Subjects

Between January 2014 and September 2017, 276 patients underwent ARCR for a rotator cuff tear at our institution. Of these, 158 patients were transferred to our hospital in the early postoperative period (within 3 weeks) for postoperative rehabilitation. The inclusion criteria were (1) individuals who had ARCR, (2) individuals who underwent a postoperative rehabilitation program and were available for follow-up for at least 1 year postoperatively, and (3) individuals who had rigorous imaging evaluation with magnetic resonance imaging (MRI). The exclusion criteria were (1) individuals with periarticular fracture, (2) individuals with progressive arthritis, (3) individuals with osteoarthritis, (4) individuals with infection, (5) individuals with reoperation, and (6) individuals who had preoperative hand lesions such as ROM restriction or edema. Finally, 103 patients (66 males and 37 females; mean age, 63.6 ± 8.2 years; mean period from onset to surgery, 10.4 ± 11.6 months) were included in this study (Table 1). Patient clinical scores and MRI images were extracted retrospectively from the medical records and imaging data.

Surgical Procedure

ARCR was considered for patients who did not respond to non-operative treatment for ≥3 months, which included the administration of anti-inflammatory medication, subacromial/glenohumeral injections of corticosteroids or hyaluronic acid, and rehabilitation with a focus on physical therapy. ARCR was performed with the patient in the beach chair position under general anesthesia. The torn cuff was repaired using a single-row (one row of anchors placed on the lateral aspect of the footprint and the torn cuff fixed with interrupted sutures) or suture bridge (one row of anchors placed on the medial aspect of the footprint with or without tying and the torn cuff fixed with a transosseous knotless anchor on the lateral aspect of the footprint) method. Acromioplasty was performed in all patients, and capsular release and biceps tendon procedures (tenotomy/tenodesis) were performed as needed.

Postoperative Regimen

Postoperatively, patients were immobilized in a sling for 6 weeks using an abduction pillow and were instructed to maintain the shoulder at neutral rotation and 20° of abduction. Passive ROM exercises for the scapulothoracic, elbow, wrist, and finger joints were initiated immediately after surgery. Passive ROM of the glenohumeral joint was initiated 4 days postoperatively in small/medium tears and 4 weeks postoperatively in large/massive tears. Active ROM exercise was permitted at 6 weeks postoperatively. At 8 weeks, isometric muscle strengthening exercises were introduced and at 12 weeks, isotonic muscle strengthening exercises were allowed.

Diagnosis of CRPS

The present study used the criteria suggested by the MHLWJ [8]. The hand was evaluated for five items (trophic changes, motor dysfunctions, abnormal sensory processing, asymmetric sudomotor activity, and asymmetric edema), and any applicable items were scored as 1 point, which were converted to a CRPS score of 0–5 points. For example, limited finger ROM was assigned 1 point for the motor dysfunctions item. CRPS was determined when at least two corresponding items were met subjectively and
A well-trained orthopedist blinded to the study diagnosed CRPS using these criteria. CRPS was assessed weekly from the immediate postoperative period until 12 weeks postoperatively and then at 3, 6, 9, and 12 months postoperatively.

Neurotropin (Nippon Zoki Pharmaceutical Co., Osaka, Japan) was administered orally to patients diagnosed with CRPS according to the CRPS criteria. If necessary, tramadol or pregabalin or both tramadol and pregabalin were added. Stellate ganglion block and vortex flow baths with laser beams were routinely applied. Patients with persistent symptoms were referred to an anesthesiologist who specializes in nerve blocks.

Outcome Measures
Patient information, including age, sex, and disease duration, was collected preoperatively. Japanese Orthopaedic Association (JOA) score (total score of 100 points, scored for items like pain, function, ROM, radiographic findings, and joint stability), University of California, Los Angeles (UCLA) score, Constant score, 36-item short form health survey (SF-36) score, and Quick Disabilities of the Arm, Shoulder, and Hand (QuickDASH) score were evaluated preoperatively and at 12 months postoperatively. Clinical outcomes of the study were assessed by three physiotherapists with more than 10 years of experience.

The integrity of the rotator cuff was determined using MRI at 12 months postoperatively. Fatty degeneration was assessed using the Goutallier classification (supraspinatus, infraspinatus, and subscapularis) on preoperative MRI “Y view” [16], and the global fatty degeneration index [17] was then calculated. The MRI data were evaluated by a radiologist familiar with orthopedic diseases.

Statistical Analysis
JMP 13 (SAS Institute Inc., Cary, NC, USA) was the software program used for statistical analysis. The Wilcoxon rank-sum test was used for continuous data, and the chi-square test was used for categorical data.

### Table 1. Patient demographics

<table>
<thead>
<tr>
<th>Variable</th>
<th>Total (n = 103)</th>
<th>CRPS (n = 20)</th>
<th>Non-CRPS (n = 83)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demographic variable</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age (yr)</td>
<td>63.6 ± 8.2</td>
<td>64.9 ± 7.5</td>
<td>63.3 ± 8.4</td>
<td>0.43†</td>
</tr>
<tr>
<td>Sex (male:female)</td>
<td>66:37</td>
<td>16:4</td>
<td>50:33</td>
<td>0.10</td>
</tr>
<tr>
<td>Diabetes</td>
<td>12 (11.7)</td>
<td>1 (5.0)</td>
<td>11 (13.3)</td>
<td>0.30</td>
</tr>
<tr>
<td>Dominant-side surgery</td>
<td>64 (62.1)</td>
<td>16 (80.0)</td>
<td>48 (57.8)</td>
<td>0.07‡</td>
</tr>
<tr>
<td>Traumatic onset</td>
<td>48 (46.6)</td>
<td>11 (55.0)</td>
<td>37 (44.6)</td>
<td>0.43‡</td>
</tr>
<tr>
<td>Symptom duration (mo)</td>
<td>10.4 ± 11.6</td>
<td>10.3 ± 11.0</td>
<td>10.4 ± 11.8</td>
<td>0.84†</td>
</tr>
<tr>
<td>Workers’ compensation</td>
<td>14 (13.6)</td>
<td>2 (10.0)</td>
<td>12 (14.5)</td>
<td>0.60‡</td>
</tr>
<tr>
<td>Structural variable</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tear size (cm)</td>
<td>2.6 ± 1.2</td>
<td>2.8 ± 1.2</td>
<td>2.5 ± 1.2</td>
<td>0.25†</td>
</tr>
<tr>
<td>Tear size classification</td>
<td></td>
<td></td>
<td></td>
<td>0.67‡</td>
</tr>
<tr>
<td>Small</td>
<td>17</td>
<td>2</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td>40</td>
<td>7</td>
<td>33</td>
<td></td>
</tr>
<tr>
<td>Large</td>
<td>40</td>
<td>10</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Massive</td>
<td>6</td>
<td>1</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Preoperative global fatty degeneration index</td>
<td>1.2 ± 0.6</td>
<td>1.1 ± 0.7</td>
<td>1.2 ± 0.6</td>
<td>0.48†</td>
</tr>
<tr>
<td>Retear at 12 months</td>
<td>14 (13.6)</td>
<td>4 (20.0)</td>
<td>10 (12.0)</td>
<td>0.40‡</td>
</tr>
<tr>
<td>Intraoperative variable</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Repair technique</td>
<td></td>
<td></td>
<td></td>
<td>0.77‡</td>
</tr>
<tr>
<td>Suture bridge</td>
<td>99</td>
<td>19</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>Single row</td>
<td>4</td>
<td>1</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Capsular release</td>
<td>24 (23.3)</td>
<td>6 (30.0)</td>
<td>18 (21.7)</td>
<td>0.33‡</td>
</tr>
<tr>
<td>Manipulation</td>
<td>17 (16.5)</td>
<td>6 (30.0)</td>
<td>11 (13.3)</td>
<td>0.07‡</td>
</tr>
<tr>
<td>Contracture*</td>
<td>24 (23.3)</td>
<td>7 (35.0)</td>
<td>17 (20.5)</td>
<td>0.18‡</td>
</tr>
<tr>
<td>Treatment of long head of biceps tendon</td>
<td></td>
<td></td>
<td></td>
<td>0.48‡</td>
</tr>
<tr>
<td>Untreated</td>
<td>27 (26.2)</td>
<td>4 (20.0)</td>
<td>23 (27.7)</td>
<td></td>
</tr>
<tr>
<td>Treated</td>
<td>25 (24.3)</td>
<td>16 (80.0)</td>
<td>60 (72.3)</td>
<td></td>
</tr>
</tbody>
</table>

Values are presented as mean±standard deviation or number (%).
CRPS: complex regional pain syndrome.
*Contracture was judged by manipulation or capsular release; †Continuous data: Wilcoxon rank sum test; ‡Categorical data: chi-square test.
test was used for continuous data such as age and clinical outcomes, and the chi-square test was used for categorical data such as sex and retear rate, to compare basic characteristics between the two groups. The Friedman test was used to compare the variance between CRPS scores from onset to 1 year postoperatively in the CRPS group. The Steel-Dwass test was used for multiple comparisons of CRPS scores. The significance level was set at <5%.

RESULTS

Of 103 patients, 20 (19.4%) had CRPS-related hand lesions that developed entirely within 2 months postoperatively (mean 19.6 ± 19.6 days after surgery). Consequently, patients were divided into two groups: 83 patients in the non-CRPS group and 20 patients in the CRPS group. The CRPS score of the CRPS group was 2.4 ± 0.5 points at the onset of CRPS (range, 1–8 weeks), 2.05 ± 0.67 points at 8 weeks postoperatively, 2.05 ± 0.76 points at 9 weeks postoperatively, 1.95 ± 0.83 points at 10 weeks postoperatively, 1.9 ± 0.85 points at 11 weeks postoperatively, 1.8 ± 0.89 points at 12 weeks postoperatively, 0.95 ± 1.0 points at 6 months postoperatively, 0.5 ± 0.76 points at 9 months postoperatively, and 0.4 ± 0.75 points at 12 months postoperatively. There was a significant improvement at 6 months postoperatively compared to the onset of CRPS (p < 0.001) (Fig. 1). Symptoms at the onset of CRPS-related hand lesions included motor dysfunction of the fingers (100%), edema (95%), abnormal sensory processing (30%), asymmetric sudomotor activity (15%), and trophic changes (0%).

The JOA scores (CRPS and non-CRPS group) were 65.3 ± 12.4 and 69.1 ± 12.5 preoperatively and 87.3 ± 7.1 and 88.0 ± 9.4 at 12 months postoperatively, and both groups showed significant improvement at 12 months postoperatively compared with that observed preoperatively (p < 0.001, respectively), but there was no significant difference between the two groups preoperatively and postoperatively (Fig. 2A). The UCLA scores (CRPS and non-CRPS group) were 15.6 ± 5.1 and 15.8 ± 4.9 preoperatively and 27.4 ± 5.4 and 29.2 ± 5.8 at 12 months postoperatively, and both groups showed significant improvement at 12 months postoperatively compared with that observed preoperatively (p < 0.001), but there was no significant difference between the two groups preoperatively and postoperatively (Fig. 2B). The Constant scores (CRPS and non-CRPS group) were 47.8 ± 17.8 and 52.6 ± 16.2 preoperatively and 79.6 ± 12.9 and 80.0 ± 14.9 at 12 months postoperatively, and both groups showed significant improvement at 12 months postoperatively compared with that preoperatively (p < 0.001), but there was no significant difference between the two groups preoperatively and postoperatively (Fig. 2C).

In the SF-36 scores, there were no significant differences between the two groups, except for “general health perceptions” at

Fig. 1. Change in complex regional pain syndrome (CRPS) score from the onset of CRPS-related hand lesions to 12 months after surgery. *P<0.001.

Fig. 2. Comparison of shoulder scores. (A) Japanese Orthopaedic Association score, (B) University of California at Los Angeles score, (C) Constant score. There were no statistically significant differences between the complex regional pain syndrome (CRPS) and non-CRPS groups in clinical shoulder scores before and at 12 months after surgery: NS: not significant.
The clinical scores of these three patients were relatively low compared with those of other groups (17 patients in the CRPS group and 83 patients in the non-CRPS group) (Table 4).

**DISCUSSION**

Complications associated with ARCR, including loose hardware, failure of repair, traction in the lateral position, direct injury, compression secondary to fluid extravasation, tourniquet-like problems associated with wrapping the operative extremity, and postoperative stiffness have been reported [6]. CRPS-related hand lesions also develop after ARCR although there has been a paucity of English literature that has focused on this complication. In several Japanese reports, CRPS incidence was reported to be 21.7%, 11.8%, and 16.2% [14,18,19] according to the MHLWJ criteria. Thus, CRPS-related hand lesions develop mainly on the surgical side within 3 months postoperatively, and similar results were observed in this study. However, it has been reported that the development of hand lesions related to CRPS may be triggered by exacerbation of shoulder pain due to orthotic removal [14,15]. In this study, the abduction brace was removed at 6 weeks postoperatively, but the timing of brace removal may be affected.

Previous Japanese studies have shown that CRPS-related hand lesions do not affect shoulder function after ARCR [13-15]. Kobayashi et al. [15] compared the JOA scores at 1 year postoperatively in the early-onset group with those in the late-onset group and non-CRPS group. As a result, the period from onset did not affect the clinical outcome of patients in these groups. Kiba et al. [18] compared the JOA scores at 6 months postoperatively in the presence or absence of symptoms. In their study, CRPS-related hand lesions had no effect on the clinical outcomes; however, these studies focused only on shoulder function and not on the whole upper-limb function. The present study evaluated both functions and found that coexisting CRPS-related hand lesions have less effect on whole upper-limb function, including shoulder function.

Generally, CRPS develops as a hand lesion on the operative side following ARCR [9-15,18,19]. Kobayashi et al. [14] found that all symptoms improved in an average of 7 months following ARCR. In a study by Kiba et al. [18], CRPS-related hand lesions improved in 80% of the cases by 6 months postoperatively, but this symptom was persistent in a case with high CRPS score of ≥3 points at onset. In the present study, CRPS-related hand lesions improved in 75% of cases at 6 months and in 85% of cases at 9 months postoperatively; however, three patients with a CRPS score ≥3 points still had residual ROM restriction of the fingers and/or extensive edema on the dorsal side at 12 months postoperatively.
Table 4. Clinical scores for patients with CRPS-unimproved, CRPS-improved, and non-CRPS groups

<table>
<thead>
<tr>
<th>Variable</th>
<th>Unimproved (n = 3)</th>
<th>Improved (n = 17)</th>
<th>Non-CRPS (n = 83)</th>
</tr>
</thead>
<tbody>
<tr>
<td>JOA score</td>
<td>Preop</td>
<td>Postop 12 mo</td>
<td></td>
</tr>
<tr>
<td></td>
<td>56.8 ± 10.8</td>
<td>66.7 ± 12.3</td>
<td>69.1 ± 12.5</td>
</tr>
<tr>
<td>UCLA score</td>
<td>Preop</td>
<td>Postop 12 mo</td>
<td></td>
</tr>
<tr>
<td></td>
<td>16.0 ± 4.6</td>
<td>15.5 ± 5.3</td>
<td>15.8 ± 4.9</td>
</tr>
<tr>
<td>Constant score</td>
<td>Preop</td>
<td>Postop 12 mo</td>
<td></td>
</tr>
<tr>
<td></td>
<td>41.0 ± 20.2</td>
<td>49.1 ± 17.7</td>
<td>52.6 ± 16.2</td>
</tr>
<tr>
<td>QuickDASH</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Disability/symptom</td>
<td>Preop</td>
<td>Postop 12 mo</td>
<td></td>
</tr>
<tr>
<td></td>
<td>55.7 ± 20.9</td>
<td>35.7 ± 17.7</td>
<td>34.6 ± 17.3</td>
</tr>
<tr>
<td>Work</td>
<td>Preop</td>
<td>Postop 12 mo</td>
<td></td>
</tr>
<tr>
<td></td>
<td>25.0 ± 6.0</td>
<td>13.0 ± 10.4</td>
<td>12.7 ± 13.9</td>
</tr>
<tr>
<td>Sports/music</td>
<td>Preop</td>
<td>Postop 12 mo</td>
<td></td>
</tr>
<tr>
<td></td>
<td>100</td>
<td>69.8 ± 29.4</td>
<td>53.3 ± 38.8</td>
</tr>
<tr>
<td>SF-36</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physical functioning</td>
<td>Preop</td>
<td>Postop 12 mo</td>
<td></td>
</tr>
<tr>
<td></td>
<td>35.0 ± 14.1</td>
<td>70.3 ± 23.5</td>
<td>75.0 ± 16.3</td>
</tr>
<tr>
<td>Role physical</td>
<td>Preop</td>
<td>Postop 12 mo</td>
<td></td>
</tr>
<tr>
<td></td>
<td>21.9 ± 3.4</td>
<td>57.8 ± 27.8</td>
<td>53.0 ± 24.8</td>
</tr>
<tr>
<td>Bodily pain</td>
<td>Preop</td>
<td>Postop 12 mo</td>
<td></td>
</tr>
<tr>
<td></td>
<td>26.5 ± 6.4</td>
<td>39.9 ± 18.9</td>
<td>43.1 ± 19.6</td>
</tr>
<tr>
<td>General health perception</td>
<td>Preop</td>
<td>Postop 12 mo</td>
<td></td>
</tr>
<tr>
<td></td>
<td>42.5 ± 3.5</td>
<td>59.2 ± 16.3</td>
<td>61.4 ± 17.8</td>
</tr>
<tr>
<td>Vitality</td>
<td>Preop</td>
<td>Postop 12 mo</td>
<td></td>
</tr>
<tr>
<td></td>
<td>34.4 ± 13.3</td>
<td>56.9 ± 16.8</td>
<td>57.7 ± 19.7</td>
</tr>
<tr>
<td>Social functioning</td>
<td>Preop</td>
<td>Postop 12 mo</td>
<td></td>
</tr>
<tr>
<td></td>
<td>37.5 ± 0</td>
<td>56.3 ± 14.7</td>
<td>65.3 ± 24.5</td>
</tr>
<tr>
<td>Role emotional</td>
<td>Preop</td>
<td>Postop 12 mo</td>
<td></td>
</tr>
<tr>
<td></td>
<td>16.7 ± 11.8</td>
<td>57.8 ± 25.6</td>
<td>62.0 ± 30.5</td>
</tr>
<tr>
<td>Mental health</td>
<td>Preop</td>
<td>Postop 12 mo</td>
<td></td>
</tr>
<tr>
<td></td>
<td>45.0 ± 21.2</td>
<td>55.5 ± 25.1</td>
<td>66.5 ± 19.0</td>
</tr>
</tbody>
</table>

Values are presented as mean ± standard deviation.

Erative. de Mos et al. [20] reported that the degree of CRPS-related hand lesions was associated with remission periods; thus, hand lesions in cases with a high CRPS score (≥3 points) at onset may be persistent and further long-term follow-up will be required in these patients.

In 1994, the IASP criteria were proposed as a diagnostic method for CRPS [21,22] with high sensitivity and low specificity [23], which was then revised in 2005 [24]. To establish more specific and suitable criteria for the Japanese population, an original diagnostic criterion was developed in 2010 by the MHLWJ research team (sensitivity, 0.83 and specificity, 0.79) [8]. The incidence of CRPS-related hand lesions following ARCR using this criterion ranged from 11.7% to 21.7% [14,18,19] compared with that using the IASP 2005 criteria (ranging from 0.4% to 6%) [9-11]. It has been suggested that the IASP diagnostic criteria are affected by different cultural backgrounds and health care systems [25], and that the MHLWJ criteria are more suitable for Japanese people [8]. This may explain why the incidence of CRPS was relatively higher using the MHLWJ criteria than the IASP 2005 criteria. However, the low incidence of IASP criteria confirms another diagnosis with similar clinical manifestations and appropriate treatment.

Harada et al. [26,27] reported that the most common complication with hand symptoms after ARCR is flexor tenosynovitis.
followed by carpal tunnel syndrome, and prompt treatment with corticosteroid injections is recommended. Thus, the possibility that hand lesions after ARCR may be influenced by other diseases presenting with CRPS-like symptoms is becoming clearer. Bharwani et al. [28] stated that the pathophysiology of CRPS is multifactorial; therefore, there is a need for systematic diagnosis and treatment of CRPS symptoms with an algorithm. In view of these findings, a systematic diagnosis and treatment of hand lesions after ARCR using multiple criteria is recommended.

This study had several limitations. First, it has a retrospective design with a small sample size and short follow-up period. Second, the effects of drug treatments given only to the CRPS group cannot be ruled out. Third, all surgeries were performed in the beach chair position, and it is not clear whether differences in surgical posture affect hand symptoms. Fourth, the follow-up rate was relatively low because the subjects of the present study were patients transferred to our hospital for postoperative rehabilitation. However, the CRPS-related hand lesion incidence in this study was close to that observed in previous studies [11-16], and validity of this study was proven to some extent. As a strength of this study, we confirmed three cases in which symptoms of CRPS-related hand lesions persisted at the final follow-up, and these hand lesions did not essentially affect upper-limb function, including the involved shoulder.

CRPS-related hand lesions developed in 19.4% of patients after ARCR. Shoulder or upper-limb function improved in most cases at 12 months, with satisfactory results of SF-36 patient-based evaluation. ROM of the involved fingers did not improve in three patients with high CRPS score at onset; therefore, long-term follow-up will be necessary in these patients.

**ORCID**

Takaki Imai https://orcid.org/0000-0002-4399-2623

**REFERENCES**

18. Kiba T, Morishita T, Tachihi T, Kubo T, Kurokawa M. Clinical
outcome of symptoms like CRPS after rotator cuff repair. Kata-
kanetsu (Shoulder Jt) 2011;35:889-92.
19. Tachiiri H, Morihara T, Kiba T, Kubo T, Kurokawa M. Change
in the hand after rotator cuff repair: relation with CRPS type I.
Katakansetsu (Shoulder Jt) 2010;34:495-8.
20. de Mos M, Huygen FJ, van der Hoeven-Borgman M, Dieleman
JP, Ch Stricker BH, Sturkenboom MC. Outcome of the complex
and differential diagnosis. In: Janig W, Stanton-Hicks M, eds.
Reflex sympathetic dystrophy: diagnosis. Seattle, WA: IASP
23. Galer BS, Bruehl S, Harden RN. IASP diagnostic criteria for
complex regional pain syndrome: a preliminary empirical valida-
dery study. International Association for the Study of Pain.
24. Harden RN, Bruehl S, Stanton-Hicks M, Wilson PR. Proposed
new diagnostic criteria for complex regional pain syndrome.
25. Perez RS, Collins S, Marinus J, Zuurmond WW, de Lange JJ. Di-
agnostic criteria for CRPS I: differences between patient profiles
using three different diagnostic sets. Eur J Pain 2007;11:895-
902.
26. Harada M, Mura N, Takahara M, Takagi M. Complications of
the fingers and hand after arthroscopic rotator cuff repair. Open
27. Harada M, Mura N, Takahara M, Tsuruta D, Takagi M. Early
detection and treatment of complications in the fingers and
hand after arthroscopic rotator cuff repair. JSES Int 2020;4:612-
18.
28. Bharwani KD, Dirckx M, Huygen FJ. Complex regional pain
Investigation of the range of motion of the shoulder joint in subjects with rotator cuff arthropathy while performing daily activities

Mohammad Taghi Karimi, Sahar Khademi

Rehabilitation Sciences Research Center, Shiraz University of Medical Sciences, Shiraz, Iran

**Background:** Patients who have rotator cuff arthropathy experience a limited range of motion (ROM) of the shoulder joint and experience problems in performing their daily activities; however, no evidence is available to suggest the exact ROM of the shoulder joint in this population. Therefore, this study sought to determine the degree of motion of the shoulder joint in three planes during different activities.

**Methods:** Five subjects with rotator cuff injuries participated in this study. The motion of the shoulder joints on both the involved and normal sides was assessed by a motion analysis system while performing forward abduction (task 1), flexion (task 2), and forward flexion (task 3). The OpenSIM software program was used to determine the ROM of the shoulder joints on both sides. The difference between the ranges of motion was determined using a two-sample t-test.

**Results:** The ROMs of the shoulder joint in task 1 were 93.5°±16.5°, 72.1°±2.6°, and 103.9°±25.7° for flexion, abduction, and rotation, respectively, on the normal side and 28°±19.8°, 31°±31.5°, and 48°±33.5° on the involved side (p<0.05). There was no significant difference between the flexion/extension and rotation movements of the shoulder joint when performing task 1. However, the difference between flexion and rotation movements of the shoulder joints for the second task was significant (p>0.05).

**Conclusions:** Those with rotator cuff arthropathy have functional limitations due to muscle weakness and paralysis, especially during the vertical reaching task. However, although these individuals have decreased ROM for transverse reaching tasks, the reduction was not significant.

**Keywords:** Rotator cuff paralysis; Kinematic; Joint movements

**INTRODUCTION**

Rotator cuff tear (RCT) arthropathy was first described by Neer [1]. It is classified by subacromial impingement of the humeral head, acetabularization of the acromion, and glenoid erosion after a massive tear of the rotator cuff. This pathology is associated with a decrease in stabilization compressive force across the glenohumeral (GH) joint and superior migration of the humeral head in the direction of the deltoid pull [2-4].

The rotator cuff demonstrates two principal functions of generation of the torque necessary for rotation of the humerus on the glenoid and compression of the humeral head into the gle-
noid cavity [5-8]. Although the etiology of rotator cuff arthropathy is unknown, factors such as genetic predisposition, extrinsic impingement and biomechanical imbalance from structures surrounding the cuff, and degeneration changes in tendons have been mentioned in this regard [9]. The incidence of this pathology differs between countries, especially in people older than 50 years. It has been estimated that between 30% and 70% of cases of shoulder pain stem from disorders of the rotator cuff. Those with RCT experience superior humeral head translation together with increased superior GH joint force, acromioclavicular joint pressure, and pain when performing daily activities [10,11].

Based on the results of various studies, the kinematics of the shoulder joint are altered significantly in those with RCT, especially during daily activities. GH elevation is reduced in such patients, especially in the context of flexion and abduction. Moreover, they have more scapulothoracic lateral flexion relative to that of normal individuals [1]. In research performed by Kozono et al. [12], full abduction of the shoulder complex in the scapular plane was investigated, and a medial shift at the late phase of motion of the humeral head center was observed. Moreover, during full axial rotation, the humeral head center experienced a greater anterior shift in the patients with rotator cuff arthropathy relative to the normal matched group [12]. In another study, it was reported that the patients with rotator cuff arthropathy demonstrated an altered and predominantly scapular motion pattern [13]. Most studies have focused on the use of simple motion analysis and reported a decrease in GH joint motion, which might be due to an increase in pain. In other words, patients experience decrease in range of motion (ROM) of the joint as a compensatory mechanism to reduce pain [14-16].

Various approaches have been used to decrease the pain of subjects with RCT and to increase their ROMs, including surgery and conservative treatment (e.g., exercise). Therefore, the main question posed here is the limitations of motions in such a group of patients when performing simple daily activities. This information can help clinicians to determine which group or groups of muscles should be strengthened in these patients and also can help surgeons to transfer appropriate muscles to restore the performance of the shoulder complex.

**METHODS**

Five male subjects with massive rotator cuff rupture participated in this study. The men showed a mean age of 62 ± 5 years, height of 158 ± 10 cm, and weight of 58 ± 8.5 kg. Ethical approval was obtained from the Shiraz University of Medical Sciences Ethical Committee. Moreover, each subject provided informed consent before data collection. Eligible patients were those with a diagnosis of large to massive RCT. All study participants were scheduled to undergo rotator cuff surgery. The large to massive full thickness of the RCT was confirmed by magnetic resonance imaging prior to study inclusion. Moreover, X-ray imaging was used to classify severity of the disease based on Hamedâ’s classification scheme [12]. According to this classification scheme, all patients exhibited a grade 5 condition (with humeral head collapse). The main exclusion criteria were neuromuscular disorders and previous surgery.

A motion analysis system with eight high-speed cameras was used to record the motions of the shoulder joint complex. Some reflective markers were attached to the anterior superior iliac spine, posterior superior iliac spine, acromioclavicular joint, medial and lateral elbow joints, and medial and lateral styloid processes at the wrist on both the right and left sides. Moreover, markers were attached to the sternum, sternoclavicular joints, C7, and T11. All study participants had RCT on the right side.

The OpenSIM software program (Simbios; Stanford University, Stanford, CA, USA) was used to determine joint ROMs of both the right and left sides. Study participants were asked to complete three tasks, including upward movement of the shoulder joint along the frontal plane with the elbow in an extended position (task 1), upward movement of the shoulder joint in the plane of the scapula with the elbow in 90° flexion (task 2), and upward movement of the shoulder joint along the sagittal plane (task 3). These motions are considered complex and each one consists of flexion, abduction, and rotation. The tests were performed separately for right and left sides. A well-developed model was used to evaluate the ROM of the shoulder joint in the aforementioned task [17,18]. Static test results were collected from the subjects in a sitting position and were used to scale the model in the OpenSIM software program. The Mokka software (Biomechanical ToolKit) program was used to convert the test data from C3D to TRC format, which is compatible with the OpenSIM software program. Scaling of the model was completed.
with an error less than 3 cm. The same procedure was used to collect dynamic test results. Inverse kinematic and inverse dynamic data were used to quantify ROM and joint movements, respectively.

The normal distribution of the parameters was determined by the Shapiro-Wilk test. The difference between ROMs of the joints on the right and left sides and the peaks of the movements of the respective shoulder joints was determined using a two-sample t-test with significance at \( p = 0.05 \).

**RESULTS**

The ROMs of the shoulder joint in task 1 were \( 93.5° \pm 16.5°, 72.1° \pm 2.6°, \) and \( 103.9° \pm 25.7° \) for flexion, abduction, and rotation, respectively on the normal side, compared with \( 28° \pm 19.8°, 31° \pm 31.56°, \) and \( 48° \pm 33.5° \) on the involved side (\( p < 0.05 \)). There was a significant difference between the normal and involved sides in abduction ROM during task 2 (\( p = 0.025 \)). Meanwhile, during task 3, although the ROMs of shoulder flexion/extension, abduction/adduction, and rotation decreased on the involved side relative to on the normal side, the difference was not significant.

Table 1 summarizes the motions of the shoulder joints during these tasks. The mean values of abduction moment of the shoulder joint when performing task 1 were \( 7.36 \pm 2.7 \) N/m for the normal side and \( 3.6 \pm 2.2 \) N/m for the involved side, and the difference between these mean values was statistically significant (\( p = 0.034 \)). There was no significant difference between flexion/extension and rotation movements of the shoulder joint during task 1, but this difference was significant (\( p < 0.05 \)) for the second task. The mean values of abduction moment of the shoulder joint were \( 2.35 \pm 1.3 \) N/m on the normal side and \( 1.22 \pm 0.37 \) N/m on the involved side.

### Table 1. Mean ROM values of the shoulder joint on the involved (right) and normal (left) sides

<table>
<thead>
<tr>
<th>Variable</th>
<th>Abduction/adduction (°)</th>
<th>Flexion/extension (°)</th>
<th>Rotation (°)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Task 1</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal side</td>
<td>93.5 ± 16.5</td>
<td>72.1 ± 25.6</td>
<td>103.9 ± 25.7</td>
</tr>
<tr>
<td>RCT side</td>
<td>28 ± 19.8</td>
<td>31 ± 31.56</td>
<td>48 ± 33.5</td>
</tr>
<tr>
<td>p-value</td>
<td>0.0</td>
<td>0.039</td>
<td>0.015</td>
</tr>
<tr>
<td><strong>Task 2</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal side</td>
<td>61.5 ± 19.3</td>
<td>81.4 ± 20.6</td>
<td>89.4 ± 44.5</td>
</tr>
<tr>
<td>RCT side</td>
<td>34.42 ± 12</td>
<td>64.8 ± 24.8</td>
<td>53.5 ± 33.4</td>
</tr>
<tr>
<td>p-value</td>
<td>0.025</td>
<td>0.167</td>
<td>0.11</td>
</tr>
<tr>
<td><strong>Task 3</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal side</td>
<td>48.8 ± 41.7</td>
<td>85.2 ± 49.3</td>
<td>60 ± 37.9</td>
</tr>
<tr>
<td>RCT side</td>
<td>15.1 ± 8.9</td>
<td>32.7 ± 22.3</td>
<td>25.85 ± 23.65</td>
</tr>
<tr>
<td>p-value</td>
<td>0.12</td>
<td>0.08</td>
<td>0.12</td>
</tr>
</tbody>
</table>

Values are presented as mean±standard deviation.

ROM: range of motion, RCT: rotator cuff tear.

### Table 2. Mean values of shoulder joint moment on the involved (right) and normal (left) sides

<table>
<thead>
<tr>
<th>Variable</th>
<th>Abduction/adduction (N/m)</th>
<th>Flexion/extension (N/m)</th>
<th>Rotation (N/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Task 1</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal side</td>
<td>7.36 ± 2.7</td>
<td>2.71 ± 0.9</td>
<td>1.77 ± 0.962</td>
</tr>
<tr>
<td>RCT side</td>
<td>3.6 ± 2.2</td>
<td>2.85 ± 1.42</td>
<td>1.77 ± 1.1</td>
</tr>
<tr>
<td>p-value</td>
<td>0.034</td>
<td>0.4</td>
<td>0.0</td>
</tr>
<tr>
<td><strong>Task 2</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal side</td>
<td>4.3 ± 2.77</td>
<td>6.56 ± 1.59</td>
<td>2.34 ± 0.77</td>
</tr>
<tr>
<td>RCT side</td>
<td>2.39 ± 1.05</td>
<td>4.14 ± 1.38</td>
<td>1.14 ± 0.49</td>
</tr>
<tr>
<td>p-value</td>
<td>0.12</td>
<td>0.025</td>
<td>0.017</td>
</tr>
<tr>
<td><strong>Task 3</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal side</td>
<td>2.35 ± 1.3</td>
<td>8.1 ± 1.65</td>
<td>2.3 ± 0.93</td>
</tr>
<tr>
<td>RCT side</td>
<td>1.22 ± 0.37</td>
<td>6.22 ± 1.62</td>
<td>2.3 ± 1.32</td>
</tr>
<tr>
<td>p-value</td>
<td>0.11</td>
<td>0.105</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Values are presented as mean±standard deviation.

RCT: rotator cuff tear.
the involved side (p = 0.11). There was no difference between flexion and rotation movements of the shoulder joint when performing task 3. Table 2 reports the movements of the shoulder joint during the aforementioned tasks.

**DISCUSSION**

Patients with rotator cuff arthropathy suffer loss in abilities to perform daily activities with normal ROM. Shoulder motions are mixed and require various degrees of abduction/adduction, flexion/extension, and rotation depending on type of motion. There is not enough evidence in the literature regarding the ROM and movements of the shoulder joint in those with rotator cuff arthropathy. Therefore, this study sought to determine the difference between ROM of the shoulder joint in daily activities on normal and involved sides of the body. The outputs of this research can be used to assess and improve performance of the shoulder complex by way of exercise or surgery.

Our results suggest that those with rotator cuff rupture experience degrees of shoulder joint motion restriction, especially when performing task 1 (abduction) (Table 1). Most individuals can be expected to have problems in completing this task as their ranges of flexion-extension, abduction, adduction, and rotation were decreased significantly. More broadly, our participants had problems performing tasks predominantly requiring motions in the plane above the shoulder joint. For other tasks that can be performed below shoulder level, they experienced less problems (e.g., when performing transverse reaching tasks). However, they also had problems during vertical reaching tasks, as these required greater degree of shoulder abduction and required motions conducted in a plane up to the shoulder joint. The results of kinematic analysis of the shoulder joint support this idea (Table 1). In performing tasks above the shoulder joint, a combination of movements of the GH, scapulothoracic, and other joints in the shoulder joint complex is required. Based on research performed by Zdravkovic et al. [13], those with RCT show irregularities in intra-articular motions, which are essential for motion of the shoulder joint (i.e., patients with RCT showed an altered and predominantly scapular motion pattern).

Movements of the shoulder joint during the mentioned tasks were evaluated in this study, and the participants showed weakness of the abductor muscles when performing an abduction task (vertical reaching, task 1); however, for task 2, they demonstrated weakness of the shoulder flexor. The results of this study support previous studies, confirming that those with rotator cuff injuries demonstrate reduced shoulder flexion and abduction [12,16,19].

Importantly, the decrease in shoulder motion is not simply due to pain, as was mentioned in previous research; it also can be due to weakness in the muscles. This means that those with rotator cuff paralysis cannot complete the ROM of the shoulder joint and have to use some compensatory mechanism such as trunk lean to the contralateral side, which is often not successful for achieving their goal.

Based on the outputs of this study, it can be confirmed that those with rotator cuff injuries have limitations in fulfilling the ROM in the plane above the shoulder joint; however, they show no significant problems with motions below the plane of the scapula. The results of this research highlight that strengthening of the shoulder abductor by physical therapy exercises or tendon transfer (mainly pectoralis, latissimus dorsi) is warranted to restore the abilities of those with such injuries.

There are some limitations that should be acknowledged regarding this study. The main limitation was the small number of participants. Therefore, it is recommended that additional study be performed with a greater number of subjects. Moreover, it is recommended that other types of tasks be evaluated. The results of this study suggest that individuals with RCTs experience degrees of functional limitation due to muscle weakness, especially during vertical reaching tasks. However, although they experience decreased ROM for motions below the plane of the scapula, the difference was not significant. It is recommended that abductor muscles of the shoulder complex be strengthened in this group by way of physical therapy exercises or tendon transfer.

**ORCID**

Mohammad Taghi Karimi https://orcid.org/0000-0001-6162-8131
Sahar Khademi https://orcid.org/0000-0002-3330-5789

**REFERENCES**


Distal biceps tendon injection

Jacqueline van der Vis1, Stein J. Janssen2, Ronald L.A.W. Bleys3, Denise Eygendaal2,4, Michel P.J. van den Bekerom1,5; on behalf of Elbow Study Collaborative

1Department of Orthopedic Surgery, OLVG, Amsterdam, The Netherlands
2Department of Orthopedic Surgery, Academic Medical Center, Amsterdam, The Netherlands
3Department of Anatomy, University Medical Center Utrecht, Utrecht, The Netherlands
4Department of Orthopedic Surgery, Amphia Ziekenhuis, Breda, The Netherlands
5Department of Human Movement Sciences, Vrije Universiteit Amsterdam, Amsterdam Movement Sciences, Amsterdam, The Netherlands

Background: Injection therapy around the distal biceps tendon insertion is challenging. This therapy may be indicated in patients with a partial distal biceps tendon tear, bicipitoradial bursitis and tendinopathy. The primary goal of this study was to determine the accuracy of manually performed injections without ultrasound guidance around the biceps tendon.

Methods: Seven upper limb specialists, two general orthopedic specialists, and three orthopedic surgical residents manually injected a cadaver elbow with acrylic dye using an anterior and a lateral infiltration approach. After infiltration the cadaveric elbows were dissected to determine the location of the acrylic dye.

Results: In total, 79% of the injections were localized near the biceps tendon. Of these injections, 20% were localized on the radius near the bicipitoradial bursa. In total, 53% of the performed infiltrations were injected by anterior and 47% by lateral approaches. Of the injections near the distal biceps (79%), 47% were injected by an anterior and 53% by a lateral approach. Of the injections on the radius (20%), 33% were injected by anterior and 67% by lateral approach. Of the inaccurate injections (21%), 75% were injected anterior and 25% lateral.

Conclusions: Manual infiltration without ultrasound guidance for distal biceps pathology lacks accuracy. We therefore recommend ultrasound guidance for more accurate infiltration.

Keywords: Elbow; Partial biceps tendon tear; Bicipitoradial bursitis; Biceps tendinopathy; Injection therapy

INTRODUCTION

Injection therapy around the distal biceps tendon can be performed in patients with a partial biceps tendon tear, bicipitoradial bursitis or distal biceps tendinopathy. Injection therapy with platelet-rich plasma or glucocorticoids around the distal biceps tendon and in the bicipitoradial bursa is challenging because of the lack of clearly palpable landmarks; complex distal biceps anatomy; and proximity of the brachial artery, median nerve, and posterior interosseous nerve [1-7]. The bicipitoradial bursa is located between the distal biceps tendon and the anterior part of the proximal radius. The bicipitoradial bursa surrounds the biceps tendon in supination. In pronation, the radial tuberosity compresses the bicipitoradial bursa between the biceps tendon and the radial cortex [5-9].

There are different injection techniques with different ap-
The primary aim of this study was to determine the accuracy of manually performed injections of the biceps tendon without radiological guidance by upper extremity surgeons. We hypothesized that manually performed injections are inaccurate and that the majority of injections (>50%) would not be located in the bicipitoradial bursa or near the biceps tendon.

METHODS

Study Design and Ethics Statement
This prospective study was performed during an arthroscopy and arthroplasty cadaveric course of the elbow at the University Medical Centre in Utrecht, The Netherlands. No Institutional Review Board approval is needed for cadaveric studies performed at our institution. These specimens were derived from bodies that entered the Department of Anatomy through a donation program. Written consent was obtained from these persons during life that allowed for the use of their entire bodies for educational and research purposes.

Participants
Twenty orthopedic surgeons and residents in their final year of residency attended this course that used 10 cadaveric elbows. For study purposes, the most experienced attendants of the pairs (surgeon or resident) were invited to perform two infiltrations (anterior and lateral technique) and thereby participate in this study. Twelve participants performed the infiltrations divided over these ten cadaveric elbows: seven participants performed infiltrations using both techniques; one participant only performed an anterior infiltration due to miscommunication; and four participants performed the infiltration together (in turn), one using the lateral technique and the other using the anterior technique. Seven participants were upper extremity surgeons (mean experience, 3.1 years; range, 1–10 years), two were general orthopedic surgeons (7 and 21 years of experience), and three were orthopedic surgery residents (in their final year of training).

Fresh-frozen human cadaveric elbow specimens were derived from bodies that had entered the Department of Anatomy of the University Medical Centre through a donation program. Written informed consent that allowed for the use of their entire bodies for educational and research purposes was obtained from these persons during their lives. None of the specimens showed signs of previous trauma or surgery affecting the elbow. The cadaveric arms were attached to a metal construction, making rotation of the arm around its axis and pronation, supination, flexion and extension of the elbow possible.

Description of Infiltration Technique
Each participant was asked to manually infiltrate the distal biceps tendon through an anterior and lateral infiltration technique using acrylic dye after instructions by one of the researchers. For the anterior approach the elbow was slightly flexed (±50°–90°), the forearm fully supinated, and the biceps tendon was localized through palpation. Then the needle was placed in the middle of the cubital fossa towards the radial tuberosity and the dye was injected. For the lateral approach the elbow was positioned in the same manner as the anterior approach. After localization of the biceps tendon, the needle was placed laterally on the elbow, radial to ulnar, with the needle passing beneath the distal biceps tendon towards the radial tuberosity. The dye was then injected. All participants received two disposable 10-mL syringes with 23-G needles. One syringe was filled with 2 mL of green acrylic dye; the other syringe was filled with 2 mL of red acrylic dye. The syringe with the red acrylic dye was used for the anterior infiltration technique; the syringe with the green acrylic dye was used for the lateral infiltration technique.

Outcome Measures and Explanatory Variables
The amount and location of injected dye was assessed. After the infiltrations, the elbows were dissected in order to determine whether the dye was given in or near the bicipitoradial bursa and the biceps tendon. The presence and the amount of acrylic dye were assessed and reported. The amount of acrylic dye was classified as “none,” “a little” or “a lot.” The location of the acrylic dye was reported as “in or near the bicipitoradial bursa” or “in or near the biceps tendon.” After 5 to 10 minutes the participants were asked to dissect the elbow and locate the dye. Assessment of location was performed by both participants by consensus.

All participants were asked to complete questionnaires concerning their subspecialty, years of experience as an orthopedic surgeon and/or an upper extremity surgeon, and overall experience infiltrating the biceps tendon.

RESULTS

Each participant performed one perforation per infiltration and all injected 2 mL of acrylic dye in both techniques.

A total of 19 injections (10 [53%] using the anterior infiltration
technique and 9 [47%] using the lateral infiltration technique) were performed in 10 cadaveric elbows. Of the 19 performed infiltrations, 15 injections (79%) were located during dissection in or near the biceps tendon. The dye was not located near the biceps tendon in the remaining four injections (21%). Of these four injections, three were anteriorly injected (75%) and one was laterally injected (25%). Three out of the 15 injections (20%) were located (totally or partially) on the radius near the bicipitoradial bursa. Of these injections, one was given anteriorly (33%) and two laterally (67%). The remaining 12 injections (80%) were located (totally or partially) in or near the biceps tendon. We found “a lot” of dye in 13 (87%) of these injections. We found “a little” dye in the other two (13%), one of which was injected anteriorly (50%) and one laterally (50%) (Tables 1 and 2).

DISCUSSION

We hypothesized that manually performed injections of the biceps tendon without ultrasound guidance would be inaccurate and that the majority of the injections would not be located in the bicipitoradial bursa or near the biceps tendon. The most important finding of this study was that manually performed injections of the biceps tendon lack accuracy. Only three of the nineteen injections were located (totally or partially) near the bicipitoradial bursa.

Table 1. Baseline characteristics and results of infiltration

<table>
<thead>
<tr>
<th>Participant no.</th>
<th>Cadaver no.</th>
<th>Infiltration technique</th>
<th>Dye color</th>
<th>Dye in or near the biceps tendon</th>
<th>Dye in or near bicipitoradial bursa</th>
<th>Amount of dye</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>Anterior</td>
<td>Red</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>Lateral</td>
<td>Green</td>
<td>○</td>
<td>-</td>
<td>A lot</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>Anterior</td>
<td>Red</td>
<td>○</td>
<td>○</td>
<td>A lot</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>Lateral</td>
<td>Green</td>
<td>○</td>
<td>○</td>
<td>A little</td>
</tr>
<tr>
<td>5</td>
<td>3</td>
<td>Anterior</td>
<td>Red</td>
<td>○</td>
<td>-</td>
<td>A little</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lateral</td>
<td>Green</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>4</td>
<td>Anterior</td>
<td>Red</td>
<td>○</td>
<td>-</td>
<td>A lot</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lateral</td>
<td>Green</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>5</td>
<td>Anterior</td>
<td>Red</td>
<td>○</td>
<td>-</td>
<td>A lot</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lateral</td>
<td>Green</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>6</td>
<td>Anterior</td>
<td>Red</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lateral</td>
<td>Green</td>
<td>○</td>
<td>-</td>
<td>A lot</td>
</tr>
<tr>
<td>9</td>
<td>7</td>
<td>Anterior</td>
<td>Red</td>
<td>○</td>
<td>-</td>
<td>A lot</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lateral</td>
<td>Green</td>
<td>-</td>
<td>-</td>
<td>A lot</td>
</tr>
<tr>
<td>10</td>
<td>8</td>
<td>Anterior</td>
<td>Red</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lateral</td>
<td>Green</td>
<td>○</td>
<td>○</td>
<td>A lot</td>
</tr>
<tr>
<td>11</td>
<td>9</td>
<td>Anterior</td>
<td>Red</td>
<td>○</td>
<td>○</td>
<td>A lot</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lateral</td>
<td>Green</td>
<td>○</td>
<td>○</td>
<td>A lot</td>
</tr>
<tr>
<td>12</td>
<td>10</td>
<td>Anterior</td>
<td>Red</td>
<td>○</td>
<td>-</td>
<td>A lot</td>
</tr>
</tbody>
</table>
locate the pain. This may facilitate accurate infiltration. The biomechanical properties of tissue are different in cadavers as compared to living subjects. However, the fresh frozen cadavers used in this study accurately resembled living tissue [10]. Second, during the study we mainly focused on the location of the dye. We did not assess the structures passed by the needle; therefore, the needle may have caused neurovascular injuries. Leaving the needle in place and dissecting the pathway might have helped assess this. Third, the acrylic dye had to set for 5–10 minutes, but some participants started their dissection too early due to other course activities. This may explain the smaller amounts of dye found. Fourth, bias may have been introduced by having the participants dissect and assess their own injected elbows. Fifth, the sample size of the cadavers and participants in our study was small and did not allow for stratification based on experience or skill. However, a larger sample size would probably not change our conclusions. Further, none of the participants had previously performed an infiltration of the distal biceps tendon without radiological guidance. Most colleagues ask a radiologist to perform these infiltrations using ultrasound guidance in daily practice.

Previous studies have shown that infiltration in the bicipitoradial bursa with ultrasound guidance is difficult. There are several viable options described for infiltration with ultrasound guidance. Sellon et al. [1] found a high success rate for sonographically guided peritendinous and intratendinous infiltration of the distal biceps tendon through multiple approaches. All of their peritendinous injections were successful, and 94% of their intratendinous injections were successful. Mautner et al. [4] demonstrated with their case study that an ultrasound-guided, posterior, in-plane approach for distal biceps tendon infiltration was safe and effective. Chang et al. [11] demonstrated that an ultrasound-guided infiltration of the bicipitoradial bursa for bicipitoradial bursitis was safe and successful. In comparison, for the infiltration of the shoulder girdle, Aly et al. [12] found an improved accuracy for ultrasound-guided injections compared to landmark-guided injections.

In daily practice we recommend infiltration of the bicipitoradial bursa using ultrasound guidance. This technique allows for a more accurate injection and more optimal treatment of a partial biceps tendon tear, bicipitoradial bursitis or tendinopathy. Further studies on infiltrations of the distal biceps tendon in living human subjects are needed. These should focus on the clinical efficacy and accuracy of ultrasound-guided and manually performed injections. Infiltration of the bicipitoradial bursa without ultrasound guidance lacks accuracy. For more accurate treatment of a partial biceps tendon tear, bicipitoradial bursitis or tendinopathy, we recommend infiltration of the bicipitoradial bursa using ultrasound guidance. Further studies on infiltrations of the distal biceps tendon in human subjects, particularly a study that directly compares manual versus ultrasound-guided infiltrations, will be useful.

ACKNOWLEDGMENTS

Elbow Study Collaborative: Marc Wagener, Lex Boerboom, Carina Gerritsma, Bertram The, Roger van Riet, Jaap Willems.

REFERENCES

10. Doormeirk DE, Kruse RR, Reiijn MM, Koziciz TL, Kooloois


INTEROBSERVER AGREEMENT FOR DETECTING HILL-SACHS LESIONS ON MAGNETIC RESONANCE IMAGING

Hassanin Alkaduhimi¹, Aïmane Saarig¹, Ihsan Amajjar¹, Just A. van der Linde², Marieke F. van Wier¹, Nienke W. Willigenburg¹, Michel P.J. van den Bekerom¹; Shoulder and Elbow Center

¹Shoulder and Elbow Unit, Joint Research, OLVG Hospital, Amsterdam, Netherlands
²Department of Orthopedic Surgery and Traumatology, Reinier Haga Orthopedisch Centrum, Zoetermeer, Netherlands

**Background:** Our aim is to determine the interobserver reliability for surgeons to detect Hill-Sachs lesions on magnetic resonance imaging (MRI), the certainty of judgement, and the effects of surgeon characteristics on agreement.

**Methods:** Twenty-nine patients with Hill-Sachs lesions or other lesions with a similar appearance on MRIs were presented to 20 surgeons without any patient characteristics. The surgeons answered questions on the presence of Hill-Sachs lesions and the certainty of diagnosis. Interobserver agreement was assessed using the Fleiss’ kappa (κ) and percentage of agreement. Agreement between surgeons was compared using a technique similar to the pairwise t-test for means, based on large-sample linear approximation of Fleiss’ kappa, with Bonferroni correction.

**Results:** The agreement between surgeons in detecting Hill-Sachs lesions on MRI was fair (69% agreement; κ, 0.304; p<0.001). In 84% of the cases, surgeons were certain or highly certain about the presence of a Hill-Sachs lesion.

**Conclusions:** Although surgeons reported high levels of certainty for their ability to detect Hill-Sachs lesions, there was only a fair amount of agreement between surgeons in detecting Hill-Sachs lesions on MRI. This indicates that clear criteria for defining Hill-Sachs lesions are lacking, which hampers accurate diagnosis and can compromise treatment.

**Keywords:** Observer variation; Shoulder; Joint instability; Bankart lesions; Hill-Sachs

INTRODUCTION

During anterior shoulder dislocation, the head of the humerus can be pressed against the antero-inferior part of the glenoid rim and cause an impression fracture of the posterior superior lateral humeral head, known as a Hill-Sachs lesion [1]. The incidence of these Hill-Sachs lesions is reported to be between 40% and 90% for patients with anterior instability and could be as high as 100% for patients with recurrent dislocation [2]. Furthermore, humeral bone loss associated with a Hill-Sachs lesion can increase the risk of recurrent dislocation depending on the size and location of the lesion [1]. Treatment algorithms, such as the instability severity index score and glenoid track instability management score, have been developed to assess whether instability could be treated with a soft-tissue procedure or a bony procedure [3]. In these treatment algorithms a more aggressive approach is recommend-
ed based on the presence of factors that result in a higher recurrent instability rate, and a Hill-Sachs lesion is one of these factors. Since the presence of a Hill-Sachs lesion is important for determining treatment, it is important that healthcare providers agree on the presence of a Hill-Sachs lesion.

A Hill-Sachs lesion can be detected on radiographic imaging, but computed tomography (CT) and magnetic resonance imaging (MRI) are more sensitive [4,5]. Traditionally, CT scans were obtained to assess humeral and glenoid bone loss. In contrast to CT scans, MRI does not expose patients to radiation and assessment of the soft-tissue can be more accurate [6]. Therefore, MRI is the preferred imaging modality by orthopedic shoulder surgeons [7]. Saqib et al. [8] recently reported high sensitivity and specificity of magnetic resonance arthrography reviewed by experienced radiologists in detecting Hill-Sachs lesions compared to arthroscopy by one single surgeon. Although the accuracy of MRI to detect Hill-Sachs lesions is documented (Table 1) [8-17] insight into the reliability is limited.

This gap in the literature is critical, as discordant diagnoses by healthcare professionals can have detrimental impacts on patient care and recovery. Consequently, if reliability is low, healthcare providers do not agree on the presence of Hill-Sachs lesions. That means that patients with (and without) Hill-Sachs lesions can be diagnosed and treated differently by surgeon. Additionally, the incidence of Hill-Sachs lesions in the literature can vary, largely due to differences in clinical judgement. We are interested specifically in treating surgeon radiological judgement rather than the expert radiologist assessment judgement because surgeons always assess MRIs before discussing treatment options with the patient.

Halma et al. [18] reported fair interobserver agreement in surgeons and radiologists that assessed Hill-Sachs lesions compared to only 3 of 50 MRIs that included a Hill-Sachs lesion in the present study. Therefore, concrete conclusions on the reliability of detecting Hill-Sachs lesions could not be made. Beason et al. [19] evaluated interobserver agreement for detecting Hill-Sachs lesions among shoulder/sports medicine fellowship-trained orthopedic surgeons based only on coronal and axial T2-weighted MRI series. However, the surgeon’s level of expertise was not taken into account, and the overall agreement was fair. van Grinsven et al. [20] has assessed the agreement between radiologists and orthopedic surgeons for instability-related shoulder lesions on MRI, although the study did not report on the number of Hill-Sachs lesions in the population. Furthermore, they reported the agreement for all instability-related shoulder lesions without specifying the agreement for Hill-Sachs lesions.

This is the fourth study on this important topic, and we aimed to provide further insight into the role of MRI as a diagnostic instrument that can be used by surgeons. Specifically, we aimed to determine: (1) the interobserver reliability for surgeons to detect Hill-Sachs lesions on MRI, (2) the certainty of surgeons regarding their judgement, and (3) the effects of surgeon characteristics on agreement. To achieve this, we incorporated results from a substantially sized group of surgeons with varying levels of expertise to assess multiple MRIs with and without Hill-Sachs lesions and with no additional patient characteristics for context. We hypothesized that agreement would be fair, certainty would be high, and agreement would increase with corresponding increase in level of expertise.

**METHODS**

**Patients**

This study has been approved by the IRB of the OLVG Hospital (No. WO 16.052). Our hospital database was screened for available shoulder MRIs of patients with shoulder instability based on diagnosis codes. The medical records of these patients were manually screened by two researchers (HA and AS) for MRIs with Hill-Sachs lesions (n = 19) or other defects with a similar appearance (n = 10). These other defects were visible at the typical location for a Hill-Sachs lesion, but were not a Hill-Sachs lesion as reported by the musculoskeletal radiologist. Such lesions included bone cyst, erosion of cartilage, small grooves, or the bare area of the humeral head [21]. The majority of MRIs was performed without intra-articular contrast, and the Hill-Sachs lesions varied in size (Fig. 1). Proton density turbo spin echo MRIs were performed with a Siemens Magnetom Aera device (Siemens Healthineers, Erlangen, Germany). All MRIs were performed with the same MRI device and using the same protocol, positioning, and slice thickness.

**Methods and Assessment**

The MRI results were uploaded to a secure online survey platform (http://www.shoulderelbowcenter.com/) offering additional tools to perform measurements including lengths, angles, multiplanar reconstruction, and areas of surfaces. Experienced orthopedic surgeons with a specialization in shoulder pathology were invited to assess the MRIs and answer two questions based on the images: whether there was a Hill-Sachs lesion (yes/no) and how certain they were about the presence of a Hill-Sachs lesion (absolutely certain/certain/some doubts/very uncertain). General information about the assessing surgeons included the geographical location of their practice, years of clinical experience, scope of clinical interest, and whether they were involved in resident or
Table 1. Studies since 2000 that have assessed MRI accuracy and reliability

<table>
<thead>
<tr>
<th>Study</th>
<th>Observer</th>
<th>Number of MRIs wherein Hill Sachs is studied</th>
<th>Kappa</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beason et al. (2019) [19]</td>
<td>22 Shoulder/sports medicine fellowship-trained orthopedic surgeons</td>
<td>20</td>
<td>0.33</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Halma et al. (2012) [18]</td>
<td>2 Radiologists, 1 orthopedic surgeon</td>
<td>50</td>
<td>R1 vs. R2: 0.21</td>
<td>0–33</td>
<td>72.3–95.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>R1 vs. OS: 0.31</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>R2 vs. OS: –0.01</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Saqib et al. (2017) [8]</td>
<td>Radiologist</td>
<td>194</td>
<td>-</td>
<td>91</td>
<td>91</td>
</tr>
<tr>
<td>Kalson et al. (2011) [9]</td>
<td>Shoulder radiologist or musculoskeletal radiologist</td>
<td>95</td>
<td>-</td>
<td>71</td>
<td>85</td>
</tr>
<tr>
<td>Hayes et al. (2010) [10]</td>
<td>2 Radiologists</td>
<td>87</td>
<td>-</td>
<td>96.3</td>
<td>90.6</td>
</tr>
<tr>
<td>Theodoropoulos et al. (2010) [11]</td>
<td>Community-based radiologists</td>
<td>238</td>
<td>1 (Unenhanced MRI)</td>
<td>0.788 (MR arthrogram)</td>
<td>0–33</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Unenhanced MRI: 85–100</td>
<td>MR arthrogram: 50–70</td>
<td>MR arthrogram: 99–100</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0 (due to only 1 patient not having a Hill-Sachs)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Probyn et al. (2007) [22]</td>
<td>Musculoskeletal radiologist or musculoskeletal imaging fellow</td>
<td>15</td>
<td>-</td>
<td>100</td>
<td>0 (due to only 1 patient not having a Hill-Sachs)</td>
</tr>
<tr>
<td>Kirkley et al. (2003) [13]</td>
<td>2 Musculoskeletal radiologists</td>
<td>16</td>
<td>-</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>van Grinsven et al. (2015) [20]</td>
<td>4 Radiologists</td>
<td>45</td>
<td>Between radiologists: 0.51 and 0.46</td>
<td>41.1–73.8</td>
<td>81.3–88.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Between orthopedic surgeons: 0.46 and 0.41</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chauvin et al. (2013) [14]</td>
<td>3 Radiologists with experience in musculoskeletal disorders</td>
<td>66</td>
<td>-</td>
<td>100</td>
<td>94</td>
</tr>
<tr>
<td>Mahmoud et al. (2013) [15]</td>
<td>2 Musculoskeletal radiologists</td>
<td>31</td>
<td>-</td>
<td>81.8</td>
<td>95.2</td>
</tr>
<tr>
<td>O’Brien et al. (2012) [16]</td>
<td>2 Musculoskeletal radiologists</td>
<td>165</td>
<td>0.964</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Simão et al. (2012) [17]</td>
<td>3 Radiologists</td>
<td>56</td>
<td>0.64</td>
<td>100</td>
<td>78</td>
</tr>
</tbody>
</table>

MRI: magnetic resonance imaging. R1: radiologist 1, R2: radiologist 2, OS: orthopedic surgeon, MR: magnetic resonance.
fellowship training.

We did not provide any patient characteristics to isolate and assess the role of the MRI, which is just one of the available diagnostic tools. Because age, sex, and history of recurrent instability can predispose patients toward a Hill-Sachs or other diagnosis in regular clinical practice, not providing this information allowed assessment of the research question based purely on MRI.

Statistical Analysis

Sample size was based on expert opinion, numbers of MRIs and respondents in previous studies, [19,20,22], and feasibility in terms of the time needed to complete the survey for the set of MRIs. All analyses were performed with Stata ver. 14 (StataCorp., College Station, TX, USA). Fleiss’ Kappas were compared using the STATA package Kappaetc [23].

The interobserver variability was determined using Fleiss’ Kappa, a statistical measure for assessing agreement of a fixed number of more than two observers. The kappa (κ) value is interpreted as poor (<0 points), slight (0.01–0.20), fair (0.21–0.40), moderate (0.41–0.60), substantial (0.61–0.80), or almost perfect (0.81–1) agreement. The overall kappa values were calculated for each MRI and indicated the extent to which surgeons agreed on the presence or absence of a Hill-Sachs lesion. All surgeon characteristics were presented in absolute numbers and percentages, and surgeons were grouped according to characteristics. A technique similar to the classical pairwise t-test for means, based on a large-sample linear approximation of Fleiss’ kappa, was used to test differences in interobserver agreement [24]. For clarity, we also presented the percentage of (observed) agreement, calculated as the average agreement between all possible pairs of r raters [23]. Statistical significance was set at p < 0.05. When comparing three groups, we applied the Bonferroni correction. For each MRI, the overall certainty was calculated by dividing the total numbers for each response that were given as absolutely certain, certain, some doubts, or very uncertain for all the questions by the total number of surgeons.

RESULTS

Surgeon Characteristics

We invited 106 surgeons in total, and 20 surgeons completed the survey (19%). The majority was employed in Europe and specialized in shoulder and elbow surgery. Among the three surgeons with another specialty, two specialized in orthopedic traumatology.

Interobserver Agreement for Presence of Hill-Sachs Lesions

The observer answers are summarized in Table 2, and there were only two cases with complete agreement between all surgeons. For eight of the 29 MRIs (28%), the responses were almost randomly distributed; 40%–60% of the surgeons identified a Hill-Sachs lesion, while the other 60%–40% did not. Together, all answers resulted in fair overall interobserver agreement for presence of a Hill-Sachs lesion (69% agreement; κ = 0.304; p < 0.001).

Certainty

Reponses for evaluating the presence of a Hill-Sachs lesion indicated that 32% of the answers were very certain, 52% were certain, 16% had some doubts, and 0% were very uncertain.

Effect of Characteristics on Interobserver Variability

Surgeons with 11–20 years of experience had better agreement than surgeons with 6–10 years of experience (11–20 years: 90% agreement; κ = 0.703 vs. 6–10 years: 66% agreement; κ = 0.235, p = 0.005). Having 0–5 years of experience did not influence agreement in comparison with 6–10 years (71% agreement; κ = 0.363 vs. 66% agreement; κ = 0.235, p = 0.046) or 11–20 years (71% agreement, κ = 0.363 vs. 90% agreement, κ = 0.703, p = 0.05).
Table 2. Results per MRI

<table>
<thead>
<tr>
<th>MRI</th>
<th>Hill-Sachs present</th>
<th>Certainty regarding presence of Hill-Sachs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yes (%)</td>
<td>No (%)</td>
</tr>
<tr>
<td>1</td>
<td>90</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>45</td>
<td>55</td>
</tr>
<tr>
<td>3</td>
<td>90</td>
<td>10</td>
</tr>
<tr>
<td>4</td>
<td>95</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>95</td>
</tr>
<tr>
<td>6</td>
<td>80</td>
<td>20</td>
</tr>
<tr>
<td>7</td>
<td>90</td>
<td>10</td>
</tr>
<tr>
<td>8</td>
<td>30</td>
<td>70</td>
</tr>
<tr>
<td>9</td>
<td>90</td>
<td>10</td>
</tr>
<tr>
<td>10</td>
<td>60</td>
<td>40</td>
</tr>
<tr>
<td>11</td>
<td>80</td>
<td>20</td>
</tr>
<tr>
<td>12</td>
<td>60</td>
<td>40</td>
</tr>
<tr>
<td>13</td>
<td>55</td>
<td>45</td>
</tr>
<tr>
<td>14</td>
<td>20</td>
<td>80</td>
</tr>
<tr>
<td>15</td>
<td>30</td>
<td>70</td>
</tr>
<tr>
<td>16</td>
<td>75</td>
<td>25</td>
</tr>
<tr>
<td>17</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>18</td>
<td>55</td>
<td>45</td>
</tr>
<tr>
<td>19</td>
<td>90</td>
<td>10</td>
</tr>
<tr>
<td>20</td>
<td>60</td>
<td>40</td>
</tr>
<tr>
<td>21</td>
<td>95</td>
<td>5</td>
</tr>
<tr>
<td>22</td>
<td>90</td>
<td>10</td>
</tr>
<tr>
<td>23</td>
<td>75</td>
<td>25</td>
</tr>
<tr>
<td>24</td>
<td>5</td>
<td>95</td>
</tr>
<tr>
<td>25</td>
<td>70</td>
<td>30</td>
</tr>
<tr>
<td>26</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>27</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>28</td>
<td>90</td>
<td>10</td>
</tr>
<tr>
<td>29</td>
<td>60</td>
<td>40</td>
</tr>
</tbody>
</table>

MRI: magnetic resonance imaging.

Country of specialty, shoulder and elbow specialty, and involvement in resident or fellowship training did not affect the level of agreement within subgroups of surgeons, as detailed in Table 3.

DISCUSSION

This study showed fair interobserver reliability to detect Hill-Sachs lesions on MRI, indicating that MRI alone should be interpreted with caution in clinical decision making. Although the surgeons were mostly (84%) certain or very certain regarding their decision about the presence of a Hill-Sachs lesion, the degree of agreement between surgeons in detecting a Hill-Sachs lesion on MRI was only fair. In this sample of 20 surgeons, agreement was not affected consistently by surgeon’s country of specialty, years of experience, specialty, or fellowship training.

The fair agreement for the presence of Hill-Sachs lesions could be attributed to difference in interpretation of the transition zone between cartilage and bone. Lack of cartilage can have the same appearance as an impression fracture and could be mistaken for a Hill-Sachs lesion, or vice versa. Moreover, the articular surface of the humeral head is the smallest in the superior-posterior segment and is the typical location of a Hill-Sachs lesion [25]. The anatomical humeral groove could be mistaken for a Hill-Sachs lesion [26]. Furthermore, detecting a Hill-Sachs lesion is difficult, even when assessing on arthroscopic videos, even though arthroscopy is the gold standard. Sasyniuk et al. [27] reported that only 35% of the surgeons assessing videotapes of arthroscopic procedures agreed on the presence of a Hill-Sachs lesion. Additionally, a previous study showed fair agreement between radiologists and fair to poor agreement between radiologists and an
orthopedic surgeon in detecting Hill-Sachs lesions [18]. However, the present study included only two radiologists and one orthopedic surgeon.

The fact that the two surgeons with 11–20 years of experience had better agreement when assessing the presence of a Hill-Sachs lesion supports the value of subspecialties. Our results show a slightly higher agreement between surgeons with less than 5 years of experience in comparison with those with 6–10 years, but both agreements were fair with a difference of only 5%, which limits the clinical relevance of this finding. The fair agreement with high level of confidence about the presence of a Hill-Sachs lesion indicates that surgeons cannot rely on their personal sense of certainty for these types of diagnostic and treatment decisions.

We included a representative mix of MRIs that consisted of smaller and larger Hill-Sachs lesions as well as lesions that are similar in appearance to simulate the clinical setting. We agree that adding these cases of lesions with a similar appearance to a Hill-Sachs lesion likely limits agreement between surgeons, but deemed this inclusion an important parameter for adequately assessing agreement as these cases provided relevant simulations of the clinical population. There were cases in the set of MRIs that had varying agreement that ranged from bad to good, but the overall agreement was fair. We think that the overall agreement best represents the clinical setting that consists not only of cases wherein lesions are easily distinguished from each other.

There are some limitations for interpreting the results of this study. First, we only had a response rate of 19%, which could influence our data due to lack of generalizability to all surgeons. Second, we did not confirm the Hill-Sachs lesions by arthroscopy. However, the accuracy and correlation between the MRI and arthroscopic findings have been documented in previous studies [8,28]. Additionally, only 35% of the surgeons agreed on the presence of a Hill-Sachs lesion when assessing videotapes of arthroscopic procedures [27]. More importantly, MRI typically guides the decision for conservative or operative treatment. Therefore, it is important to reliably assess Hill Sachs lesions on MRI, prior to arthroscopic or other surgery. Given the lack of a true gold standard, we did not intend to standardize or confirm the presence or absence of the lesions, but instead provide evidence of a substantial lack of consensus, which needs to be addressed.

Another limitation is that we looked at years of experience of the surgeons and not at the volume of shoulder and elbow procedures they had performed. Years of experience might be biased due to young, subspecialized shoulder surgeons performing many more shoulder procedures than older surgeons who have a wider scope of interest. Finally, some of the MRIs were performed with intravascular contrast. To our knowledge, there is no known difference in assessing Hill-Sachs lesions between MRIs with and without contrast.

A strength of this study was that a widely used interobserver agreement method (kappa) was used to assess the degree of consensus between surgeons regarding the presence and treatment of Hill-Sachs lesions and was augmented with percentage of agreement, which is easier to interpret. Moreover, we assessed

### Table 3. Agreement by surgeon characteristics on presence of Hill-Sachs lesions

<table>
<thead>
<tr>
<th>Variable</th>
<th>Agreement (%)</th>
<th>Fleiss' kappa (κ)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Country of specialty</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Europe (n = 15, 75%)</td>
<td>70</td>
<td>0.323</td>
<td>0.863 (vs. USA)</td>
</tr>
<tr>
<td>United States (n = 2, 10%)</td>
<td>66</td>
<td>0.289</td>
<td>0.394 (vs. other)</td>
</tr>
<tr>
<td>Other (n = 3, 15%)</td>
<td>66</td>
<td>0.114</td>
<td></td>
</tr>
<tr>
<td><strong>Year of practice</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0–5 (n = 8, 40%)</td>
<td>71</td>
<td>0.363</td>
<td>0.046 (vs. 6–10)</td>
</tr>
<tr>
<td>6–10 (n = 10, 50%)</td>
<td>66</td>
<td>0.235</td>
<td>0.050 (vs. 11–20)</td>
</tr>
<tr>
<td>11–20 (n = 2, 10%)</td>
<td>90</td>
<td>0.703</td>
<td>0.005*(vs. 11–20)</td>
</tr>
<tr>
<td><strong>Specialty</strong></td>
<td></td>
<td></td>
<td>0.876</td>
</tr>
<tr>
<td>Shoulder and elbow surgery (n = 17, 85%)</td>
<td>69</td>
<td>0.298</td>
<td></td>
</tr>
<tr>
<td>Other (n = 3, 15%)</td>
<td>68</td>
<td>0.276</td>
<td></td>
</tr>
<tr>
<td><strong>Involved in resident or fellow training</strong></td>
<td></td>
<td></td>
<td>0.172</td>
</tr>
<tr>
<td>Yes (n = 13, 65%)</td>
<td>67</td>
<td>0.259</td>
<td></td>
</tr>
<tr>
<td>No (n = 7, 35%)</td>
<td>72</td>
<td>0.366</td>
<td></td>
</tr>
</tbody>
</table>

*Statistically significant.

https://doi.org/10.5397/cise.2021.00115
consensus based on MRIs, which are most commonly used to detect pathology that causes glenohumeral instability [7]. In addition, we deliberately withheld patient characteristics from the reviewers to isolate the role of MRI in detecting a Hill-Sachs lesion without confounding factors. Our findings of limited agreement support the need for international criteria and guidelines for diagnosing Hill Sachs lesions.

Future research could address the disagreements that arise by evaluating and defining the criteria for individual surgeons to use to diagnose Hill Sachs lesions. These criteria can be considered and included in guideline development. Furthermore, an important and trending topic is to evaluate the most reliable measurement for glenoid and humeral bone loss [29,30]. Finally, the interobserver agreement of surgeons or radiologists could be measured for other imaging techniques, such as CT scans. Although surgeons are highly confident in their ability to detect Hill-Sachs lesions, in the absence of patient characteristics, there is only fair agreement between surgeons for detecting Hill-Sachs lesions on MRI.

ACKNOWLEDGMENTS

Shoulder and Elbow Center (collaborators): Gregory R. Waryasz; Matthijs R. Krijnen; Pierre Mansat; Sven A.F. Tulner; Christian M. Fortanier; Carola E. van Eck; Ruud P. van Hove; Christiaan J.A. van Bergen; John N. Trantalis; Paul Hoogervorst; Tjarco D.W. Alta; Guus J.M. Janus; Alexander van Tongel; Diederik J.W. Meijer; Ronald N. Wessel; Mark Schnetze; John Cheung; Derek F.P. van Deurzen.

ORCID

Hassanin Alkaduhimi https://orcid.org/0000-0002-3762-9828
Ihsan Amajjar https://orcid.org/0000-0001-5464-8636
Marije F. van Wier https://orcid.org/0000-0002-6464-1291
Nienke W. Willigenburg https://orcid.org/0000-0002-3698-7658
Michel P.J. van den Bekerom https://orcid.org/0000-0002-1184-0529

REFERENCES


Distal clavicle fractures have been classified by many authors, and the most accepted classification was proposed by Neer [1]. When present, fracture displacement is conditioned by the weight of the arm that displaced the distal fragment downwardly and by insertion of the trapezius muscle to move the proximal fragment superiorly. We present an unusual case of inferior displacement of the proximal fragment with indemnity of the coracoclavicular ligaments, and we propose the mechanism of injury.

CASE REPORT

The patient signed the informed consent provided by our institution. A 15-year-old male sustained a painful right shoulder injury following a fall from a bike onto an outstretched hand. Physical examination showed pain and swelling at the level of the distal clavicle and disclosed no neurovascular injuries. The radiographic exam, including a Zanca view, showed an unstable fracture of the distal clavicle with decreased coracoclavicular distance. The proximal fragment of the fracture was displaced inferiorly and slightly posteriorly onto the supraspinatus fossa. There was no contact between the ends of the fracture (Fig. 1). A three-dimensional computed tomography (CT) reconstruction showed a decrease in distance between the clavicle and coracoid process, suggesting that the coracoclavicular ligaments were unaffected. The distal fragment showed an increase of 10–11 mm, within the normal limit (Figs. 2 and 3), and slight posterior displacement (Fig. 4).

As contact between fragments was not appreciated, the risk of nonunion was considered high, so surgical treatment was chosen. Using a superior approach, we performed an open reduction and internal fixation. For osteosynthesis, we use an locking compression plate distal clavicle plate (DePuy Synthes, Bridgewater, MA, USA) (Fig. 5). The integrity of the coracoclavicular ligaments, revealed during surgery, was intact but stretched. The injured limb was immobilized in a sling for three weeks, after which the patient began a specific rehabilitation treatment. Ten weeks after surgery, fracture healing was observed on the X-ray.

Keywords: Clavicle; Fracture; Fracture fixation, internal
DISCUSSION

Many authors have proposed classification systems for clavicle fractures. Allman [2] classified clavicle fractures into three types based on anatomical location without considering treatment or prognostic significance. Nordqvist and Petersson [3] broadened Allman’s classification according to degree of displacement. Robinson [4] classified clavicle fractures base on joint involvement. The most accepted classification, described by Neer [1] and described by Rockwood [5], added two subtypes to describe five types of fractures of the distal clavicle. Type I fracture occurs lateral to the coracoclavicular ligaments attachment with minimal displacement. Fractures of this type are subject to conservative exam, and the patient reached a pain-free range of motion.
treatment. A type II fracture is medial to the ligament attachment and is divided into IIA and IIB. In IIA, both coracoclavicular ligaments are attached to the distal fragment, while in IIB, the conoid is detached from the proximal fragment of the fracture while the trapezoid remains attached to the distal fragment. Type III is an intra-articular fracture. Type IV occurs in children when a periosteal sleeve avulses from the inferior side of the clavicle with the attached coracoclavicular ligaments. Similar to type II, type V is a fracture with an avulsion that leaves behind an inferior cortical fragment attached to the coracoclavicular ligaments. In types II, IV, and V, the proximal fragment is displaced superiority by the action of trapezius muscle.

In the present case, the fracture was lateral to the insertion of the coracoclavicular ligaments, so it would be classified as a type I clavicular fracture. Type I fractures, however, have minimal displacement, so it is difficult to classify our case into this group. Furthermore, although this case could be considered a type IV variant given the age of the patient, the superior displacement of the medial fragment and the complete ossification of the epiphyseal cartilage exclude this type.

The mechanism of injury most often associated with a clavicle fracture is a direct blow to the shoulder. The compressive strength causes the fracture and the usual displacement of the fragments [6]. We suggest that the mechanism of injury in this case is different than usual because the patient reported a fall onto an outstretched hand, an indirect mechanism in which a force applied through the upper limb causes an increase of the proximal humerus and promotes injury. This mechanism has been reported previously as a rare cause of clavicle fracture in only 6% of cases [6].

An indirect mechanism has been reported in some cases of acromioclavicular dislocation [7]. Upward force applied to the humerus disrupts the acromioclavicular ligaments. This mechanism causes downward displacement of the clavicle, corresponding to type VI of Rockwood's classification [8]. Inferior dislocation of the distal end of the clavicle is rare, often is the result of severe trauma, and is combined frequently with multiple injuries. In type VI clavicle fractures, the coracoclavicular ligaments are intact if displacement of the proximal fragment is subacromial or torn if it is subcoracoid [7]. We suggest that the mechanism of injury in the present case is similar to that of type VI of Rockwood's classification but does not involve ligament rupture. In our case, instead of acromioclavicular dislocation, there is a fracture of the distal clavicle with inferior displacement of the medial fragment (Fig. 6).

The literature does not reveal any cases similar to ours. One report described two cases with a similar pattern of fracture but with coracoclavicular ligaments rupture [9]. Following the existing classifications for fractures of the distal clavicle, our case corresponds to type I of Neer's classification and should be susceptible to conservative treatment. The large displacement caused by the unusual indirect mechanism, however, prompted osteosynthesis, with an excellent functional outcome.

**ORCID**

Alberto Izquierdo Fernández  https://orcid.org/0000-0002-4270-0852
José Carlos Minarro  https://orcid.org/0000-0002-4491-0124

**REFERENCES**

Renal cell carcinoma (RCC) originates from the epithelium of the proximal convoluted renal tubules. RCC has a propensity for metastasis, and the frequency of spread varies: 60%–75% spread to the lungs, 60%–65% to the regional lymph nodes, 39%–40% to the liver, 20%–35% to the bones, and 5%–7% to the brain [1].

Even though more than 60% of RCC patients develop various metastases during the course of their disease, not many reports describe metastasis around orthopedic implants. Here, we present a case of RCC that metastasized to the proximal humerus in a patient who had undergone arthroscopic rotator cuff repair using suture anchor implants 6 years previously. After diagnosis of bone metastasis, she was successfully treated with metastasectomy and internal fixation using a plate and screws, with cement augmentation. This report is the first to document metastases around a suture anchor in a bone and suggests the vulnerability of suture anchor implants to tumor metastasis.

Keywords: Metastasis; Renal cell carcinoma; Suture anchor; Orthopedic implant; Metastasectomy

CASE REPORT

A 78-year-old female was referred for pain and pseudoparesis of the right shoulder along with a firm, bulging mass. Six years previously, she had undergone arthroscopic rotator cuff repair (RCR) for a painful and large rotator cuff tear using crossFT (Conmed, Utica, NY, USA) suture anchors at the medial footprint and SwiveLock SP (Arthrex, Naples, FL, USA) anchors at the lateral humeral cortex. The crossFT anchor was composed of polyether ether ketone materials, and the SwiveLock SP anchor had a titanium tip. The patient's symptoms improved after RCR, and postoperative images showed well-maintained continuity and thickness of the repaired tendon. Two weeks after RCR, a 7.9-cm-sized heterogeneous mass was detected in the upper pole of the
left kidney, and she underwent laparoscopic nephrectomy one week later. The final diagnosis was grade 3 clear cell RCC.

About 75 months after RCR, a simple X-ray showed an expansile lytic bone lesion with an ill-defined border and a broad zone of transition in the right proximal humerus around anchor implants (Fig. 1A and B). Magnetic resonance imaging showed a T2-hyperintense and T1-hypointense, 4.3×3.5×4.3-cm-sized, poorly circumscribed, cortical-destructive lesion with peri-osseous mass formation (Fig. 1C and D). The findings suggested metastasis, and infection or anchor foreign body reactions were unlikely. Collaborating with colleagues in the Departments of Medical Oncology and Radiation Oncology, we planned the patient’s postoperative treatment, such as palliative radiotherapy or systemic chemotherapy. A whole-body bone scan to identify additional metastatic lesions prior to surgery demonstrated foci, suggesting the possibility of bone metastases in the left ischium, lateral condyle of the left femur, and distal shaft of the right femur in addition to the primary focus (Fig. 1E). Because the patient did not report additional symptoms that correlated with the scan result, further evaluation was not performed.

For treatment of this metastatic lesion, she underwent metastasectomy without preoperative embolization and internal fixation with cement augmentation. During the metastasectomy, an exophytic highly vascular mass with several feeding arteries surrounded by lateral anchors was found and removed. After surgery, only a friable medial cortex remained, and the distal humerus was impacted into the humeral head. Therefore, plate (PHILOS; DePuy Synthes, Raynham, MA, USA) fixation with cement augmentation was performed to increase stability (Fig. 2A-D). Histopathology confirmed that the lesion was metastatic clear cell RCC (Fig. 3).

The patient’s postoperative course was uneventful. One month after surgery, she started Votrient (pazopanib) chemotherapy, resulting in symptomatic improvement in her right shoulder. Two months after surgery, she could dress herself, and the range of motion improved, with 70° of active elevation, active deltoid muscle contracture. A postoperative chest radiograph demonstrated no evidence of fixation loss or recurrence (Fig. 2E). Informed consent for this retrospective study was waived under the approval of the Institutional Review Board of Konkuk University.

Fig. 1. Anteroposterior (A) and axial (B) radiographs demonstrated an osteolytic radiolucent lesion of the proximal humerus that also surrounded suture anchor implants. T2 coronal (C) and T1 coronal (D) magnetic resonance images revealed a cortical destructive mass lesion with peri-osseous mass formation. (E) A whole-body bone scan demonstrated multiple bone metastases.

https://doi.org/10.5397/cise.2021.00199
DISCUSSION

RCC is classified into clear cell, papillary, chromophobe, multilocular cystic, collecting duct, medullary, and unclassified types according to histology. The clear cell type is most frequently reported. Bone metastasis, observed in one-third of patients with RCC, has a higher incidence in patients with clear cell type RCC [1]. Resection of the metastases followed by local and systemic therapies is reported to improve prognosis. Surgical excision, however, can be difficult because metastases tend to be large, progressive, highly destructive, hypervascularized, and associated with a soft-tissue mass.

Only a few studies have previously reported metastasis around orthopedic implants, and most of these reports were confined to implants of total arthroplasty or plates [2,3]. The reported cases of metastasis around orthopedic implants have originated from non-Hodgkin’s lymphoma, malignant fibrous histiocytoma, immunoblastic lymphoma, carcinomas of the lung, gastric carcinoma, endometrial carcinoma, ovarian carcinoma, RCC, hepatocellular carcinoma, and prostate cancer [2-4]. Although various cancers have been reported, no definite common denominator exists among cases of metastasis. Most metastatic lesions, however, showed periprosthetic osteolysis around the metal implants. Although we do not know the exact mechanism of metastasis around implants (or whether there is a cause-and-effect relationship), we believe that dissemination of cancer cells via blood ves-

Fig. 2. An expansile metastatic mass (black arrow) (A) was observed intraoperatively, followed by plate fixation and cement augmentation (B). Immediate postoperative anteroposterior (C) and axial (D) radiographs demonstrated the metastasectomy margin, and postoperative chest radiograph (E) revealed neither fixation loss nor recurrence at 8 months following surgery.

Fig. 3. High-power photomicrography (H&E, ×100) confirmed metastatic renal cell carcinoma with polyclonal cells containing abundant clear cytoplasm and round-to-oval hyperchromatic nuclei, similar to clear cell change (black arrow).
sels to tissues weakened by surgical trauma can affect the course of metastasis, and more cancer cells can accumulate on implants, which are foreign bodies [5].

Regarding RCC metastases to orthopedic implants, three case reports described metastases around total hip arthroplasty implants [6-8]. Two occurred around femoral implants [6,8], and one occurred around an acetabular implant [7]. All three cases showed loosening of the implants by metastatic infiltration. Two cases [7,8] were treated by revision arthroplasty, and one case [6] utilized open biopsy of the femoral bone for diagnosis followed by palliative treatment.

No previous reports documented metastasis around a suture anchor inserted in bone. RCC is a highly vascularized tumor with extensive, thin-walled, sinusoid-like vessels, producing areas with a rich blood supply (such as the vertebrate or pelvis) prone to metastasis. We believe this feature of blood-born RCC metastasis can cause cancer cells to spread around the suture anchor at a site of surgical trauma. Several authors have postulated that abnormal blood flow increases due to surgical insult and the healing response, and this increased blood flow can create a predilection for metastases. In addition, a hematoma formed during RCR could be a hotbed for cancer cell seeding [9]. Furthermore, the suture anchor implant is a foreign body inside a bone, which can cause a foreign body reaction, such as activation of macrophages, giant cells, and leukocytes [10]. This foreign body reaction can facilitate the growth of blood-borne tumors, as suggested by Murphy et al. [5] However, these explanations for increased susceptibility to metastasis around implants are only hypotheses and are not fully understood; thus, they warrant further study. We believe our case demonstrates the vulnerability of suture anchor implant after RCR to increase susceptibility to tumor metastasis.

This is the first report documenting a case of RCC metastasis around a suture anchor implant after RCR. Clinicians must maintain a high index of suspicion and consider the possibility of metastases around orthopedic implants in patients with malignancies of various origins.

ORCID

Samuel Baek https://orcid.org/0000-0001-9904-1184
Myung Ho Shin https://orcid.org/0000-0002-2134-6946
Tae Min Kim https://orcid.org/0000-0002-3977-536X
Kyung-Soo Oh https://orcid.org/0000-0002-9812-9130
Dong Ryun Lee https://orcid.org/0000-0001-5305-1475
Seok Won Chung https://orcid.org/0000-0002-8221-9289

REFERENCES

The best options in superior capsular reconstruction

Dong Hyun Kim, Young Soo Jung, Kyung-Rock Kim, Jong Pil Yoon

Department of Orthopedic Surgery, School of Medicine, Kyungpook National University, Daegu, Korea

Irreparable massive rotator cuff tears cause pain, loss of function, and a decrease in range of motion, which cause serious disturbances in daily life. Young patients, in particular, are active and have relatively high functional requirements, and their surgical options are limited. Superior capsular reconstruction (SCR) was first proposed for irreparable massive rotator cuff tears, and good clinical results have been reported in short-term follow up. Since then, SCR has been used increasingly worldwide for irreparable massive rotator cuff tears, and various studies have been published on clinical outcomes, biomechanical outcomes, surgical techniques, and graft types. This article reviews the optimal graft and surgical options for improving clinical outcomes in SCR.

Keywords: Rotator cuff; Shoulder; Superior capsular reconstruction; Tendon

INTRODUCTION

Irreparable massive rotator cuff tears cause pain, loss of function, and a decrease in range of motion, which cause serious disturbances in daily life [1,2]. In addition, since repairing irreparable massive rotator cuff tears have difficulty in complete footprint coverage and a high frequency of re-rupture, the postoperative clinical results often are unsatisfactory [3,4]. For this reason, in elderly patients with relatively few functional requirements, there are various surgical options for massive rotator cuff tears, such as debridement, biceps tenotomy/tenodesis, partial repair, tendon transfer, and reverse total shoulder arthroplasty (RTSA) [5-7]. However, since young patients are active and have relatively high functional requirements, these surgical options are limited to tendon transfer and patch augmentation [8,9]. In addition, although previous studies have reported that RTSA has good clinical result in elderly patients with massive rotator cuff tears, RTSA in active young patients under the age of 65 demonstrates relatively high complications and failure rates, and it is not an optimal surgical option in terms of longevity [10-12].

Mihata et al. [13,14] first proposed superior capsular reconstruction (SCR) using autologous tissue for irreparable massive rotator cuff tears, and they reported good clinical results in short-term follow up. Since then, SCR has been increasingly used for irreparable massive rotator cuff tears, and various studies have been published on clinical outcomes, biomechanical outcomes, surgical techniques, and graft types. A previous systematic review reported that SCR reduced acromial contact pressure, produced superior humeral translation, and improved short-term clinical outcomes [15,16]. However, biologic healing at the contact sur-
face between graft and bone is the most important factor to improve mid- and long-term outcomes of SCR [16,17]. Therefore, for optimal biologic healing, selection of an optimal graft and appropriate surgical technique must be considered. For this reason, this article reviews the optimal graft and surgical options for improving clinical outcomes in SCR.

**GRAFT OPTIONS**

Mihata et al. [13] originally used a fascia lata autograft to reconstruct the superior capsule. Although their early results are promising, the fascia lata graft is thin, requiring doubling of the construct and a relatively large donor incision for harvesting. As an alternative, acellular dermal allografts were proposed for their theoretical advantages of reduced donor site morbidity, shorter associated operative times, ease of preparation, and strength of the graft [18,19]. Most of the previously reported studies described SCR using fascia lata graft or dermal allograft (Table 1) [20-29]. Various biomechanical studies and clinical results report their use in SCR. Recently, however, various other autografts, allografts, xenografts, and synthetic grafts have been used in SCR, and the clinical results have been reported (Table 2) [30-34].

**Tensor Fascia vs. Dermal Allograft**

In a biomechanical cadaveric study comparing a fascia lata graft and a human dermal graft, single-layered human dermal allografts partially restored superior glenohumeral stability, whereas a fascia lata allograft completely restored superior glenohumeral stability [35]. A biomechanical comparison on the effect of SCR using a 3- and 6-mm-thick acellular dermal allograft demonstrated that SCR with a 6-mm-thick acellular dermal allograft better restored normal glenohumeral joint position and forces compared with a 3-mm-thick graft [36]. A biomechanical characterization of SCR using a fascia lata allograft, double layer dermal allograft, and single layer dermal allograft revealed that all three graft types can restore superior translation and subacromial contact pressure depending on the glenohumeral abduction angle, and fascia lata and double layer dermis can be more effective than single layer dermis [37]. SCR with a single 6-mm-thick acellular dermal allograft is non-inferior to fascia lata regarding subacromial space distance and peak subacromial contact pressures while restoring the superior stability of the glenohumeral joint compared to an intact joint [38].

Mihata et al. [39] reported the functional and radiographic results of SCR after 5 years of follow-up. Healed arthroscopic superior capsule reconstruction restored shoulder function and resulted in high rates of return to recreational sport and work. None of the 27 patients who experienced graft healing showed progression of cuff tear arthropathy, but all three patients with a graft tear had severe cuff tear arthropathy at 5 years postoperatively. A systematic review described two studies using only a fascia lata autograft and three studies using only a human dermal allograft, and the mean follow-up time ranged from 12 to 48 months. All studies reported statistically significant and clinically important mean improvements in active elevation (range of mean, 28°–56°), the Constant score (range of mean, 12–47.1 points), or the American Shoulder and Elbow Surgeons (ASES) score (range of mean, 29.3–56 points). In total, 218 shoulders underwent postoperative magnetic resonance imaging. The graft tear rate reported in the studies using a fascia lata autograft (181 shoulders) ranged from 5% to 32%, whereas the values reported in studies using a human dermal allograft (37 shoulders) ranged from 20% to 75% [40]. Another systematic review reported five fascia lata autograft clinical studies and four only-human dermal allograft clinical studies. Increases in ASES scores, forward elevation and external rotation values, and acromiohumeral distance (AHD) were found in all clinical fascia lata autograft studies. The human dermal allograft clinical studies reported increases in ASES scores, forward elevation values, and AHD but decreases in VAS scores [16].

**Other Graft Materials**

In SCR, there are not many studies on grafts other than fascia lata and dermal graft. However, as with patch augmentation in massive rotator cuff tears, various types of grafts are being tried. Few reports on the clinical outcome of these various grafts exist, and the surgical techniques are still mostly introduced.

**Biceps autograft**

The long head of the biceps tendon (LHBT) is a local autograft; the patient does not have donor site morbidity. All procedures are performed on the same shoulder, reducing operative time and risk of infection. Preserved vascular supply of the transposed LHBT can improve healing progression of rotator cuff repair. There is no extra cost for an allograft or an artificial graft [31]. Few reports reveal the clinical outcome of SCR using LHBT, but it has been reported to have significant effects in several biomechanical studies [41,42]. Most reports describe the surgical technique of SCR using LHBT [31,43-46].

El-Shaa et al. [42] reported in a study of 10 cadaveric shoulders that SCR with an LHBT autograft is a feasible procedure that is biomechanically equivalent and potentially even stronger than SCR with a fascia lata autograft for prevention of superior humeral migration. SCR with an LHBT autograft required...
<table>
<thead>
<tr>
<th>Study</th>
<th>Graft type</th>
<th>Graft thickness (mm)</th>
<th>Approach</th>
<th>Graft tensioning</th>
<th>Fixation technique</th>
<th>Margin convergence suture</th>
<th>Acromioplasty</th>
</tr>
</thead>
<tbody>
<tr>
<td>de Campos Azevedo et al. (2018) [22]</td>
<td>TF</td>
<td>5–8</td>
<td>A/S</td>
<td>10° Abduction</td>
<td>Med, 2 anchors; Lat, 2 by 2 double row</td>
<td>Anterior</td>
<td>(+/–)</td>
</tr>
<tr>
<td>Lim et al. (2019) [26]</td>
<td>TF</td>
<td>&gt; 6</td>
<td>A/S</td>
<td>NA</td>
<td>Med, 2 or 3 anchors; Lat, 2 by 2 double row</td>
<td>Anterior</td>
<td>(+)</td>
</tr>
<tr>
<td>Yoon et al. (2018) [27]</td>
<td>TF</td>
<td>NA</td>
<td>A/S</td>
<td>NA</td>
<td>Med, 2 anchors; Lat, 2 by 2 double row</td>
<td>Anterior</td>
<td>NA</td>
</tr>
<tr>
<td>Lee and Min (2018) [23]</td>
<td>TF</td>
<td>~6</td>
<td>A/S</td>
<td>30° Abduction</td>
<td>Med, 2 anchors; Lat, 2 anchors single row</td>
<td>Posterior</td>
<td>NA</td>
</tr>
<tr>
<td>Hirahara et al. (2017) [28]</td>
<td>ADM</td>
<td>1.5/3.5</td>
<td>A/S</td>
<td>NA</td>
<td>Med, 2 by 1 PASTA bridge; Lat, 2 by 2 double row</td>
<td>Posterior</td>
<td>NA</td>
</tr>
<tr>
<td>Pogorzelski et al. (2017) [29]</td>
<td>ADM</td>
<td>3</td>
<td>A/S</td>
<td>NA</td>
<td>NA</td>
<td>Posterior</td>
<td>(+/–)</td>
</tr>
<tr>
<td>Denard et al. (2018) [20]</td>
<td>ADM</td>
<td>1/2/3</td>
<td>A/S</td>
<td>NA</td>
<td>Med, 2 or 3 anchors; Lat, 2 by 2 double row</td>
<td>Posterior</td>
<td>(+/–)</td>
</tr>
<tr>
<td>Pennington et al. (2018) [24]</td>
<td>ADM</td>
<td>3</td>
<td>A/S</td>
<td>45° Abduction</td>
<td>Med, 3 push-in anchors; Lat, 2 by 2 double row</td>
<td>Anterior</td>
<td>NA</td>
</tr>
<tr>
<td>Burkhart et al. (2020) [21]</td>
<td>ADM</td>
<td>3</td>
<td>A/S</td>
<td>20°–30° Abduction</td>
<td>Med, 2 or 2 anchors; Lat, 2 by 2 double row</td>
<td>Anterior</td>
<td>NA</td>
</tr>
</tbody>
</table>

Table 2. Graft options reported in SCR

<table>
<thead>
<tr>
<th>Category</th>
<th>Graft type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Autografts</td>
<td>Fascia lata, biceps tendon, semitendinosus tendon</td>
</tr>
<tr>
<td>Allografts</td>
<td>Human dermal matrix, fascia lata, Achilles tendon, semitendinosus tendon</td>
</tr>
<tr>
<td>Synthetic grafts</td>
<td>Teflon Patch</td>
</tr>
<tr>
<td>Xenografts</td>
<td>Acellular porcine dermal xenograft, DX reinforce-ment matrix</td>
</tr>
</tbody>
</table>

SCR: superior capsular reconstruction.

393.2% ± 87.9% (p = 0.029) of the force needed for superior humeral migration in massive rotator cuff tear, while SCR with a fascia lata autograft required 194.0% ± 21.8% (p = 0.013). The LHBT reconstruction group trended toward a stronger reconstruction when normalized to the torn condition (p = 0.059). Han et al. [41] reported a cadaveric study in seven shoulders. A modified SCR using LHBt both with and without side-to-side repair shifted the humeral head inferiorly at 30° and 60° of glenohumeral abduction, with the contact area further reduced at 60°. The techniques had comparable results for contact pressure and total rotational range of motion. They suggested that the LHBt with appropriate distal insertion on the greater tuberosity restores shoulder stability in irreparable rotator cuff tears by re-centering the humeral head on the glenoid.

Barth et al. [30] reported the clinical outcomes in 24 patients who underwent SCR with LHBt autograft. Twenty-four months after surgery, the group undergoing SCR with the LHBt showed improvement in absolute Constant score from 50 to 77, ASES from 45 to 80, Subjective Shoulder Score from 41% to 75%, the Simple Shoulder Test from 3.6 to 8.4, and the visual analog scale (VAS) from 5.2 to 1.4. In all cases, the p-value was < 0.001. The strength of the operated arm improved from 2.3 kg to 6.4 kg (p < 0.001), and 91.7% (22/24) of the SCR group remained healed on ultrasound.

Semitendinosus tendon autograft
Rosales-Varo et al. [47] proposed an open technique for SCR with an autologous semitendinosus tendon graft in a reverse V-shaped configuration (single fixation point on the glenoid and double fixation on the greater tuberosity). They found an improvement in Constant score from 49 (before SCR) to 77.25 (1 year after the operation). The mean active flexion significantly increased from 99.3° to 142.5° (p < 0.01). The mean preoperative AHD increased from 5.25 (before surgery) to 8.18 (after SCR). There were no tears of the graft during follow-up [47]. The technique is safe and reliable and has some potential advantages related to cost and lesser morbidity than the fascia lata autograft. Moreover, the tendon length allows for different configurations (double strand, V shaped, reverse V shaped, or box shaped). Milano et al. [48] also reported an all-arthroscopic technique for superior capsule reconstruction using a doubled semitendinosus tendon autograft in a box-shaped configuration. They only reported the surgical technique, however, and not the clinical outcome.

Patellar tendon allograft
Croom et al. [49] reported SCR using a patellar tendon allograft (PT-SCR) in a study of eight cadaveric shoulders. They compared rotational range of motion, superior translation, and subacromial contact pressure, which were measured in the following experimental conditions: intact rotator cuff, massive rotator cuff tear, and PT-SCR. Application of the PT-SCR resulted in a decrease of superior translation compared with massive rotator cuff tear (p < 0.001). At 0° abduction/60° external rotation and 0° abduction/90° external rotation, massive rotator cuff tear showed significantly greater peak subacromial contact pressure compared with the intact state (p < 0.006). At both of these positions, PT-SCR was able to reduce peak pressure to lower than or no significant difference from the intact state. There was no significant change in graft thickness, length, or width after testing. PT-SCR was able to reduce superior translation of the humeral head and peak subacromial contact pressure without restricting range of motion. Furthermore, there was no significant graft deformation during testing. They suggested that PT-SCR in this validated cadaveric model demonstrates favorable biomechanical properties and is a viable source of graft material for SCR.

Achilles tendon-bone allograft
Kim and Nam [33] reported arthroscopic SCR by the mini-open modified keyhole technique using an Achilles tendon–bone allograft. Using a keyhole to reduce graft tear in the greater tuberosity, they focused on saving operative time and the surface, such that bone-to-bone healing was induced by the tendon-bone graft. In another study on anterior cruciate ligament reconstruction, healing and revascularization were induced by grafting the Achilles tendon-bone through bone tunneling. In this way, they confirmed that the Achilles tendon–bone graft had a good effect in SCR by creating a keyhole-shaped tunnel in the humeral head. An appropriate size and thickness can be achieved with the Achilles tendon through appropriate folding due to the large-sized graft. Although there is a risk of additional fractures due to artificial hole formation, it can be difficult to rehabilitate because bone healing should occur within a particular time frame. However, they followed the same rehabilitation protocol as that used in the general SCR technique.
Xenograft

Acellular porcine dermal xenograft

Polacek [50] evaluated the short-term clinical outcomes and complications related to arthroscopic SCR with an acellular porcine dermal xenograft for treatment of irreparable massive rotator cuff tears in a total of 20 shoulders in 19 patients with rotator cuff tear. He reported mean range of motion, and the Shoulder Pain and Disability Index score showed significant improvement from 51.3% to 10.4% at 1-year follow-up. Active abduction improved from 65.4° to 149.3°, and active forward flexion improved from 68.6° to 151.4° at 1-year follow-up. However, the procedure had a 30% complication rate, including a 15% rate of immunologic rejection of the xenograft [50].

DX reinforcement matrix

Kalina et al. [32] reported the clinical outcome of SCR using the DX Reinforcement (Arthrex, Naples, FL, USA) at 1 year (range, 6–18 months) in a total of 20 SCRs. The University of California–Los Angeles score improved from 10 to 29, the ASES from 23.8 to 73.2, and the VAS from 7 to 2. The mean active shoulder flexion was 74° preoperatively and 161° postoperatively. The mean active abduction was 74° preoperatively and 161° postoperatively. The mean active external rotation of the shoulder joint was 20° preoperatively and 56° postoperatively. The mean active external rotation at 90° abduction was 21° preoperatively and 82° postoperatively. No complication specifically associated with use of xenograft has been reported.

Teflon patch

Teflon felt has been used for conventional patch graft surgery [51-53] (tendon reconstruction for rotator cuff tears), as well as in thoracic and cardiovascular surgery [54]. Okamura et al. [34] investigated the clinical and radiographic outcomes and postoperative complications of SCR using a Teflon graft of either 1 or 3 layers. They reported that SCR using a Teflon graft of either 1 or 3 layers significantly improved the ASES and VAS scores and muscle strength in shoulder abduction, with low rates of graft tears and complications after surgery.

Graft Tensioning (Fixation Angle)

For optimal fixation, graft tensioning has been implicated to play a major role in glenohumeral contact properties and forces [56]. In addition, previous literature suggests differences in ideal abduction angles during SCR graft fixation based on type of material used intraoperatively [20,56]. One method for tensioning the graft is through abduction of the glenohumeral joint during fixation. Mihata et al. [56] suggested that 8 mm graft thickness and an arm position between 15° and 45° of shoulder abduction are the major aspects for sufficient reconstruction of the superior capsule. Various abduction angles using dermal allografts have been described, ranging from 20° to 45° of clinical shoulder abduction [18,57]. However, the optimum graft tension for best results in SCR remains unclear. Adams et al. [58] reported that SCR with anterior and posterior margin convergence tensioned at 15° of glenohumeral abduction showed similar deltoid abduction force requirements to the native state in their biomechanical study. Dyrna et al. [59] reported in a biomechanical study of 10 fresh-frozen cadaveric shoulders that SCR using a graft fixed under tension (30 to 35 N) demonstrated a significant increase in maximum shoulder abduction compared with a nontensioned graft (65.0° ± 12.6° vs. 54.1° ± 16.1°, p = 0.04). However, abduction remained significantly less than in the intact state (79.8° ± 5.8°, p = 0.04). A tensioned SCR restored a maximum abduction of 81% of the native condition. Clinically, most surgeons have performed SCR graft fixation at 10° to 45° shoulder abduction per Mihata’s recommendation [21-24]. But, there is a lack of clear clinical evidence for optimal abduction angle based on graft type in SCR.
MARGIN CONVERGENCE SUTURING (SIDE-TO-SIDE SUTURING)

Mihata et al. [13] recommended side-to-side suturing between the graft and infraspinatus tendon or subscapularis tendon when performing SCR in irreparable rotator cuff tears. In biomechanical studies, SCR without side-to-side suturing did not decrease glenohumeral superior translation, although subacromial peak contact pressure decreased [60]. Adding side-to-side suturing restored superior stability to the intact level by achieving capsular continuity in the transverse direction. Total ROM did not decrease significantly after SCR with or without side-to-side suturing when the graft size matched the defect size [60].

ACROMIOPLASTY

Although SCR can increase the AHD, friction can be induced on the undersurface of the graft and acromion through movement after surgery, and this can cause a tear in the graft. Mihata et al. [13] recommended acromioplasty during SCR for irreparable rotator cuff tears. They also investigated the effects of acromioplasty on shoulder biomechanics after superior capsule reconstruction for irreparable supraspinatus tendon tears [61]. Including acromioplasty decreased the subacromial contact area without increasing the subacromial contact pressure in SCR. Clinically, it is not necessary to perform acromioplasty in SCR, and acromioplasty was not necessarily performed in other studies. However, most surgeons performed acromioplasty if there was evidence of abrasion on the undersurface of the acromion [24,62,63].

CONCLUSION

Since Mihata et al. [13] introduced SCR for irreparable rotator cuff tear several years ago, various studies on SCR have been conducted, and considerable progress has been made. The long-term clinical results of SCR are insufficient, however, and further studies on the various factors necessary for the best results in irreparable rotator cuff tear are needed. Knowledge of these various factors that must be considered for a successful SCR will lead to a better life for patients with massive rotator cuff tears.

ORCID

Dong Hyun Kim https://orcid.org/0000-0001-9078-5953
Young Soo Jung https://orcid.org/0000-0003-2518-2560
Kyung-Rock Kim https://orcid.org/0000-0002-1203-2742
Jong Pil Yoon https://orcid.org/0000-0001-6446-6254

REFERENCES

15. Smith TJ, Gowd AK, Kunkel J, Kaplin L, Waterman BR. Superi-
or capsular reconstruction provides sufficient biomechanical outcomes for massive, irreparable rotator cuff tears: a systematic review. Arthroscopy 2021;37:402-10.


Instructions to authors

Enacted from June 1, 2009
Revised on December 31, 2010
June 1, 2013
March 1, 2014
May 13, 2014
September 1, 2017
March 1, 2019
December 1, 2019

1. AIMS AND SCOPE

CiSE is an international, peer-reviewed journal and the official journal of Korean Shoulder and Elbow Society. It was first launched in 1998. It is published quarterly in the first day of March, June, September, and December, with articles in English, and has been published as an online-only journal since 2019.

The purpose of CiSE are: first to contribute in the management and education of shoulder and elbow topics; second, to share latest scientific informations among international societies; and finally to promote communications on shoulder/elbow problems and patient care. It can cover all fields of clinical and basic researches in shoulder and elbow.

Manuscripts submitted to CiSE should be prepared according to the following instructions. CiSE follows the Recommendations for the Conduct, Reporting, Editing, and Publication of Scholarly Work in Medical Journals (http://www.icmje.org/icmje-recommendations.pdf) from the International Committee of Medical Journal Editors (ICMJE).

2. RESEARCH AND PUBLICATION ETHICS

The journal adheres to the guidelines and best practices published by professional organizations, including ICMJE Recommendations and the Principles of Transparency and Best Practice in Scholarly Publishing (joint statement by the Committee on Publication Ethics [COPE], Directory of Open Access Journals [DOAJ], World Association of Medical Editors [WAME], and Open Access Scholarly Publishers Association [OASPA]; https://doaj.org/bestpractice). Further, all processes of handling research and publication misconduct shall follow the applicable COPE flowchart (https://publicationethics.org/resources/flowcharts).

Statement of Human and Animal Rights
Clinical research should be conducted in accordance with the World Medical Association’s Declaration of Helsinki (https://www.wma.net/what-we-do/medical-ethics/declaration-of-helsinki/). Clinical studies that do not meet the Helsinki Declaration will not be considered for publication. For human subjects, identifiable information, such as patients’ names, initials, hospital numbers, dates of birth, and other protected health care information, should not be disclosed. For animal subjects, research should be performed based on the National or Institutional Guide for the Care and Use of Laboratory Animals. The ethical treatment of all experimental animals should be maintained.

Statement of Informed Consent and Institutional Approval
Copies of written informed consent should be kept for studies on human subjects. Clinical studies with human subjects should provide a certificate, an agreement, or the approval by the Institutional Review Board (IRB) of the author’s affiliated institution. For research with animal subjects, studies should be approved by an Institutional Animal Care and Use Committee (IACUC). If necessary, the editor or reviewers may request copies of these documents to resolve questions regarding IRB/IACUC approval and study conduct.

Conflict of Interest Statement
The author is responsible for disclosing any financial support or benefit that might affect the content of the manuscript or might cause a conflict of interest. When submitting the manuscript, the author must attach the letter of conflict of interest statement (http://cisejournal.org/authors/copyright_transfer_agreement.php). Examples of potential conflicts of interest are financial support from or connections to companies, political pressure from interest groups, and academically related issues. In particular, all sources of funding applicable to the study should be explicitly stated.

Originality, Plagiarism, and Duplicate Publication
Redundant or duplicate publication refers to the publication of a paper that overlaps substantially with one already published. Upon receipt, submitted manuscripts are screened for possible
plagiarism or duplicate publication using Crossref Similarity Check. If a paper that might be regarded as duplicate or redundant had already been published in another journal or submitted for publication, the author should notify the fact in advance at the time of submission. Under these conditions, any such work should be referred to and referenced in the new paper. The new manuscript should be submitted together with copies of the duplicate or redundant material to the editorial committee. If redundant or duplicate publication is attempted or occurs without such notification, the submitted manuscript will be rejected immediately. If the editor was not aware of the violations and of the fact that the article had already been published, the editor will announce in the journal that the submitted manuscript had already been published in a duplicate or redundant manner, without seeking the author’s explanation or approval.

Secondary Publication
It is possible to republish manuscripts if the manuscripts satisfy the conditions for secondary publication of the ICMJE Recommendations.

Authorship and Author’s Responsibility
Authorship credit should be based on (1) substantial contributions to conception and design, acquisition of data, and analysis and interpretation of data; (2) drafting the article or revising it critically for important intellectual content; (3) final approval of the version to be published; and (4) agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. Authors should meet these four conditions.

- The contributions of all authors must be described. CiSE has adopted the CRediT Taxonomy (https://www.casrai.org/credit.html) to describe each author’s individual contributions to the work. The role of each author and ORCID number should be addressed in the title page.
- Correction of authorship: Any requests for such changes in authorship (adding author(s), removing author(s), or re-arranging the order of authors) after the initial manuscript submission and before publication should be explained in writing to the editor in a letter or e-mail from all authors. This letter must be signed by all authors of the paper. A copyright assignment must be completed by every author.
- Role of corresponding author: The corresponding author takes primary responsibility for communication with the journal during the manuscript submission, peer review, and publication process. The corresponding author typically ensures that all of the journal’s administrative requirements, such as providing the details of authorship, ethics committee approval, clinical trial registration documentation, and conflict of interest forms and statements, are properly completed, although these duties may be delegated to one or more coauthors. The corresponding author should be available throughout the submission and peer review process to respond to editorial queries in a timely manner, and after publication, should be available to respond to critiques of the work and cooperate with any requests from the journal for data or additional information or questions about the article.
- Contributors: Any researcher who does not meet all four ICMJE criteria for authorship discussed above but contribute substantially to the study in terms of idea development, manuscript writing, conducting research, data analysis, and financial support should have their contributions listed in the Acknowledgements section of the article.

Process for Managing Research and Publication Misconduct
When the journal faces suspected cases of research and publication misconduct, such as redundant (duplicate) publication, plagiarism, fraudulent or fabricated data, changes in authorship, undisclosed conflict of interest, ethical problems with a submitted manuscript, appropriation by a reviewer of an author’s idea or data, and complaints against editors, the resolution process will follow the flowchart provided by COPE (http://publicationethics.org/resources/flowcharts). The discussion and decision on the suspected cases are carried out by the Editorial Board.

Editorial Responsibilities
The Editorial Board will continuously work to monitor and safeguard publication ethics: guidelines for retracting articles; maintenance of the integrity of academic records; preclusion of business needs from compromising intellectual and ethical standards; publishing corrections, clarifications, retractions, and apologies when needed; and excluding plagiarized and fraudulent data. The editors maintain the following responsibilities: responsibility and authority to reject and accept articles; avoid any conflict of interest with respect to articles they reject or accept; promote the publication of corrections or retractions when errors are found; and preserve the anonymity of reviewers.

3. EDITORIAL POLICY

Copyright
Copyright in all published material is owned by the Korean Shoulder and Elbow Society. Authors must agree to transfer copyright (http://cisejournal.org/authors/copyright_transfer_agreement.
php) during the submission process. The corresponding author is responsible for submitting the copyright transfer agreement to the publisher.

Open Access Policy
CiSE is an open-access journal. Articles are distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by-nc/4.0/), which permits unrestricted non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited. Author(s) do not need to permission to use tables or figures published in CiSE in other journals, books, or media for scholarly and educational purposes. This policy is in accordance with the Budapest Open Access Initiative definition of open access.

Registration of Clinical Trial Research
It is recommended that any research that deals with a clinical trial be registered with a clinical trial registration site, such as http://cris.nih.go.kr, http://www.who.int/ictrp/en, and http://clinicaltrials.gov.

Data Sharing
CiSE encourages data sharing wherever possible, unless this is prevented by ethical, privacy, or confidentiality matters. Authors wishing to do so may deposit their data in a publicly accessible repository and include a link to the DOI within the text of the manuscript.


Archiving Policy
CiSE provides electronic archiving and preservation of access to the journal content in the event the journal is no longer published, by archiving in the National Library of Korea. According to the deposit policy (self-archiving policy) of Sherpa/Romeo (http://www.sherpa.ac.uk/), authors cannot archive pre-print (i.e., pre-refereeing) but they can archive post-print (i.e., final draft post-refereeing). Authors can archive the publisher’s version/PDF.

4. SUBMISSION AND PEER-REVIEW PROCESS

Submission
All manuscripts should be submitted online via the journal’s website (https://submit.cisejournal.org/) by the corresponding author.

Once you have logged into your account, the online system will lead you through the submission process in a stepwise orderly process. Submission instructions are available at the website. All articles submitted to the journal must comply with these instructions. Failure to do so will result in the return of the manuscript and possible delay in publication.

Peer Review Process
All papers, including those invited by the Editor, are subject to peer review. Manuscripts will be peer-reviewed by two accredited experts in the shoulder and elbow with one additional review by prominent member from our editorial board. CiSE’s average turnaround time from submission to decision is 4 weeks. The editor is responsible for the final decision whether the manuscript is accepted or rejected.

• The journal uses a double-blind peer review process: the reviewers do not know the identity of the authors, and vice versa.
• Decision letter will be sent to corresponding author via registered e-mail. Reviewers can request authors to revise the content. The corresponding author must indicate the modifications made in their item-by-item response to the reviewers’ comments. Failure to resubmit the revised manuscript within 4 weeks of the editorial decision is regarded as a withdrawal.
• The editorial committee has the right to revise the manuscript without the authors’ consent, unless the revision substantially affects the original content.
• After review, the editorial board determines whether the manuscript is accepted for publication or not. Once rejected, the manuscript does not undergo another round of review.

Appeals of Decisions
Any appeal against an editorial decision must be made within 2 weeks of the date of the decision letter. Authors who wish to appeal a decision should contact the Editor-in-Chief, explaining in detail the reasons for the appeal. All appeals will be discussed with at least one other associate editor. If consensus cannot be reached thereby, an appeal will be discussed at a full editorial meeting. The process of handling complaints and appeals follows the guidelines of COPE available from (https://publicationethics.org/appeals). CiSE does not consider second appeals.

5. MANUSCRIPT PREPARATION

Authors are required to submit their manuscripts after reading the following instructions. Any manuscript that does not conform to the following requirements will be considered inappropriate and may be returned.

www.cisejournal.org
General Requirements

• All manuscripts should be written in English.
• The manuscript must be written using Microsoft Word and saved as “.doc” or “.docx” file format. The font size must be 12 points. The body text must be left aligned, double spaced, and presented in one column. The left, right, and bottom margins must be 3 cm, but the top margin must be 3.5 cm.
• The page numbers must be indicated in Arabic numerals in the middle of the bottom margin, starting from the abstract page.
• Neither the authors' names nor their affiliations should appear on the manuscript pages.
• Only standard abbreviations should be used. Abbreviations should be avoided in the title of the manuscript. Abbreviations should be spelled out when first used in the text and the use of abbreviations should be kept to a minimum.
• The names and locations (city, state, and country only) of manufacturers of equipment and non-generic drugs should be given.
• Authors should express all measurements in conventional units using International System (SI) units.
• P-value from statistical testing is expressed as capital P.

Reporting Guidelines for Specific Study Designs

For specific study designs, such as randomized controlled studies, studies of diagnostic accuracy, meta-analyses, observational studies, and non-randomized studies, authors are encouraged to consult the reporting guidelines relevant to their specific research design. A good source of reporting guidelines is the EQUATOR Network (https://www.equator-network.org/) and NLM (https://www.nlm.nih.gov/services/research_report_guide.html).

Composition of Manuscripts

• The manuscript types are divided into Original Article, Review Article, Case Report, and other types. There is no limit to the length of each manuscript; however, if unnecessarily long, the author may be penalized during the review process.
• Original Articles should be written in the following order: title page, abstract, keywords, main body (introduction, methods, results, discussion), acknowledgments (if necessary), references, tables, figure legends, and figures. The number of references is limited to 30.
• Review Articles should focus on a specific topic. Format of a review article is not limited. Publication of these articles will be decided upon by the Editorial Board.
• Case Reports should be written in the following order: title page, abstract, keywords, main body (introduction, case report, discussion), acknowledgments (if necessary), references, tables, figure legends, and figures. The number of references is limited to 10.

The Abstract should not exceed 200 words, and must be written as one unstructured paragraph. Authors are warned that these have a high rejection rate.
• Technical Notes should not exceed 1,500 words. The abstract should be an unstructured summary not exceeding 150 words. The body of these manuscripts should consist of introduction, technique, discussion, references, and figure legends and tables (if applicable). References should not exceed 10. A maximum of 3 figures and 1 table are allowed.
• Current Concepts deal with most current trends and controversies of a single topic in shoulder and elbow. Authors are recommended to update all the knowledge to most recent studies and researches.
• Systemic Review examines published material on a clearly described subject in a systematic way. There must be a description of how the evidence on this topic was tracked down, from what sources and with what inclusion and exclusion criteria.
• Meta-analysis: A systematic overview of studies that pools results of two or more studies to obtain an overall answer to a question or interest. Summarizes quantitatively the evidence regarding a treatment, procedure, or association.
• Letters to the Editor: The journal welcomes readers' comments on articles published recently in the journal or orthopedic topics of interest.
• Editorial is invited by the editors and should be commentaries on articles published recently in the journal. Editorial topics could include active areas of research, fresh insights, and debates in the field of orthopedic surgery. Editorials should not exceed 1,000 words, excluding references, tables, and figures.
• Concise Review is short version of systemic review requested to submit in the journal by the Editorial board. Usually, previous papers regarding such topic were published by the main author(s).
• Special Reports/Expert Opinions (Level V studies) of various topics in shoulder and elbow can be submitted. They are limited to 2,700 words excluding references, tables, and figures.

Title Page

• The title page must include a title, the authors' names and academic degrees (include ORCID*), affiliations, and corresponding authors' names and contact information. In addition, a running title must be written in English within up to 50 characters including spaces. The corresponding authors' contact information must include a name, addresses, e-mails, telephone numbers, and fax numbers.
• ORCID: We recommend that the open researcher and contributor ID (ORCID) of all authors be provided. To have an ORCID,
authors should register in the ORCID website: http://orcid.org/. Registration is free to every researcher in the world.

- If there are more than two authors, a comma must be placed between their names (with academic titles). Authors’ academic titles must be indicated after their names.
- The contributions of all authors must be described using the CRediT (https://www.casrai.org/credit.html) Taxonomy of author roles. All persons who have made substantial contributions, but who have not met the criteria for authorship, are acknowledged here.
- All sources of funding applicable to the study should be stated here explicitly.

Abstract and Keywords
Each paper should start with an abstract not exceeding 250 words. The abstract should state the background, methods, results, and conclusions in each paragraph in a brief and coherent manner. Relevant numerical data should be included. Under the abstract, keywords should be inserted (maximum 5 words). Authors are recommended to use the MeSH database to find Medical Subject Heading Terms at http://www.nlm.nih.gov/mesh/meshhome.html. The abstract should be structured into the following sections.

- Background: The rationale, importance, or objective of the study should be described briefly and concisely in one to two sentences. The objective should be consistent with that stated in the Introduction.
- Methods: The procedures conducted to achieve the study objective should be described in detail, together with relevant details concerning how data were obtained and analyzed and how research bias was adjusted.
- Results: The most important study results and analysis should be presented in a logical manner with specific experimental data.
- Conclusions: The conclusions derived from the results should be described in one to two sentences, and must match the study objective.

Guidelines for the Main Body
- All articles using clinical samples or data and those involving animals must include information on the IRB/IACUC approval or waiver and informed consent. An example is shown below. “We conducted this study in compliance with the principles of the Declaration of Helsinki. The study’s protocol was reviewed and approved by the Institutional Review Board of OO (IRB no. OO). Written informed consent was obtained / Informed consent was waived.”
- Description of participants: Ensure the correct use of the terms “sex” (when reporting biological factors) and “gender” (identity, psychosocial, or cultural factors), and, unless inappropriate, report the sex and/or gender of study participants, the sex of animals or cells, and describe the methods used to determine sex and gender. If the study was done involving an exclusive population, for example, in only one sex, authors should justify why, except in obvious cases (e.g., ovarian cancer). Authors should define how they determined race or ethnicity and justify their relevance.
- Introduction: State the background or problem that led to the initiation of the study. Introduction is not a book review, rather it is best when the authors bring out controversies which create interest. Lead systematically to the hypothesis of the study, and finally, to a restatement of the study objective, which should match that in the Abstract. Do not include conclusions in the Introduction.
- Methods: Describe the study design (prospective or retrospective, inclusion and exclusion criteria, duration of the study) and the study population (demographics, length of follow-up). Explanations of the experimental methods should be concise, but yet enable replication by a qualified investigator.
- Results: This section should include detailed reports on the data obtained during the study. All data in the text must be presented in a consistent manner throughout the manuscript. All issues which the authors brought up in the method section need to be in result section. Also it is preferred that data to be in figures or table rather than long list of numbers. Instead, numbers should be in tables or figures with key comment on the findings.
- Discussion: The first paragraph of the discussion should deal with the key point in this study. Do not start by article review or general comment on the study topic. In the Discussion, data should be interpreted to demonstrate whether they affirm or refute the original hypothesis. Discuss elements related to the purpose of the study and present the rationales that support the conclusion drawn by referring to relevant literature. Discussion needs some comparison of similar papers published previously, and discuss why your study is different or similar from those papers. Care should be taken to avoid information obtained from books, historical facts, and irrelevant information. A discussion of study weaknesses and limitations should be included in the last paragraph of the discussion. Lastly you must briefly state your new (or verified) view of the problem you outlined in the Introduction.
- References must be numbered with superscripts according to their quotation order. When more than two quotations of the same authors are indicated in the main body, a comma must be placed between a discontinuous set of numbers, whereas a dash must be placed between the first and last numerals of a continu-
uous set of numbers: “Kim et al. [2,8,9] insisted…” and “However, Park et al. [11−14] showed opposing research results.”

- Figures and tables used in the main body must be indicated as “Fig.” and “Table.” For example, “Magnetic resonance imaging of the brain revealed… (Figs. 1–3).

Figures and Figure Legends
Figures should be cited in the text and are numbered using Arabic numbers in the order of their citation (e.g., Fig. 1). Figures are not embedded within the text. Each figure should be submitted as an individual file. Location of figure legends begins at the next page after last table. Every figure has its own legend. Abbreviation and additional information for any clarification should be described within each figure legend. Figure files are submitted in EPS, TIFF, or PDF formats. Requirement for minimum resolutions are dependent on figure types. For line drawings, 1,200 dpi are required. For grey color works (i.e., picture of gel or blots), 600 dpi are required. For color or half-tone artworks, 300 dpi are required. The files are named by the figure number.

- Staining techniques used should be described. Photomicrographs with no inset scale should have the magnification of the print in the legend.
- Papers containing unclear photographic prints may be rejected.
- Remove any writing that could identify a patient.
- Any illustrations previously published should be accompanied by the written consent of the copyright holder.

Tables
- Tables should be numbered sequentially with Arabic numerals in the order in which they are mentioned in the text.
- If an abbreviation is used in a table, it should be defined in a footnote below the table.
- Additional information for any clarification is designated for citation using alphabetical superscripts (a, b, …) or asterisks (*).

Explanation for superscript citation should be done as following examples:

- Not tested. *P < 0.05, **P < 0.01, ***P < 0.001.
- Tables should be understandable and self-explanatory, without references to the text.

References
- The number of references is recommended to 30 for original article and 10 for case report and technical note.
- All references must be cited in the text. The number assigned to the reference citation is according to the first appearance in the manuscript. References in tables or figures are also numbered according to the appearance order. Reference number in the text, tables, and figures should in a bracket ([ ]).
- List names of all authors when six or fewer. When seven or more, list only the first three names and add et al.
- Authors should be listed by surname followed by initials.
- The journals should be abbreviated according to the style used in the list of journals indexed in the NLM Journal Catalog (http://www.ncbi.nlm.nih.gov/nlmcatalog/journals).
- The overlapped numerals between the first page and the last page must be omitted (e.g., 2025-6).
- References to unpublished material, such as personal communications and unpublished data, should be noted within the text and not cited in the References. Personal communications and unpublished data must include the individual’s name, location, and date of communication.
- Other types of references not described below should follow IC-MJE Recommendations (https://www.nlm.nih.gov/bsd/uniform_requirements.html).
- Examples of references are as follows:

Journal article

Book & book chapter

Website
6. FINAL PREPARATION FOR PUBLICATION

Final Version
After the paper has been accepted for publication, the author(s) should submit the final version of the manuscript. The names and affiliations of the authors should be double-checked, and if the originally submitted image files were of poor resolution, higher resolution image files should be submitted at this time. Symbols (e.g., circles, triangles, squares), letters (e.g., words, abbreviations), and numbers should be large enough to be legible on reduction to the journal's column widths. All symbols must be defined in the figure caption. If references, tables, or figures are moved, added, or deleted during the revision process, renumber them to reflect such changes so that all tables, references, and figures are cited in numeric order.

Manuscript Corrections
Before publication, the manuscript editor will correct the manuscript such that it meets the standard publication format. The author(s) must respond within two days when the manuscript editor contacts the corresponding author for revisions. If the response is delayed, the manuscript’s publication may be postponed to the next issue.

Gallery Proof
The author(s) will receive the final version of the manuscript as a PDF file. Upon receipt, the author(s) must notify the editorial office (or printing office) of any errors found in the file within two days. Any errors found after this time are the responsibility of the author(s) and will have to be corrected as an erratum.

Errata and Corrigenda
To correct errors in published articles, the corresponding author should contact the journal's Editorial Office with a detailed description of the proposed correction. Corrections that profoundly affect the interpretation or conclusions of the article will be reviewed by the editors. Corrections will be published as corrigenda (corrections of the author's errors) or errata (corrections of the publisher's errors) in a later issue of the journal.

7. ARTICLE PROCESSING CHARGES

There are no author fees required for manuscript processing and/or publishing materials in the journal since all cost is supported by the publisher, the Korean Shoulder and Elbow Society until there is a policy change. Therefore, it is the so-called platinum open access journal.
Author’s checklist

- Manuscript in MS-WORD (.doc) format.

- Double-spaced typing with 10-point font.

- Sequence of title page, abstract and keywords, introduction, methods, results, discussion, conclusions, acknowledgments, references, tables, and figure legends. All pages and manuscript text with line should be numbered sequentially, starting from the abstract.

- Title page with article title, authors’ full name(s) and affiliation(s), address for correspondence (including telephone number, e-mail address, and fax number), running title (less than 10 words), and acknowledgments, if any.

- Abstract in structured format up to 250 words for original articles and in unstructured format up to 200 words for case reports. Keywords (up to 5) from the MeSH list of Index Medicus.

- All table and figure numbers are found in the text.

- Figures as separate files, in JPG, GIF, or PPT format.

- References listed in proper format. All references listed in the reference section are cited in the text and vice versa.

- Covering letter signed by the corresponding author.
Copyright transfer agreement

Clinics in Shoulder and Elbow requires a formal written Copyright Transfer Form of the author(s) for each article published. We therefore ask you to complete and return this form, retaining a copy for your records. Your cooperation is essential and appreciated. Publication cannot proceed without a signed copy of this agreement. If the manuscript is not published in Clinics in Shoulder and Elbow, this agreement shall be null and void.

Copyright Transfer Agreement. I/we have read and agreed with the terms and conditions stated on this page of this agreement. I/we hereby confirm the transfer of all copyrights in and relating to the manuscript, in all forms and media of expression now known or developed in the future, including reprints, translations, photographic reproductions, microform, electronic form (offline, online) or any other reproductions of similar nature, to Korean Shoulder and Elbow Society, effective from the date stated below. I/we acknowledge that Korean Shoulder and Elbow Society are relying on this agreement in publishing the manuscript.

Manuscript Title:

Manuscript Number (if applicable):

Date:

All authors appearing in manuscript should be signed in order.

Each of the undersigned is an author of the manuscript and all authors are named on this document.

<table>
<thead>
<tr>
<th>Print Name</th>
<th>Signature</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>