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Clinics in Shoulder and Elbow

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Aims and Scope

Clinics in Shoulder and Elbow (Clin Shoulder Elbow, CiSE; eISSN: 2288-8721;pISSN: 2383-8337 till 2018) is the official journal of the Korean Shoulder and Elbow Society. The *Clinics in Shoulder and elbow* was first launched in 1998 and was formerly known as the Journal of the Korean Shoulder and Elbow Society until June 2010 (volume 13). It was published semiannually until 2013 and has been published quarterly on the first day of March, June, September, and December since 2014. Articles have been published in English only since 2014, and the journal has been published online only since 2019.

It aims: first, to contribute to the management and education of shoulder and elbow topics; second, to share the latest scientific information among international societies; and finally, to promote communications on shoulder/elbow problems and patient care.

Its scope includes basic and clinical research, focusing on the etiology and epidemiology, biomechanics and pathogenesis, management and surgery, complication and prognosis for the disease of shoulder and elbow. Its regional scope is mainly Asia but it welcomes submissions from researchers all over the world.

Its main publication types are original articles, case reports, invited review articles, editorials, and letters to the editor. Other types are negotiable also with editor-in-chief. All submissions are processed online. The editior-in-chief determines the fate of the submitted manuscripts after hearing from peer reviewers, who are experts in their specific fields of shoulder and elbow.

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Can "infraspinatus rotational transfer" be a surgical option for severe rotator cuff tears?

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The treatment of severe rotator cuff tears remains challenging [1]. Complete repair of a rotator cuff tear gives good results, but some cases are difficult to repair due to severe retraction or poor quality [2]. Therefore, in severe rotator cuff tear, various surgical methods such as debridement, partial repair, tendon transfer, superior capsule reconstruction, and reverse shoulder arthroplasty have been introduced. However, the optimal method is controversial due to its high failure rate, longevity concerns, and unpredictable results [3-5].

The importance of covering the original footprint in rotator cuff repair is well known [6]. However, the re-tear rate increases when excessive tension is applied to the repaired rotator cuff tendon [7]. After Debeyre et al. [8] introduced the muscle advancement technique to elevate the supraspinatus from the supraspinatus fossa for covering the footprint in 1965, various modifications have been reported. Recently, Yokoya et al. [9] and Gupta et al. [10] reported good results using both supraspinatus and infraspinatus advancement techniques.

On the other hand, Harada et al. [11] introduced a new surgical method for severe rotator cuff tear using only infraspinatus advancement in "The clinical outcomes of infraspinatus rotational transfer for irreparable posterosuperior rotator cuff tears: a preliminary report." In this study, Harada reported a low failure rate (2/34, 5.9%) at 1 year after surgery in 34 patients. Compared with the failure rate of previous surgical methods of severe rotator cuff tear, the results were superior or similar [12]. Rotator cuff repair using its own tendon produces better results than other reconstruction or transfer surgery [9]. It is also meaningful in that it showed satisfactory results even at the age of 75 or older. All functional scores and shoulder elevation range were significantly improved after 1 year of surgery. However, there was no improvement in external rotation range or strength related to the infraspinatus. As mentioned by the authors, the elevation was improved by increasing the efficiency of the deltoid muscle due to the "spacer effect" of the transferred infraspinatus, but the function of the infraspinatus may have been sacrificed. However, previous muscle advancement studies have shown improved external rotation strength in the 2-year follow-up after surgery, so close observation is likely to be required [13].

There is a risk of suprascapular nerve palsy in this muscle advancement technique [14]. Compared to the recent surgical technique that advanced both infraspinatus and supraspinatus, in case of advancement of only the infraspinatus, a longer length of infraspinatus must be advanced to cover the great tuberosity. This may cause retraction of the suprascapular nerve and may increase the risk of palsy. Therefore, suprascapular nerve release will have to include cutting of the transverse scapular ligament during surgery [15]. It is also necessary to consider cosmetic is-

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sues due to open surgery and scapular dyskinesis due to muscle damage around the scapular.

Nevertheless, "infraspinatus rotational transfer" may be a good surgical option for severe rotator cuff tears. However, in a situation where various surgical methods for irreparable rotator cuff tear are being reported, biomechanical studies and comparison studies that can show superiority are needed. In addition, due to the short follow-up period, research on long-term outcomes and complications should continue.

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Significant radiologic factors related to clinical outcomes after arthroscopic rotator cuff retear repair

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Background: Healing of the tendon itself is not always related to successful clinical outcomes after rotator cuff repair. It was hypothesized that certain radiologic factors affecting clinical outcomes could exist in case of the retear after arthroscopic rotator cuff repair (ARCR) and the radiologic factors could help predict clinical process. The purpose of this study was to identify the radiologic factors associated with clinical outcomes of the retear after ARCR.

Methods: Between January 2012 and December 2019, among patients with sufficient footprint coverage for ARCR, 96 patients with Sugaya classification 4 or higher retear on follow-up magnetic resonance imaging were included. The association between clinical outcomes such as American Shoulder and Elbow Surgeons (ASES) score, Constant score and range of motion and radiologic variables such as initial tear dimension, retear dimension, variance of tear dimension, critical shoulder angle, acromial index, and acromiohumeral distance was analyzed.

Results: Preoperatively, the ASES and Constant scores were 59.81±17.02 and 64.30±15.27, respectively. And at the last follow-up, they improved to 81.56±16.29 and 78.62±14.16, respectively ($p<0.01$ and $p<0.01$). In multiple linear regression analysis, the variance of the mediolateral dimension of tear had statistically significant association with the ASES and Constant scores ($p<0.01$ and $p=0.01$).

Conclusions: In patients with the retear after ARCR, the variance in the mediolateral dimension of tear had significantly negative association with the clinical outcomes. This could be considered to be reference as relative criteria and needed more sample and mechanical study.

Keywords: Information system; Radiology; Rotator cuff; Tears; Retears

INTRODUCTION

Arthroscopic rotator cuff repair is widely performed, and many studies have reported good clinical results after this procedure [1,2]. However, the rate of retear ranges from 11% to 57% [3-5]. Even though the need for revision surgery due to failure of healing of the rotator cuff has been reported [6,7], healing of the tendon alone is not always related to a successful clinical outcome [5,8]. However, there have been reports of pain relief and return of function even when the healing of the tendons is lacking without revision surgery [1,9,10]. Therefore, understanding the clinical outcomes in patients with rotator cuff retears to identify associated factors is important. The rate and causes of good and poor clinical outcomes after rotator cuff retears are not well established.

Based on the hypothesis that specific radiologic variables could affect clinical outcomes after rotator cuff repairs, we tested and analyzed these radiologic factors for associations with rotator cuff retear clinical outcomes. The radiologic variables tested in-

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cluded initial tear dimension [11,12], critical shoulder angle (CSA) [13], acromiohumeral distance [13] and acromial index (AI) [14]. These were reported as predisposing factors for rotator cuff retear in a previous study and included retear dimension and variance of initial tear and retear dimension. The purpose of this retrospective study was to identify whether the radiologic factors tested are associated with clinical outcomes. The statistically significant radiologic factors could provide a treatment option reference for the patients experiencing retear after arthroscopic rotator cuff repair.

METHODS

This retrospective study was approved by the Institutional Review Board of Wonkwang University Hospital (IRB No. WKUHIRB-2021-04-007). Informed consent was confirmed by the IRB as unnecessary papers.

Study Sample

Between January 2012 and December 2019, a total of 1,171 arthroscopic rotator cuff repairs were performed by a single surgeon. Patient records were reviewed to obtain demographic data, pre- and postoperative clinical scores, range of motion (ROM) values, and radiographic and operative data from the blinded orthopedic surgeon (MSJ). Clinical scores, ROM values, and radiographic data were routinely obtained at the 3-, 6-, 12-, and 24-month follow-up after surgery. When a decision that revision surgery was necessary due to retear of the rotator cuff was made, the data immediately prior to the revision was used as last follow-up data.

The inclusion criteria for this study were (1) patients who underwent arthroscopic repair of rotator cuff tears with sufficient footprint coverage to reduce bias related to the influence of footprint coverage, (2) patients for whom pre- and operative magnetic resonance imaging (MRI) evaluation was possible and consented to, (3) patients with a tear ≥Sugaya classification 4 as observed on postoperative MRI, (4) patients for whom the double-row transosseous equivalent surgical technique (modified suture bridge technique) was used.

Patients in whom footprint coverage could not be achieved due to massive tears, had arthritic changes (glenohumeral osteoarthritis and rotator cuff arthropathy), or had partial thickness tears <Sugaya classification 4 as observed on follow-up MRI were excluded. Those who underwent concomitant subscapularis repair were also excluded. This study included 96 patients who met the inclusion criteria, and the detailed process for patient enrollment is summarized (Fig. 1). The necessity of revision surgery was determined by considering demands and activity level among the patients with poor clinical scores (American Shoulder and Elbow Surgeons [ASES] <70 or Constant score <60) [15,16] for more than 6 months after surgery. In these revision cases, the data before revision surgery were applied. There were no cases of revision due to stiffness and other causes such as infection.

Demographics

Demographic variables included sex, age, dominant arm involvement, history of ipsilateral shoulder trauma, presence of inflammatory arthritis (rheumatic arthritis, systemic lupus erythematosus, or ankylosing spondylitis), concurrent diabetes mellitus diagnosis, and positive smoking status. This information is routinely documented at the time of hospitalization.

Clinical Evaluation

Pre- and postoperative ASES scores and Constant scores with an examination of the active ROM, including forward elevation, abduction, external rotation and internal rotation behind the back, were evaluated by the outpatient physiotherapist specializing in orthopedics. For internal rotation, the most proximal point at which the tip of the thumb touched the spinous process was scored based on contiguously numbered groups: T1–12, 1–12; L1–5, 13–17; buttock 18; and greater tubercle of the proximal femur 19 [17].

Radiologic Evaluation

Pre- and postoperative standard radiographs of the shoulder (anteroposterior [AP], true AP, scapular Y, and axillary views) were evaluated. Two orthopedic physicians (MSJ and KLK) inde-

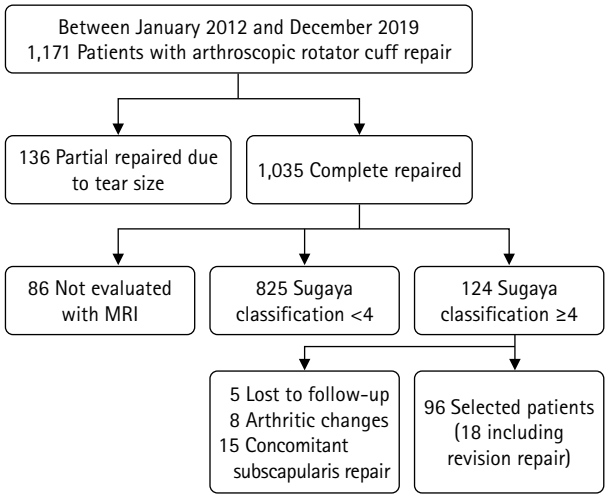

Fig. 1. Study flowchart. MRI: magnetic resonance imaging.

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pendently reviewed the preoperative radiographs to assess the CSA, AI, and acromiohumeral interval (Fig. 2). The CSA was measured as defined by Moor et al. [18], using a line connecting the superior and inferior bone margins of the glenoid and an intersecting line drawn from the inferior bone margin of the glenoid to the most lateral border of the acromion. The AI was measured as the value obtained by dividing the distance from the glenoid plane to the lateral border of the acromion by the distance from the glenoid plane to the lateral aspect of the humeral head. The acromiohumeral interval was measured as the shortest distance from the inferior surface of the acromion to the superior aspect of the humerus in the true AP view [19]. When a subacromial spur was present, the shortest distance between the spur and humeral head was measured.

Pre- and postoperative MRIs were performed. Khazzam et al. [20] reported that intact repaired rotator cuffs or full-thickness retears can be identified with moderate reliability using MRI after rotator cuff repair, and Iannotti et al. [21] reported that retears primarily occurred between 6 and 26 weeks after arthroscopic rotator cuff repair. Accordingly, postoperative MRI was routinely evaluated with the consent of the patient to identify the condition of the repaired cuff independently of clinical symptoms. MRI was performed at least 6 months (mean, 8.64±2.72 months) postoperatively.

A 3-T imaging unit (Achieva; Philips Healthcare, Best, the Netherlands) equipped with a dedicated shoulder coil (4-channel SENSE shoulder coil, Philips Healthcare) was used to obtain the MR images. The sequences and parameters of the MRI were: axial turbo spin-echo T2-weighted (field of view [FOV], 140×140 mm; repetition time/echo time [TR/TE], 3,800/80; matrix, 256×255; section thickness, 2.0 mm; and intersection gap, 0.2 mm), oblique coronal turbo spin-echo T2-weighted (FOV, 140×140 mm; TR/TE, 3,500–4,000/80; matrix, 350×248; section thickness, 2.0 mm; and intersection gap, 0.5 mm), oblique coronal fat-saturated T2-weighted (FOV, 140×140 mm; TR/TE, 3,500–4,000/80; flip angle, 90°; matrix, 256×255; section thickness, 2.0 mm; and intersection gap, 0.5 mm), and oblique sagittal turbo spin-echo T2-weighted (FOV, 140×140 mm; TR/TE, 5,400–6,000/80; matrix, 232×230; section thickness, 2.0 mm; and intersection gap, 0.5 mm).

Tendon integrity was classified based on postoperative MRI findings proposed by Sugaya et al. [22]: type I, a repaired rotator cuff with sufficient thickness and homogeneous low intensity on each image; type II, sufficient thickness associated with a partial high-intensity area; type III, insufficient thickness without discontinuity; type IV, presence of a minor discontinuity in more than one image, suggesting a small tear; and type V, presence of a major discontinuity on each image, suggesting a medium or large tear. Thus, types I, II, and III represent healing of rotator cuffs, while types IV and V represent retears.

The maximum mediolateral lengths and AP widths of pre- and postoperative tears were measured using the protocol of Davidson et al. (Fig. 3) [23], and variance of tear dimension was calculated by subtracting the preoperative dimension from the postoperative dimension for mediolateral lengths and AP widths, respectively. Two orthopedic physicians (MSJ and KLK) inde-

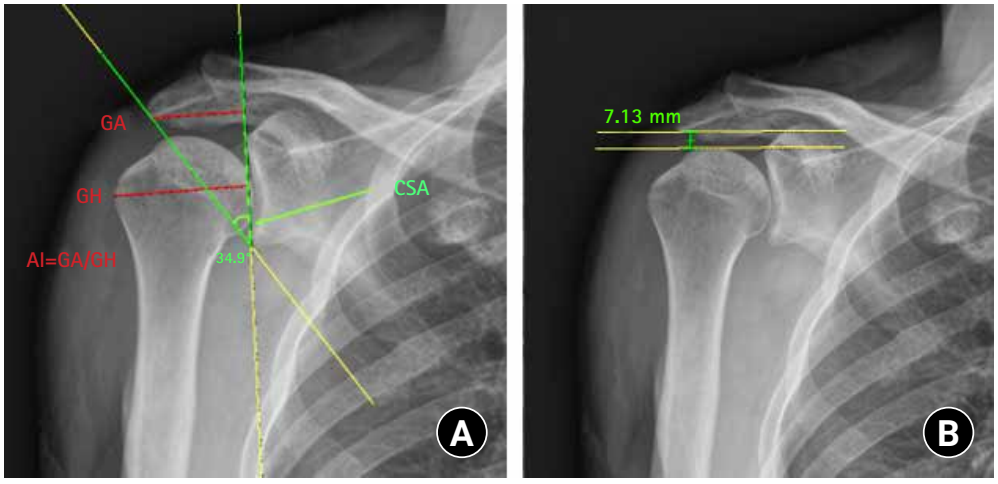

Fig. 2. Measurement of critical shoulder angle (CSA), acromial index (AI), and acromiohumeral interval (AHI) on anteroposterior shoulder radiographs. (A) CSA is formed by a line connecting the inferior with the superior border of the glenoid fossa and another line connecting the inferior border of the glenoid with the most inferolateral point of the acromion. AI is the distance from the glenoid plane to the lateral border of the acromion (GA) divided by the distance from the glenoid plane to the most lateral aspect of the humeral head (GH). (B) AHI is measured as the shortest distance from the inferior surface of the acromion to the superior aspect of the humerus.

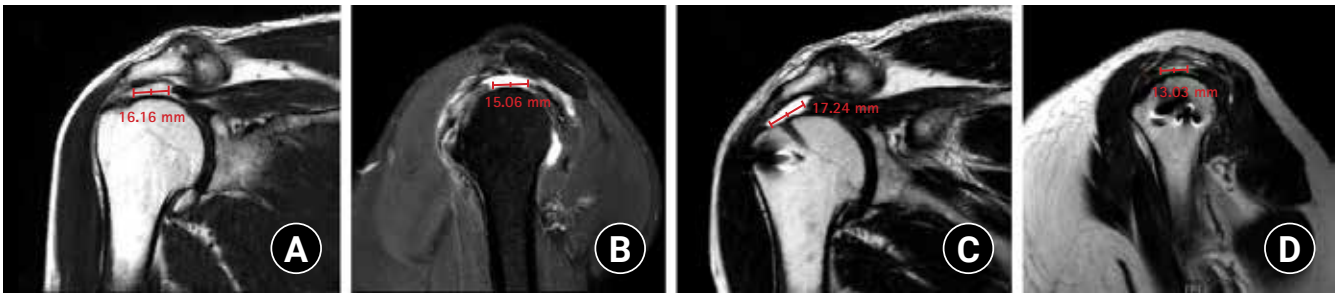

Fig. 3. Measuring pre- and postoperative tears using the magnetic resonance imaging (MRI) protocol of Davidson et al. [23]. (A) Preoperative maximal mediolateral length on T2-weighted coronal oblique MRI view. (B) Preoperative anterior to posterior widths on T2-weighted sagittal oblique MRI view. (C) Postoperative maximal mediolateral length on T2-weighted coronal oblique MRI view. (D) Postoperative anterior to posterior widths on T2-weighted sagittal oblique MRI view.

pendently reviewed the radiographs and magnetic resonance images to assess the measurement variables. The intraclass correlation coefficient was used to assess interobserver reliabilities for agreement regarding measured values. Correlation was determined to be poor if the coefficient was <0.4, marginal if ≥ 0.4 and ≤ 0.75, and good if >0.75 [24].

Statistical Analysis

All continuous variables were tested for normality using the Kolmogorov-Smirnov test. Measurements were expressed as mean ± standard deviation with 95% confidence intervals for continuous variables that complied with normal assumptions. The independent t-test or Mann-Whitney U-test were used for categorical variables such as sex, diagnosis of concurrent diabetes mellitus, positive smoking status, involvement of the dominant arm, and involvement of ipsilateral shoulder trauma to identify correlations with the clinical outcomes (ASES score and Constant score). Pearson correlation analysis was used for age, which is a continuous variable.

In univariate analysis of radiologic results, a simple linear regression analysis was used for continuous variables, and significant variables with $p<0.05$ in the univariate analysis were included in the multivariate analysis. In the multivariate analysis, multiple linear regression analysis was performed in a stepwise manner using variables that showed statistical significance in the univariate analysis. This allowed for the identification of important factors associated with clinical functional scores. Statistical significance was set at $p<0.05$. Statistical analysis was performed using IBM SPSS ver. 26.0 (IBM Corp., Armonk, NY, USA).

RESULTS

Demographic Data and Clinical Outcomes

The mean follow-up period was 26.91 ± 8.15 months. As indicated in the flow chart (Fig. 1), five cases were lost to follow-up, eight cases of arthritic changes including rotator cuff arthropathy and 15 cases of concomitant subscapularis repair were excluded among 124 patients diagnosed with rotator cuff retear. Clinical and radiologic data from 18 patients who had revision repair surgery were analyzed before revision surgery. Postoperative MRI was performed at an average of 8.64 ± 2.72 months. At the last follow-up, the ASES and Constant scores were 81.56 ± 16.29 and 78.62 ± 14.16, respectively; the ROM was 152.13° ± 28.81°, 57.59° ± 18.83°, and 12.41 ± 5.72 points in forward elevation, external rotation, and internal rotation, respectively. The p-values for preoperative and postoperative statistical significance are indicated in Table 1. There was no significant correlation between the clinical scores (ASES and Constant scores) and demographic variables (Table 2).

Radiologic Results

In the univariable analysis, the ASES at the last follow-up was significantly associated with the CSA, retear length (the mediolateral dimension of the retear), variance in the tear width, and variance in the tear length. The Constant score was significantly correlated with the CSA, variance in the tear width, and variance in the tear length (Table 3). Stepwise multiple linear regression analysis was used to identify variables with significant associations with ASES score and Constant score in univariable analyses. Both ASES and Constant scores were significantly associated with the variance in the tear length (Table 4).

The multiple regression analysis model for the ASES score was appropriate, $F=11.153$ ($p<0.001$) and adjusted $R^2=0.476$, indicating 47.6% explanatory power. The variance in the retear length was $B=-0.729$ ($p=0.002$), indicating a 7.29 decrease per 1 mm increase in the tear length variance. Similarly, the multiple regression analysis model for Constant score was appropriate, $F=12.685$ ($p<0.001$), and adjusted $R^2=0.503$, indicating 50.3% explanatory

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Table 1. Clinical outcomes preoperative and at last follow-up

Variable	Preoperative	Last follow-up	p-value
ASES score	59.81 ± 17.02	81.56 ± 16.29	< 0.001
Constant score	64.30 ± 15.27	78.62 ± 14.16	< 0.001
Active forward elevation (°)	144.21 ± 35.19	152.13 ± 28.81	0.067
Active external rotation (°)	52.01 ± 18.83	57.59 ± 18.83	0.076
Active internal rotation (point*)	12.72 ± 3.29	12.41 ± 5.72	0.063

Values are presented as mean ± standard deviation.
ASES: American Shoulder and Elbow Surgeons.
*Point was based on contiguously numbered groups: T1–12 to 1–12, L1–5 to 13–17, buttock–18, and greater tubercle of the proximal femur–19.

Table 2. The association of demographic data with clinical outcomes

Variable	Value (n = 96)	p-value of clinical outcomes at last follow-up	
		ASES score	Constant score
Age at surgery (yr)	67.9 ± 7.11	0.846	0.909
Male:female	51:45	0.496	0.754
Dominant-side surgery	68 (70.83)	0.547	0.765
Diabetes mellitus	14 (14.58)	0.514	0.961
Smoking	18 (18.75)	0.185	0.140
Body mass index (kg/m^2)	25.26 ± 3.59	0.324	0.130
Inflammatory arthritis	7 (7.29)	*	*
Ipsilateral shoulder trauma history	2 (2.08)	*	*
Follow-up (mo)	26.91 ± 8.15	-	-
Follow-up MRI (mo)	8.64 ± 2.72	-	-

Values are presented as mean ± standard deviation or number (%).
ASES: American Shoulder and Elbow Surgeons, MRI: magnetic resonance imaging.
*There were weak validity because comparable sample size was too small.

Table 3. Univariable analysis of radiologic findings associated with clinical outcomes after rotator cuff retear

Radiologic finding	Value	p-value of clinical outcomes at last follow-up	
		ASES score	Constant score
AHI (mm)	9.59 ± 1.57	0.80	0.75
CSA (°)	38.51 ± 3.03	0.02*	0.01*
AI	0.71 ± 0.07	0.75	0.76
Initial tear width (mm)	15.11 ± 6.26	0.70	0.48
Initial tear length (mm)	19.61 ± 7.57	0.33	0.13
Retear width (mm)	11.64 ± 6.16	0.06	0.10
Retear length (mm)	14.56 ± 8.75	0.01*	0.19
Variance in tear width† (mm)	−3.47 ± 6.35	< 0.01*	0.01*
Variance in tear length‡ (mm)	−5.04 ± 7.91	< 0.01*	< 0.01*

Values are presented as mean ± standard deviation.
ASES: American Shoulder and Elbow Surgeons, AHI: acromiohumeral interval, CSA: critical shoulder angle, AI: acromial index.
*Statistically significant; †Tear width: anterior to posterior dimension of tear; ‡Tear length: mediolateral dimension on tear.

power. The variance in the tear length was B = −0.671 (p = 0.01), indicating that the Constant score decreased by 6.71 per 1 mm increase in the variance in the tear length (Table 5). The intraclass correlation coefficient indexes of interobserver reliability were 0.91, 0.88 and 0.79 for AHI, CSA and AI, respectively, and were 0.81 and 0.77 for variance in tear width and length.

DISCUSSION

The results of the present study suggest that the enlarged mediolateral tear size (length) of the rotator cuff have significant negative association with the clinical outcomes of the retear after arthroscopic rotator cuff repair. The explanatory power of the vari-

ance of mediolateral tear length associating with ASES and constant score was 47.6% and 50.3%, respectively, which corresponded to a moderate level of more than 40%. Since the explanatory power is not at a high level, these results may be best used as a reference for meeting relative criteria.

As intrinsic anatomical factors, the CSA and AI have been reported to be significant factors in rotator cuff tear. In many studies, larger CSA and AI were reported to be associated with full-thickness tears of the rotator cuff [25]; however, the association with clinical outcomes after surgical rotator cuff repair is not consistent with the general consensus. Kirsch et al. [26] studied the association between the CSA and functional score 24 months after arthroscopic rotator cuff repair and reported that the CSA was not a significant predictor of clinical outcomes. However, Garcia et al. [13] reported that a large CSA was associated with worse postoperative functional outcomes. In addition, Ames et al. [27] reported that a larger AI after rotator cuff repair resulted in a lower satisfaction score, while Lee et al. [28] reported that an increase in the CSA or AI did not negatively affect functional outcomes.

In this study CSA and AI may have been factors affecting retear after rotator cuff repair; however, the analysis revealed no significant associations with clinical outcomes in patients with rotator cuff retear. The high CSA induces overload by increasing the cranially-directed shear force of the supraspinatus, and this mechanical overload of the tendon leads to a degenerative tear in the rotator cuff [29]. We assume that these mechanical effects influenced clinical outcomes; however, more detailed biomechanical study is needed to identify the degree of CSA influence.

Lee et al. [30] reported that the initial size of the rotator cuff tear may be a risk factor for a retear after repair. Gladstone et al. [31] and Wu et al. [32] identified initial tear size as an independent predictor of rotator cuff retear. Especially, in the study by Gladstone et al. [31], the initial tear size was reported to be the only independent predictor of rotator cuff retear in a multivariate analysis. In the present study, the sizes of the initial tear and retear, in both the mediolateral length and AP width, were not significantly associated with the clinical score. However, the variance in the mediolateral length, rather than in the AP width, had significant associations with the ASES and Constant scores.

In a study with a 5-year follow-up after rotator cuff repair, Gulotta et al. [33] found that for every 1 cm increase in initial tear size in the sagittal plane (anterior to posterior) on ultrasonography, the risk of defect increased 1.72 times. However, this group

Table 4. Multivariable linear regression analysis of radiologic findings associated with clinical outcomes after rotator cuff retear

Clinical outcome	Radiologic finding	p-value
ASES score	CSA	0.06
	Retear length	0.76
	Variance in tear width	0.52
	Variance in tear length	< 0.01*
Constant score	CSA	0.07
	Variance in tear width	0.50
	Variance in tear length	0.01*

Multivariable linear regression analysis of radiologic findings associated with clinical outcomes after rotator cuff retear.
ASES: American Shoulder and Elbow Surgeons, CSA: critical shoulder angle.
*Statistically significant.

Table 5. Results of multivariable linear regression analysis (ASES and Constant scores)

Variable	Unstandardized coefficient		Standardized coefficient	t (p)	TOL	VIF
	B	SE	β			
ASES score						
(Constant)	122.708	22.789				
Variance of tear length	–0.729	0.222	–0.354	–3.280 (0.002*)	0.874	1.145
F (p)			11.153 (p < 0.001*)			
Adjusted R^2			0.476			
Durbin-Watson			2.254			
Constant score						
(Constant)	114.047	19.676		5.916		
Variance of tear length	–0.671	0.190	–0.375	–3.529 (0.01*)	0.874	1.145
F (p)			12.685 (p < 0.001*)			
Adjusted R^2			0.503			
Durbin-Watson			2.287			

ASES: American Shoulder and Elbow Surgeons, B: Unstandardized Coefficients, SE: Standard error, β: Standardized Coefficients, t (p): p-value for the t-test, TOL: tolerance, VIF: variance inflation factor, F (p): p-value for the F-test.
*Statistically significant.

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also reported that the risk of defects was not associated with clinical outcomes. These results are consistent with those of the present study. In this study, we evaluated pre- and postoperative magnetic resonance images, which are more precise than ultrasonography, to determine not only the size of the initial tears and retears but also the variance in size of initial tears and retears. Similar to the study mentioned above, the clinical outcome was found to be related more with the variance in the mediolateral length than that in the AP width. Thus, the clinical outcomes after rotator cuff retear may be worse in conditions that aggravate the medial retraction of the defect in the rotator cuff. Based on this, we have extrapolated that the medial and lateral sides must be carefully aligned without excessive tension during the repair of the rotator cuff. Dierckman et al. [34] evaluated the in-vivo tension applied to the rotator cuff tendon positioned at the medial versus lateral footprint during arthroscopic rotator cuff surgery and demonstrated a significant, 5.4-fold increase in tension when the tendon edge was reduced to the lateral as opposed to the medial footprint. Therefore, in cases in which coverage of the lateral footprint is barely possible, a reduction in the medial footprint with an appropriate tension would be better for prevention of medial retraction postoperatively.

Kim et al. [35] measured the dimensions of rotator cuff tears (AP and mediolateral) and the remaining tendinous portion of the rotator cuff in patients with rotator cuff tears and analyzed the relationship between tear dimensions and the remaining tendinous portion of the rotator cuff. These researchers showed that the remaining length of the tendinous portion became shorter as the mediolateral dimension of the rotator cuff tear increased but was not affected by the AP dimension of the tear. In the present study, as the length of the mediolateral tear increased, the remaining tendinous length of the rotator cuff decreased. This may have affected the clinical outcomes; however, these findings should be verified by specific mechanical study and additional studies with larger sample sizes.

There were several limitations to the current study. This study had the inherent weaknesses of a retrospective study. As the influence of concomitant procedures (acromioclavicular joint resection, biceps tenotomy, and biceps tenodesis) were not evaluated, those could have introduced bias. In seven patients with inflammatory arthritis as an underlying disease, there were no direct arthritis findings in the shoulder joint. However, the inflammatory arthritis could affect clinical outcomes indirectly. This study evaluated only patients with rotator cuff repair using the suture bridge technique and had low correlation when other repair techniques were applied. Rehabilitation can also create a bias because the start time of passive and active ROM exercises was personalized according to the degree of patient pain and the condition of the repaired rotator cuff assessed by ultrasound during follow-up. There is a possibility that the result of this study could not be applied universally due to the substantial number of exclusion criteria to reduce bias. Also, since explanatory power of variance in mediolateral tear length associating with ASES and Constant score was only moderate, this result should be used for reference only.

However, despite the retrospective nature of the study, the reduction of bias makes the findings significant. Linear regression analysis was used to reduce selection bias that may occur from dividing groups, and the same variables were demonstrated to have statistically significant results with the two clinical functional scores (ASES and Constant scores). This increased the relevance of the results. In patients with a retear after arthroscopic rotator cuff repair, radiologic evaluation demonstrated that the variance in the mediolateral tear length has significantly negative association with the clinical outcomes. Further prospective and mechanical studies are necessary to identify more specific factors that correlate with clinical outcomes after rotator cuff retear.

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Can indirect magnetic resonance arthrography be a good alternative to magnetic resonance imaging in diagnosing glenoid labrum lesions?: a prospective study

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Background: This study was designed to evaluate and compare the diagnostic value of magnetic resonance imaging (MRI) and indirect magnetic resonance arthrography (I-MRA) imaging with those of arthroscopy and each other.
Methods: This descriptive-analytical study was conducted in 2020. All patients who tested positive for labrum lesions during that year were included in the study. The patients underwent conservative treatment for 6 weeks. In the event of no response to conservative treatment, MRI and I-MRA imaging were conducted, and the patients underwent arthroscopy to determine their ultimate diagnosis and treatment plan. Imaging results were assessed at a 1-week interval by an experienced musculoskeletal radiologist. Image interpretation results and arthroscopy were recorded in the data collection form.
Results: Overall, 35 patients comprised the study. Based on the kappa coefficient, the results indicate that the results of both imaging methods are in agreement with the arthroscopic findings, but the I-MRA consensus rate is higher than that of MRI (0.612±0.157 and 0.749±0.101 vs. 0.449±0.160 and 0.603±0.113). The sensitivity, specificity, negative predictive value, positive predictive value, and accuracy of MRI in detecting labrum tears were 77.77%, 75.00%, 91.30%, 50.00%, and 77.14%, respectively, and those of I-MRA were 88.88%, 75.00%, 92.30%, 66.66%, and 85.71%.
Conclusions: Here, I-MRA showed higher diagnostic value than MRI for labral tears. Therefore, it is recommended that I-MRA be used instead of MRI if there is an indication for potential labrum lesions.

Keywords: Shoulder; Magnetic resonance imaging; Indirect magnetic resonance arthrography; Diagnosis; Glenoid labrum

INTRODUCTION

The glenohumeral joint is one of the most unstable joints in the body. Many elements are involved in the stability of this joint, including the labrum, a fibrocartilage structure that attaches to the margin of the glenoid [1] and deepens the glenoid cavity by

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about 30%. This increased depth increases the contact area between the head of the humerus and the glenoid cavity to stabilize the joint. Labrum damage and tears usually happen following shoulder dislocations and lead to pain and instability of the shoulder joint [2,3]. [Labral lesions are divided into anterior (Bankart), posterior (reverse Bankart), and superior (SLAP) tears based on tear location [4-6].

Because of the severe pain and limitation of activity caused by labral lesions, the accuracy, efficiency, and cost-effectiveness of associated diagnostic tests need to be evaluated [7]. Physical examination is useful for diagnosing labral lesions; however, it is not enough to choose a type of treatment [8]. Moreover, detecting the exact location and size of the tear and determining the type of lesion is not easy in a physical examination because of the anatomical complexities of the shoulder joint. Therefore, clinicians turn to imaging to provide rich and useful information to support a patient's medical history and physical examination and to visualize the pathoanatomy of shoulder dysfunction [9].

Magnetic resonance imaging (MRI) and magnetic resonance arthrography (MRA) are two imaging modalities used for labral lesions [10]. Shoulder MRI has become very popular as a screening method for diagnosing labral abnormalities [11]. MRA of the shoulder comprises two types: direct (D-MRA) and indirect (I-MRA). In the I-MRA method, a contrast substance is injected intravenously, increasing the joint space and indirectly enabling arthrography [12,13]. I-MRA is less invasive and more accessible than D-MRA because it does not require fluoroscopy [14,15]. Independence from the radiologist skills needed for D-MRA and costs that are relatively similar to those of MRI are other advantages of I-MRA [13,16].

Diagnosing labral pathologies is a challenge for shoulder surgeons. The gold standard for imaging to diagnose such pathologies is D-MRA; however, given the problems with that method, some physicians have suggested using I-MRA. We conducted this study to compare the diagnostic value of MRI and I-MRA in distinguishing various labrum pathologies.

METHODS

The protocol for this study was approved by the Institutional Review Board of Guilan University of Medical Sciences (IRB No. 847). All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975 (in its most recently amended version). Informed consent was obtained from all patients included in the study.

Study Design

This prospective descriptive-analytical study was conducted in 2020 in our university orthopedic clinic. All patients older than 18 years clinically suspected to have a labral injury based on history and positive labral tests (apprehension, relocation, load and shift, inferior sulcus sign, and crank tests) were entered into the study. Informed consent was obtained from all the participants, and patients with a history of fracture or surgery in the involved shoulder, underlying disease (diabetes, hypothyroidism, or rheumatoid arthritis), degenerative joint disease in the shoulder, or unwillingness to participate in the study were excluded. All patients underwent conservative treatment (physiotherapy, anti-inflammatory drugs, and activity reduction) for 6 weeks. In the event of no response to conservative treatment, MRI and I-MRA imaging were conducted. Patients underwent arthroscopy (as the gold standard of diagnosis) to conclude a final diagnosis and treatment plan.

Data Collection

Initial information (age, sex, damaged side, and cause of damage) was collected at the first visit and recorded on a data collection form. Anonymous MRI and I-MRA images were evaluated by an experienced radiologist at a 1-week interval. The criteria used in this study to diagnose labral lesions were as follows. (1) Contrast material extending into the labral substance. (2) Irregular labral margin. (3) Linear signal intensity not parallel to the glenoid labrum. (4) High signal intensity posterior to the long head of the biceps tendon origin. (5) High signal intensity extending inferior to the 3 o'clock position. (6) Detachment of the glenoid labrum. The results of the radiologist and arthroscopy were recorded on the data collection form.

Magnetic Resonance Protocol

Imaging was performed using a 1.5 tesla GE scanner with a shoulder array coil. The slice thickness was 3 mm, inter slice gaps were 10%, and the field of view was 150 mm. The following standard MRI sequences of the shoulder were used: coronal, sagittal, and axial proton density fat suppression; sagittal T1; and coronal T1FS. Patients were given an intravenous injection of gadolinium at 0.2 mL/kg (up to 15 mL), and after a delay of 10–15 minutes, during which the joint was exercised, and post-contrast coronal and axial T1FS imaging was performed.

Surgical Technique

All surgeries were performed under general anesthesia in the beach-chair position by a specialist shoulder surgeon (MMK). Anterior, posterior, and superior labral tears were evaluated with

an arthroscope. If a tear was observed, it was repaired using an anchor suture.

Statistical Analysis

Frequency and percentage were used for descriptive data (age, sex, damaged side, and cause of damage). The diagnostic indices of sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and accuracy, as well as the kappa agreement and confidence interval (CI), were used to compare the results of MRI imaging with those of I-MRA based on arthroscopy as the gold standard for diagnosing labral lesions. The significance level was set at $p < 0.05$. All data were analyzed using IBM SPSS ver. 20 (IBM Corp., Armonk, NY, USA).

RESULTS

Of the 46 patients who met the inclusion criteria for the study, either responded to conservative treatment, and three were excluded because of follow-up unavailability. Thus, 35 patients did not respond to 6 weeks of conservative treatment and underwent MRI and I-MRA, followed by arthroscopy. The demographic characteristics of the patients are given in Table 1.

The arthroscopy results indicate that 27 patients had a labral tear (21 Bankart lesions, 6 reverse Bankart lesions), and eight patients had a normal labrum. According to the kappa test, MRI and I-MRA generally agreed with arthroscopy in diagnosing labral lesions, Bankart lesions, and reverse Bankart lesions. The two imaging methods did not differ significantly in the 95% CI

Table 1. Demographic characteristics and pre-treatment findings

Variable	Number (%)
Sex	
Male	25 (71.4)
Female	10 (28.6)
Age (yr)	
≤20	8 (22.9)
21–30	14 (40.0)
31–40	8 (22.9)
≥40	5 (14.3)
Damaged side	
Right	25 (71.4)
Left	10 (28.6)
Cause of damage	
Non-sports	10 (28.6)
Contact sports	14 (40.0)
Ball sports	8 (22.9)
Bodybuilding	3 (8.6)

Table 2. Results of arthroscopy, MRI, and I-MRA in labrum

Imaging	Labral tear	Normal	Total	Agreement
MRI				κ = 0.449 ± 0.160; 95% CI, 0.135–0.763; p < 0.001
Labral tear	21 (77.77)	2 (25.00)	23 (65.71)	
Normal	6 (22.22)	6 (75.00)	12 (34.29)	
I-MRA				κ = 0.612 ± 0.157; 95% CI, 0.581–0.919; p < 0.001
Labral tear	24 (88.88)	2 (25.00)	26 (74.29)	
Normal	3 (11.11)	6 (75.00)	9 (25.71)	
Total	27 (100)	8 (100)	35 (100)	

Values are presented as number (%).
MRI: magnetic resonance imaging, I-MRA: indirect magnetic resonance arthrography, CI: confidence interval.

Table 3. Types of shoulder labrum tears in arthroscopy, MRI, and I-MRA

Imaging	Bankart	Revers Bankart	Normal	Total	Agreement
MRI					κ = 0.603 ± 0.113;
Bankart	18 (85.71)	0	1 (12.50)	19 (54.27)	95% CI, 0.382–0.824; p < 0.001
Revers Bankart	0	3 (50.00)	1 (12.50)	4 (11.44)	
Normal	3 (14.29)	3 (50.00)	6 (75.00)	12 (34.29)	
I-MRA					κ = 0.749 ± 0.101;
Bankart	19 (90.48)	0	1 (12.50)	20 (57.14)	95% CI, 0.551– 0.947; p < 0.001
Revers Bankart	0	5 (83.33)	1 (12.50)	6 (17.14)	
Normal	2 (9.52)	1 (16.67)	6 (75.00)	9 (25.71)	
Total	21 (100)	6 (100)	8 (100)	35 (100)	

Values are presented as number (%).
MRI: magnetic resonance imaging, I-MRA: indirect magnetic resonance arthrography, CI: confidence interval.

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kappa results (Tables 2 and 3). Moreover, no complications were seen after either type of imaging.

Table 4 shows the sensitivity, specificity, PPV, NPV, and accuracy of both imaging modalities. These measures for diagnosing labral lesions, Bankart lesions, and reverse Bankart lesions were higher for I-MRA than for MRI. The specificity of the two imaging modalities was similar.

DISCUSSION

Imaging is important in preoperative diagnosis of labral lesions because the clinical signs are often nonspecific. It is important for orthopedic surgeons to accurately describe the imaging outcomes of pathological labral abnormalities and use them to prevent unnecessary surgical treatments [17]. The main diagnostic imaging methods in these shoulder injuries are MRI, I-MRA, and D-MRA [17,18]. Most previous studies have compared the diagnostic value of MRI with that of D-MRA. We compared I-MRA and MRI with arthroscopy results as the gold standard of diagnosis.

In our study, 35 patients first underwent MRI and I-MRA, and those images were evaluated by a musculoskeletal radiologist at 1-week intervals and compared with the surgical outcomes. According to the kappa coefficient, the agreement between MRI and arthroscopy (0.449±0.160 and 0.603±0.113, respectively) was less than that between I-MRA and arthroscopy (0.612±0.157 and 0.749±0.101) in diagnosing labral tears and type of lesion. Although both diagnostic methods were in good agreement with arthroscopy, the agreement was better with I-MRA. Nonetheless, the difference between the two methods was not statistically significant because the 95% CI kappa ranges overlap.

Conventional MRI is a simple imaging technique whose images are useful in shoulder joint instability evaluations [19]. Conventional MRI with 3-T scanners has high accuracy in detecting SLAP lesions [5]. In this study, we used 1.5-T scanners, which are less accurate and sensitive than 3-T scanners. Phillips et al. [20] indicated that conventional MRI was not very accurate in diagnosing upper labrum tears. Unlike D-MRA, I-MRA is a non-invasive technique independent of radiologist skill and has lower costs and fewer complications [21]. Razzano et al. [21] indicated that I-MRA has sensitivity similar to that of D-MRA. According to the results of previous studies, I-MRA seems to be as useful as D-MRA in diagnosing labral lesions. Furthermore, I-MRA has fewer complications and is less costly for patients.

The sensitivity, specificity, NPV, PPV, and accuracy of MRI in detecting labral tears were 77.77%, 75.00%, 91.30%, 50.00%, and 77.14%, respectively, and the values for I-MRA were 88.88%, 75.00%, 92.30%, 66.66%, and 85.71%. Thus, it seems that I-MRA has greater diagnostic value than MRI. Fallahi et al. [22] found results similar to ours, with higher sensitivity (95% and 97% vs. 79% and 83%) and accuracy (93% and 95% vs. 84% and 86%) of I-MRA than MRI. Phillips et al. [20] indicated that the sensitivity and accuracy of D-MRA were higher than those of MRI, while the specificity was lower. Previous studies comparing the diagnostic value of these imaging modalities for SLAP lesions indicated that I-MRA has higher diagnostic value than MRI [22,23]. Apparently, the intravenous contrast injection and MR imaging of the shoulder used in the I-MRA method show labral tears more accurately than does conventional MRI. In other words, the presence of a contrast agent in the shoulder joint enhances the imaging sharpness of the joint cavity and surrounding structures and improves the diagnostic value for glenoid labral tears. Previous studies have indicated that I-MRA has a higher diagnostic value than MRI [24,25]. However, most of those studies were retrospective and had a small sample size. Neither method has any dangerous complications for patients.

Although this study was carried out prospectively, the small sample size is one of its limitations. The other limitations are ex-

Table 4. Specificity, Specificity, PPV, NPV, and accuracy of MRI and I-MRA for diagnosis of shoulder labral tears

Variable	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Accuracy (%)
MRI					
Labral tear	77.77	75.00	91.30	50.00	77.14
Bankart	85.71	92.86	94.74	81.25	88.57
Revers Bankart	50.00	96.55	75.00	90.32	88.57
I-MRA					
Labral tear	88.88	75.00	92.30	66.66	85.71
Bankart	90.48	92.86	95.00	86.66	91.43
Revers Bankart	83.33	96.55	83.33	96.55	94.29

PPV: positive predictive value, NPV: negative predictive value, MRI: magnetic resonance imaging, I-MRA, indirect magnetic resonance arthrography.

clusion of patients because of follow-up loss, poor quality of shoulder images due to the use of old devices, and interpretation of images by only one radiologist. Based on our results, more studies are suggested for comparing I-MRA with other imaging modalities in diagnosing labral lesions and other shoulder pathologies.

Compared with MRI, I-MRA seems to have higher diagnostic value for labral tears. Because the costs of I-MRA are similar to those of MRI and neither procedure has a high risk of complications, use of I-MRA instead of MRI is recommended when imaging is indicated for labral lesions.

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Youth throwing athletes do not show bilateral differences in medial elbow width or flexor tendon thickness

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Background: Medial elbow laxity develops in throwing athletes due to valgus forces. Medial elbow instability in professional, collegiate, and high school athletes is well documented; however, the medial elbow of young throwing athletes has received less attention. This study investigated the medial elbow and common flexor tendon during applied elbow valgus stress of youth baseball players.
Methods: The study included 15 participants. The medial elbow width and thickness of the common flexor tendon were measured on ultrasound images.
Results: No significant side differences in medial elbow width or common flexor tendon were found at rest or under applied valgus stress. At rest, the medial elbow joint width was 3.34±0.94 mm on the dominant side and 3.42±0.86 mm on the non-dominant side. The dominant side increased to 3.83±1.02 mm with applied valgus stress, and the non-dominant side increased to 3.96±1.04 mm. The mean flexor tendon thickness was 3.89±0.63 mm on the dominant side and 4.02±0.70 mm on the non-dominant side.
Conclusions: These findings differ from similar studies in older throwing athletes, likely because of the lack of accumulated stress on the medial elbow of youth throwing athletes. Maintaining elbow stability in young throwing athletes is a vital step to preventing injury later in their careers.

Keywords: Ulnar collateral ligament; Youth injury; Athletic injury; Elbow

INTRODUCTION

Injuries to the medial elbow are common in overhead sports [1-3]. Injury to the ulnar collateral ligament (UCL) appears most common in overhead throwing athletes, with a lower prevalence in wrestlers, tennis players, javelin throwers, and football players [1]. Conte et al. [4] reported that an estimated 18% of relief pitchers in professional baseball have a history of UCL reconstruction. A study conducted over 5 years by the National Collegiate Athletic Association found 1936 UCL injuries occurred in collegiate baseball; 55% of these elbow injuries resulted in lost playing time, and 15% were season-ending [2]. Up to 74% of youth baseball players ages 8–18 report participating in their sport with some level of arm pain [5]. The same study reported 23% of youth baseball players to have a history of arm injury consistent with overuse [5]. Pytiak et al. [6] studied the elbow of the throwing arms in Little League Baseball players before and after a season of play to identify risk factors for pain. However, limited information is available on the stability of the medial elbow in youth throwing athletes.

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Injuries to the UCL occur due to the repetitive microtrauma experienced during overhead throwing [7]. Elbow stability is maintained by ligamentous static stabilization and muscular dynamic stabilization [8]. Damage to the stabilizing structures, especially the UCL, can cause instability or increase the medial joint space [1,7]. Fatigue of the dynamic stabilizers such as the wrist flexor muscle group can decrease overall stability and increase the medial joint space [8,9]. The repetitive stress of throwing begins to fatigue the flexor muscles and stretch the UCL, increasing medial elbow instability [7]. Nazarian et al. [10] reported a greater widening of the medial elbow joint space while placed under valgus stress in the throwing arm than in the non-throwing arm of healthy professional baseball pitchers. Glousman et al. [11] reported that pitchers with UCL injuries demonstrated decreased wrist flexor activity. Millard et al. [9] showed that fatigue of the wrist flexors might lead to an increase in medial elbow joint space. These differences have been found in professional and collegiate baseball players, though studies on youth athletes have not been reported [2,4,10,12,13]. The prevalence of UCL injury is higher in professional baseball players than collegiate baseball players [2,4]. As players age, elbow injury becomes more likely due to the stress placed on the UCL over time. Because these adaptations of the elbow develop over time, coaches and healthcare providers could intervene with preventative measures at the point when the elbow adaptation begins.

The purpose of the current study was to characterize the differences in the width of the medial elbow joint space and the thickness of the common flexor tendon between dominant and non-dominant arms in youth throwing athletes. Specifically, the hypothesis was that the medial elbow joint space is wider and the common flexor tendon is thicker on the dominant side when compared to the non-dominant side of youth throwing athletes.

METHODS

The Institutional Review Board of Marshall University approved this study (IRBNET # 1566840-1). All participants provided written informed assent and the participant's parent provided parental consent before participation.

Participants

Fifteen (14 male, 1 female) youth baseball players were included in the investigation. Descriptive data for all participants are found in Table 1. Thirteen participants were ages 10–13, while the remaining two were ages 6–7. All of the subjects were right-hand dominant. The study inclusion criteria included (1) active in organized youth baseball or softball, (2) under 18 years old, and (3) able to sit still for up to 5 minutes. In addition, participants were excluded from the investigation if the participant reported: (1) shoulder or elbow pain during or after throwing greater than 7 out of 10 on a numerical pain scale, (2) a history of shoulder or elbow surgery, (3) a history of an arm, rib, or shoulder fracture within the past year, or (4) greater than 50% loss of range of motion in the shoulder or elbow.

Table 1. Demographic characteristics

Variable	Mean ± SD
Age (yr)	10.5 ± 3.15
Participation (yr)	5.2 ± 3.3
Weight (kg)	48.7 ± 18.8
Height (cm)	149.2 ± 20.4
Dominate side strength	
Shoulder IR (kg)	21.7 ± 4.8
Shoulder ER (kg)	44.5 ± 6.1
Shoulder abduction (kg)	17.3 ± 8.6
Grip strength (kg)	10.8 ± 3.8
Non-dominate side strength	
Shoulder IR (kg)	17.2 ± 6.1
Shoulder ER (kg)	40.8 ± 6.9
Shoulder abduction (kg)	16.8 ± 7.6
Grip strength (kg)	11.9 ± 2.9

SD: standard deviation, IR: internal rotation, ER: external rotation.

Protocol

The participant's maximal voluntary isometric contraction (MVIC) strength was measured for internal shoulder rotation, external shoulder rotation, wrist extension, and grip strength using a hand-held dynamometer. The same investigator collected all ultrasound images, and a second investigator made all measurements of the medial elbow joint space and tendon thickness. The ultrasound images of the medial elbow joint space were taken as described by Ciccotti et al. [14] and DeMoss et al. [15]. The participant laid supine with their shoulder abducted to 90° and elbow flexed to 30°. The researchers measured the width of the medial elbow joint space in the unstressed condition and again during a valgus stress test. Then, measurements of the common flexor tendon thickness were collected. Each measurement was collected twice. This procedure was then repeated on the contralateral side. The order in which the sides were tested was randomized.

The investigators used a Mindray m5 US unit (Mindray Ltd. and National Ultrasound Inc., Duluth, GA, USA) with an adjustable 8.0–12.0 MHz frequency transducer. Measurements of force were made using a hand-held dynamometer (microFET2; Hog-

gan Scientific LLC, Salt Lake City, UT, USA). Grip strength was assessed using a Jamar Hand Dynamometer (Lafayette Instruments, Lafayette, IN, USA).

Procedures

Manual muscle strength

Assessment of shoulder girdle muscle strength was performed using techniques described by Kendall et al. [16]. Muscle strength was measured using hand-held dynamometry. Investigators measured each participant's grip strength in both arms with the hand-held dynameter set at position two. Each strength measurement was made twice, with a minimum 60-second rest given between each measurement; the mean of the two measures (Table 1) was used for analysis [17,18].

Ultrasound imaging

The elbow images were collected with and without an elbow valgus stress test (Fig. 1). In addition, ultrasound images of the common flexor tendon were also collected. The ultrasound probe was oriented along the long axis of the UCL to view the medial elbow joint space, using the trochlea of the humerus and the sublime tubercle of the ulna as landmarks [14]. The medial elbow joint space width was defined as the distance between the trochlea of the humerus and the coronoid process of the ulna [14].

Pilot testing completed in preparation for the current investigation revealed moderate to excellent reliability for measuring the width of the medial elbow joint space and common flexor tendon thickness. For the unstressed measurement, the intraclass correlation coefficient (ICC) was 0.97 and 0.82 for the dominant and non-dominant sides, respectively. The ICC for the stressed measure was 0.74 and 0.71 for the dominant and non-dominant sides, respectively. The ICC for tendon thickness was 0.67 and 0.90 for the dominant and non-dominant sides, respectively. The minimal detectable change for the unstressed elbow, stressed elbow, and tendon thickness was 0.08 mm, 0.26 mm, and 0.37 mm, respectively. The standard error was 0.06 mm, 0.18 mm, and 0.26 mm, respectively.

Data Analysis

The investigation used IBM SPSS ver. 21 (IBM Corp., Armonk, NY, USA) for all statistical analysis. Paired t-tests were used to determine the side-to-side differences in the width of the joint space. Statistical significance was determined at $p < 0.05$.

RESULTS

The results for width of the medial elbow joint space and common flexor tendon thickness are presented in Table 2. The mean width of the medial elbow joint space of the dominant side was 3.34 ± 0.94 mm (mean ± standard deviation) in the unstressed position and 3.83 ± 1.02 mm with the applied valgus stress. The mean joint widths for the non-dominant side were 3.42 ± 0.86 mm in the unstressed position and 3.96 ± 1.04 mm with the applied valgus stress. The increase in the width of the medial elbow joint space during the valgus stress reached statistical significance on both the dominant (mean difference, 0.49 mm; $t = -6/274$, $1\text{-}\beta = 0.997$, $p < 0.001$) and non-dominant (mean difference, 0.54 mm; $t = -4.141$, $1\text{-}\beta = 0.997$, $p = 0.001$) sides. The mean flexor tendon thickness was 3.89 ± 0.63 mm on the dominant side and 4.02 ± 0.70 mm on the non-dominant side; this difference did not reach statistical significance ($p > 0.05$).

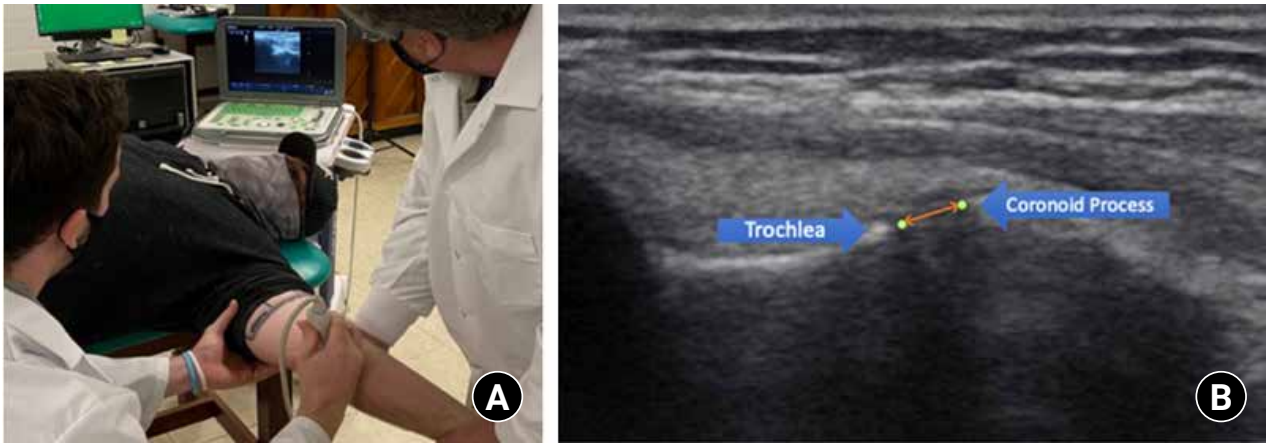

Fig. 1. Ultrasound testing position and ultrasound image of the medial elbow. Test subject positioning during ultrasound imaging (A) and an ultrasound image of the medial elbow joint with labels signifying the trochlea and the coronoid process (B).

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Table 2. Medial elbow joint width and common flexor tendon thickness

Measurment	All participants		Older participant		Younger participant	
	Dominate	Non-dominate	Dominate	Non-dominate	Dominate	Non-dominate
Joint width (mm)						
No stress	3.34 ± 0.94	3.42 ± 0.86	3.39 ± 0.91	3.43 ± 0.78	3.02 ± 1.52	3.37 ± 1.73
Stress	3.83 ± 1.02*	3.96 ± 1.04*	3.86 ± 0.99*	3.99 ± 1.06*	3.67 ± 1.73	3.80 ± 1.27
Common flexor tendon (mm)	3.89 ± 0.63	4.02 ± 0.70	3.99 ± 0.52	4.1 ± 0.57	3.25 ± 1.20	3.17 ± 1.09

Values are presented as mean ± standard deviation. The width of the medial elbow with and without valgus stress measured on ultrasound images presented along with the thickness of the common flexor tendon.
*Statistically greater than no stress condition, $p < 0.05$.

In older subjects (age 10–13 years), the mean width of the medial elbow joint space on the dominant side was 3.39 ± 0.91 mm and 3.86 ± 0.99 mm (unstressed and valgus-stressed, respectively). The mean width of the medial elbow joint space on the non-dominant side was 3.43 ± 0.78 mm, 3.99 ± 1.06 mm (unstressed and valgus-stressed respectively), demonstrating a non-statistically significant difference in joint space width between the dominant and non-dominant side elbow under valgus stress ($t = -1.947$, $1\text{-}\beta = .997$, $p = 0.075$). There was a significant increase in joint space (mean difference, 0.46 ± 0.31 mm; $t = -5.358$, $1\text{-}\beta = 0.750$, $p < 0.001$) with the applied valgus stress on the dominant side. There was a similar increase (0.55 ± 0.52 mm, $t = -3.818$, $p < 0.01$) seen on the non-dominant side. The mean flexor tendon difference between the dominant and non-dominant sides was statistically significant (–0.16 ± 0.24 mm, $t = -2.419$, $p = 0.03$)

In the younger subjects (age 6–7 years), the mean width of the medial elbow joint space on the dominant side was 3.02 ± 1.52 mm and 3.67 ± 1.73 mm (unstressed and valgus-stressed, respectively). The mean joint space width on the non-dominant side was 3.37 ± 1.73 mm, 3.80 ± 1.27 mm (unstressed and valgus-stressed respectively), demonstrating no statistically significant difference in joint space width between the dominant and non-dominant sides under valgus stress ($t = 0.42$, $p = 0.67$). There was a non-significant increase in the width of the joint space (mean difference, 0.65 ± 0.21 mm; $t = 4.333$, $p = 0.144$) with the applied valgus stress on the dominant side. There was a similar increase (0.42 ± 0.45 mm, $t = 1.308$, $p = 0.416$) seen on the non-dominant side. The mean flexor tendon difference between the dominant and non-dominant sides was –0.35 mm ± 0.07 mm ($t = 2.333$, $p = 0.258$).

DISCUSSION

This study aimed to characterize differences in the width of the medial elbow joint space between the dominant and non-dominant arms and the common flexor tendon thickness in youth throwing athletes. However, there was no significant difference between dominant and non-dominant arms. Therefore, our results did not support our hypotheses. In addition, we observed no difference in the width of the medial elbow joint space in the resting position between dominant and non-dominant arms. Both findings contrast with similar studies conducted in older throwing athletes.

The absence of a side-to-side difference can be attributed to the subjects' relative lack of exposure to medial elbow stress. The specific adaptations in question are thought to be due to accumulated stress over long periods [7]. The participants in the current study are relatively new to their sport (mean duration of participation, 5.17 ± 3.31 years) and to overhead throwing. An increased medial elbow joint width has been documented in professional baseball [10,14], collegiate [2], and high school level baseball athletes [19-21]. The absence of a difference between elbow joint space width in the youth baseball athletes could be attributed to the subjects' overall inexperience with throwing sports. The youth throwing athletes have not developed the medial elbow instability found in older throwing athletes.

Tajika et al. [19] and Sakata et al. [22] examined the elbows in youth throwing athletes via ultrasonography. Both studies reported finding osteochondritis dissecans and epicondylar apophysis (little leaguer's elbow) in youth throwers. However, neither paper reported changes in medial elbow joint space width. Little leaguer's elbow and osteochondritis dissecans are common in youth throwing athletes—much more than medial elbow instability [19,22]. The prevalence of these abnormalities could result from the forces generated during the throwing motion being distributed to anatomical structures other than the UCL in the young elbow, such as immature epiphysial plates, resulting in the literature's abnormalities.

Hattori et al. [21] measured the dominant arm's medial elbow joint space width in high school baseball players, using the same method as the present study. Hattori et al.'s study [21] showed that with the applied valgus stress on the medial elbow, the average width measurement was 5.6 ± 0.9 mm, compared to our 3.83 ± 1.03 mm [21]. The wider joint space width measured by

Hattori et al. [21] could be due to the average age of their participants being 16.6 years old with an average of 8.8 years of baseball experience. Our participants were much younger with significantly less baseball experience. The wider joint space found in Hattori's sample [21] may result from accumulated stress due to those athletes having greater playing experience than the athletes in our sample.

Keller et al. [23] conducted a similar study measuring the width of the medial elbow joint space and UCL thickness of high school pitchers before and after a competition season. The average joint width was 3.1 ± 0.7 mm in the unloaded position and 3.9 ± 1.0 mm with the applied valgus load during the pre-season [23]. The given results show a slightly smaller medial elbow gapping than our sample's data, which is unexpected. In addition, the participants in the Keller et al.'s study [23] had an average age of 16.9 years, compared to the average age being 10.5 years in the present study. This difference may be attributed to the measurement protocol used in their research. Keller et al. [23] measured the subjects sitting upright in a chair with their shoulder in maximum external rotation and elbow flexed to 30°. The measurements in our study were taken with the participant lying supine with their elbow flexed to 30°. Subjects in the supine position may relax more than subjects in a seated position, allowing for greater valgus movement in the medial elbow with added stress.

Tajika et al. [20] measured the medial elbow joint space during a valgus stress test of 132 high school baseball pitchers (age 15–17 years). Like the present study, the authors found a significant increase in the joint space width with applied valgus stress. Consistent with the current research, Tajika et al. [20] did not report side differences in the medial joint space width. Also like the present study, the side-to-side difference during the valgus stress test was not statistically significant. Sasaki et al. [13] used ultrasound to examine elbow laxity in 30 collegiate baseball players (average age, 21.7 years). Using ultrasound to view the medial elbow under gravity-valgus stress, they observed a significant increase in joint space width on the dominant side (2.7 ± 1.4 mm) compared to the contralateral side (1.6 ± 1.4 mm) [13]. These results show that an increase in medial elbow joint space can be observed in collegiate baseball players, most likely due to the longer time spent participating in the sport than youth players. However, their results were smaller in magnitude than the results of our study, meaning the joint space width observed in their collegiate sample was smaller than the width observed in our youth sample. This could be due to the method used by Sasaki et al. [13], where the subject was in a supine position with their elbow at 90° flexion. The authors reasoned that the 90° flexed position more accurately emulated the positioning of the elbow during the throwing motion [13]. However, this examination position is not commonly used among researchers and clinicians and may affect the results of their measurements. As the elbow flexes, the ulna's sublime tubercle comes closer to the humerus' trochlea, resulting in a shorter distance between the landmarks. Positioning the elbow in 90° flexion results in the medial joint space appearing smaller than when measured with the elbow at 30° flexion, like in the present study.

Ellenbecker et al. [24] reported a statistically significant increase of 0.32 mm in the width of the medial joint space on the dominant side compared to the non-dominant side with valgus stress applied in professional baseball pitchers. While statistically significant, this minor increase would be unidentifiable using manual orthopedic laxity tests. These results oppose those of other authors who examined the elbow joint space width of professional baseball players, such as Nazarian et al. [10], who observed increased laxity on pitchers' dominant arms. The use of stress radiography compared to dynamic ultrasound to measure medial elbow joint space could be the source of the discrepancies in the results. Typically, a 0.5 mm difference seen using stress radiography is used to differentiate between injured and uninjured conditions regarding medial elbow laxity [24]. The current study reported a mean increase of 0.34 mm in width of the medial joint space, which, considering the sample population was uninjured athletes, falls within and supports the use of the 0.5 mm designation for injured patient populations [24].

There was no difference in thickness of the flexor tendon between dominant and non-dominant arms in the current study. According to a study by Pexa et al. [25], the wrist flexor muscles play a role in maintaining elbow stability when a valgus force is applied to the medial elbow. The contraction of these muscles creates a varus moment, decreasing the width of the medial joint space. This stabilizing force acts against the valgus force applied during the throwing motion's acceleration phase. Therefore, it would be expected for an experienced baseball pitcher to see an increase in the thickness of the flexor tendon as an adaptation to repetitive loads. However, our results do not support such findings. This may be credited to the inexperience of our sample population. Our subjects have not participated in throwing sports for enough time to accumulate that repetitive load. Therefore, the younger throwing athletes do not exhibit the adaptations seen in older throwing athletes.

The current study supports the theory that increased laxity of the dominant elbow in throwing athletes directly correlates with the amount of time an individual has spent participating in throwing sports. Tajika et al. [19] identified multiple risk factors for elbow pain in youth throwers, including age > 11 years and

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height >150 cm (~5 ft). Sakata et al. [22] also identified increased age as a risk factor for developing elbow pain, in addition to the position one plays; pitchers have a higher risk for elbow pain than non-pitchers. Pytiak et al. [6] documented that youth athletes who participate in year-round baseball also have a higher risk of developing medial elbow abnormalities such as little leaguer's elbow. These risk factors support the theory that repetitive stress applied to the UCL and the medial elbow results in adaptations to these structures that predispose athletes to injury later in their careers.

Hattori et al. [21] reported medial joint space width measured in high school-aged pitchers during and after a pitching protocol of 100 pitches. The authors [21] reported increased joint space width as more pitches were thrown: 6.0 mm after 20 pitches, 6.2 mm after 40, 6.4 mm after 60, 6.7 mm after 80, and 7.0 mm after 100. These results exhibit the effect that fatigue and acute stress have on the stability of the medial elbow. It is important to consider how long these acute changes take to resolve. Khalil et al. [26] measured elbow joint space in the throwing arms of 11 collegiate pitchers after a season of play and then again prior to the upcoming season. The authors [26] found that both UCL thickness and medial elbow joint space increased after a season of play compared to pre-season baselines. However, after the off-season rest period, both measures returned to the pre-season baseline [26]. Furthermore, Millard et al. [9] found that the medial elbow exhibited increased laxity during a valgus stress test when the wrist flexor muscles were fatigued. Combining the results of these studies with the knowledge that increased elbow laxity increases the risk of an acute elbow injury, we can support the implementation of injury prevention strategies in youth baseball, such as pitching limits.

There were several limitations to the current investigation. First, our sample of convenience of 14 youth throwers limits the application of our results. The pilot data we gathered previously determined that with 25 subjects, our measures' reliability would be moderate and would have a standard error of 0.2 mm and a minimal detectable change of 0.16 mm. With only 14 participants, those values are expected to be higher, making it more difficult to apply our findings to the general population of youth throwing athletes. Secondly, our sample population was relatively heterogeneous in that they had different levels of experience in throwing sports, a wide age range, and a wide range of height/weight. These disparities further complicate the applicability of our results to larger populations.

Bilateral ultrasound evaluation of the medial elbow joint space width and flexor tendon thickness in youth throwing athletes revealed non-significant differences between the dominant and non-dominant arms with and without applied valgus stress. The study also found no difference in the thickness of the flexor tendon between the dominant and non-dominant sides. The authors expected this lack of side-to-side differences as youth throwing athletes have less exposure to the throwing motion and experience lower valgus forces during the acceleration phase. The current study results underscore the importance of coaches and healthcare providers closely monitoring injury prevention measures for young throwing athletes. Further research that includes more subjects is needed to generalize these results to youth throwing athlete populations. Following these athletes yearly may provide a more precise timeline for when adaptations to throwing begin to develop in the life cycle of throwing athletes.

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The clinical outcomes of infraspinatus rotational transfer for irreparable posterosuperior rotator cuff tears: a preliminary report

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Background: This study aimed to examine the preliminary clinical results of the infraspinatus rotational transfer procedure for irreparable posterosuperior rotator cuff tears.
Methods: This study included 34 patients (mean age, 68.4 years). Their mean tear width and length measurements were 50.9 mm and 50.6 mm, respectively. The functional outcomes, including physician-determined and patient-reported scores, were evaluated before and at 1 year after surgery. The structural outcomes determined using the magnetic resonance imaging examination results were also assessed.
Results: The clinical scores significantly improved after surgery compared with the scores before surgery: the Constant-Murley score (53.3±21.1 to 76.8±10.5), University of California at Los Angeles Shoulder score (15.6±3.6 to 27.8±6.7), American Shoulder and Elbow Surgeons Shoulder score (51.8±18.3 to 89.1±13.5), and WORC score (925.0±436.8 to 480.3±373.2) (all $p<0.001$). Postoperative re-tears were noted in two patients (5.9%).
Conclusions: One year postoperatively, the patient's clinical scores significantly improved, with a re-tear rate of 5.9%.

Keywords: Shoulder; Rotator cuff tear; Treatment outcome

INTRODUCTION

Full-thickness rotator cuff tears (RCTs) tend to be larger in patients under 60 years of age [1], and the tear size progresses to approximately 50% after an average of 2 years; consequently, surgery may be considered at an early stage [2]. Several randomized controlled trials and meta-analyses have shown that in RCTs, surgical repair is associated with better clinical outcomes compared with non-surgical treatment [3-5].

There has been controversy regarding the best treatment for irreparable large and massive RCTs. Several alternative surgical procedures have been applied: partial repair [6], tendon transfer (latissimus dorsi tendon [7], pectoralis major [8], and lower trapezius [9]), superior capsular reconstruction (SCR) [10], and

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balloon arthroplasty [11]. Moreover, no specific treatment strategies are currently recommended because of the paucity of high-quality clinical studies available for guiding the management of irreparable massive RCTs [12]. Therefore, the definition of an irreparable RCT remains controversial. The irreparability of the tendon is typically multifactorial and includes both imaging findings and patient factors. In addition, Warner et al. defined an irreparable RCT as an injury where the tendon stump does not reach the footprint after soft tissue mobilization [13]. Consistently, this study defined an irreparable RCT as described above.

Morihara et al. [14] reported the results of a modified Debeyre-Patte procedure for irreparable large and massive RCTs. In their study, the re-tear rate was 23% and was significantly associated with the degree of general fatty degeneration index. Asato et al. [15] modified and developed a novel surgical procedure from the Japanese literature for irreparable posterosuperior RCTs termed "infraspinatus rotational transfer." They applied this procedure in patients with more severe infraspinatus (ISP) fatty degeneration (n = 12) and demonstrated a re-tear rate of 0% after surgery. However, no studies in the English literature have reported the clinical results of infraspinatus rotational transfer (IRT) for irreparable large and massive RCTs. We have carried out the IRT procedure to treat irreparable posterosuperior large/massive RCTs since 2018. Thus, we hypothesized that this procedure leads to acceptable clinical outcomes postoperatively. The purpose of this study was to evaluate the clinical results of IRT for irreparable posterosuperior large/massive RCTs at 1 year postoperatively.

METHODS

This study was approved by the Health Sciences Institutional Review Board of Fukuoka Shion Hospital (IRB No. 13-012). Informed consent to participate in this study was obtained from all participants.

Participants

The inclusion criteria were as follows: (1) patients with large (3.0–5.0 cm) or massive (> 5.0 cm) RCTs who had undergone arthroscopic repair, (2) those who were available for magnetic resonance imaging (MRI) preoperatively, (3) those who underwent the appointed postoperative rehabilitation program, and (4) those who were available for a postoperative follow-up after 1 year. However, the exclusion criteria were as follows: (1) patients who had a successful primary repair during surgery, (2) those who had irreparable SSC tears (> Lafosse classification type 2), (3) those who had other orthopedics-associated or systemic diseases, and (4) those who could not be followed-up.

From 2017 to 2020, 179 patients with RCTs underwent arthroscopic rotator cuff repair. According to our criteria, those with small/medium-sized tears (n = 100), those who experienced primarily repaired large or massive tears (n = 79), those who had a successful primary repair during surgery (n = 37), those with RCTs that had subscapularis tendon involvement (> Lafosse classification type 2, n = 5), patients with other orthopedics-associated or systemic diseases (n = 2), and those who could not be followed-up (n = 1) were excluded. Consequently, 34 patients who met the inclusion criteria were examined and then included in the present study. There were 3 large and 31 massive tears; their mean width and length were 50.9 mm and 50.6 mm, respectively. The mean age at the time of surgery was 68.4 years (range, 57–76 years), with a mean follow-up period of 12.6 months (range, 12–18 months). Further details are shown in Table 1.

Surgical Method

After the induction of general anesthesia, the patients were placed in the beach chair position. The tendon stumps in all patients were proximally retracted beyond the glenoid edge

Table 1. Patient demographics

Variable	Total (n = 34)
Age (yr)	68.4 ± 4.8
Sex (male:female)	23:11
Body mass index (kg/m^2)	23.8 ± 3.2
Symptom duration (mo)	11.2 ± 19.4
Critical shoulder angle (°)	35 ± 4.7
Acromiohumeral interval (mm)	6.4 ± 3.1
Goutallier classification	
SSP (0:1:2:3:4)	0:0:10:17:7
ISP (0:1:2:3:4)	3:6:13:7:5
SSC (0:1:2:3:4)	17:12:5:0:0
TM (0:1:2:3:4)	22:8:0:2:2
Tear size	
Large:massive	3:31
Tear width (mm)	50.9 ± 7.2
Tear length (mm)	50.6 ± 6.1
Operation time (min)	115 ± 23.2
Estimated blood loss (mL)	110.8 ± 43.5
ASD (%)	75.7
Subscapularis partial tear (%)	35.3
LHB (intact:tenotomy:rupture)	11:9:14

Values are presented as mean ± standard deviation or number.
SSP: supraspinatus, ISP: infraspinatus, SSC: subscapularis, TM: teres minor, ASD: arthroscopic subacromial decompression, LHB: long head of biceps.

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(Fig. 1A). Despite thorough mobilization, including capsular/coracohumeral ligament release, these stumps did not reach the footprint of the greater tuberosity (Fig. 1B). Next, an approximately 4-cm straight incision was made on the scapula spina. The interface between the subcutaneous tissue and the infraspinatus (ISP) was released digitally. Using fingers and metal instruments, the margin of the ISP was gently separated from the medial border of the scapula, the posterior margin of the glenoid, the superior portion of the teres minor, and the scapula body (Fig. 2A). These procedures allowed the tendon stumps to easily reach the superior facet area near the bicipital groove (Fig. 2B). Finally, the approximated tendon was fixed using the suture bridge technique with two anchors in the medial row (Healix Advance; DePuy Synthes, Raynham, MA, USA) and two anchors in the lateral row (SwiveLock; Arthrex, Naples, FL, USA) (Fig. 1C).

In cases with osteophytes in the subacromial space, acromioplasty was performed (75.7%). Tenotomy of the long head biceps tendon was carried out when a tear of half or more of the width was present (45.9%). Partial tears of the upper subscapularis tendon were treated by shaving, not by repair; in our series, no full-thickness tears of this tendon were detected. The mean operative time was 115±23.2 minutes. Further details are shown in Table 1.

Postoperative Rehabilitation

After surgery, the patients were placed in an immobilization sling in a neutral position for 8–10 weeks. All patients underwent postoperative regimens under the strict supervision of a physical therapist. We began passive elevation exercises and external/in-

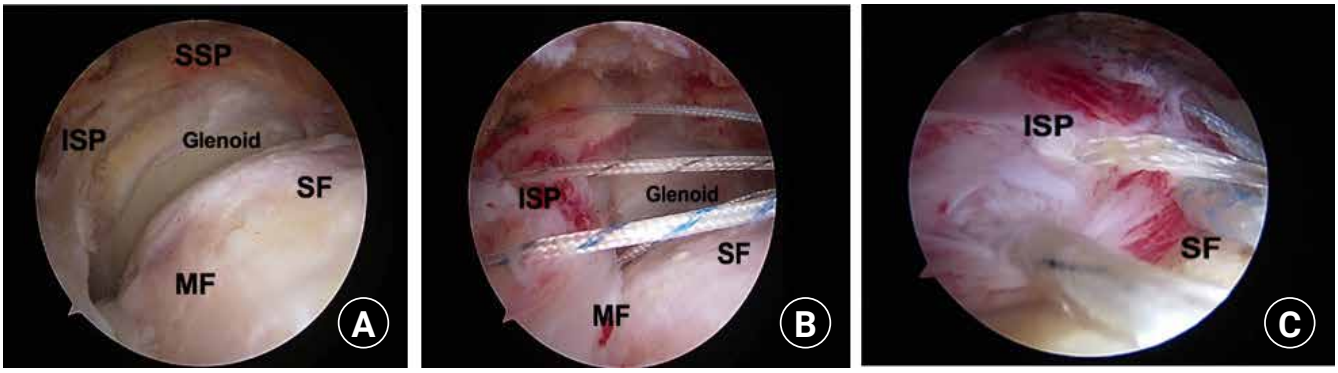

Fig. 1. (A) A massive rotator cuff tear in the right shoulder of a 73-year-old man. Viewed from the posterolateral portal. (B) After mobilization of the infraspinatus (ISP), the three stay sutures placed at the tendon's edge were pulled antero-superiorly. However, the tendon stumps failed to reach the footprint beyond the anatomical neck of the humerus. (C) After rotational ISP transfer. Once released from the surrounding tissues by the "rotational ISP transfer" technique, the ISP tendon's edge was fixed using the suture bridge technique. SSP: supraspinatus, SF: superior facet, MF: middle facet.

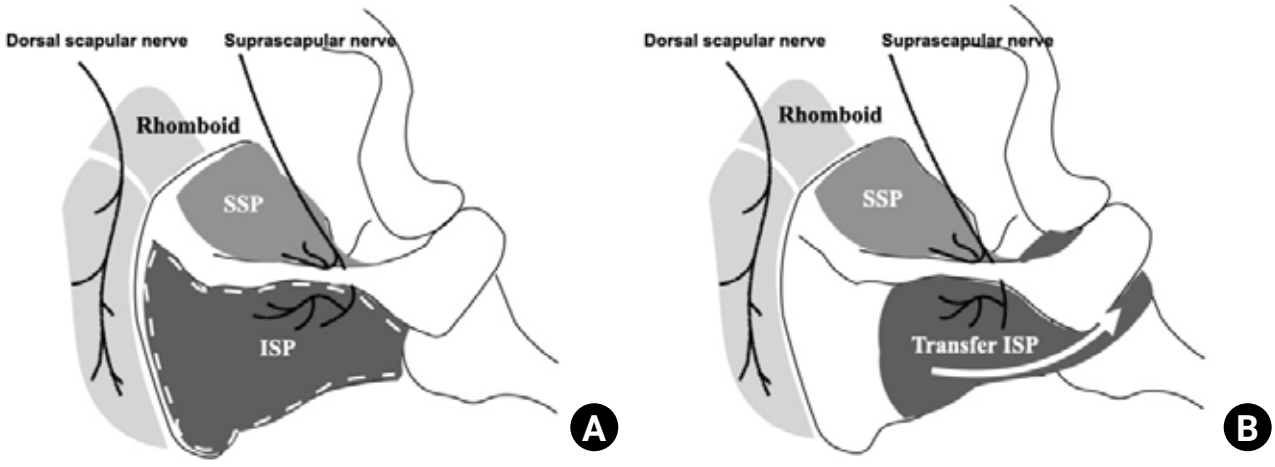

Fig. 2. Scheme of rotational infraspinatus (ISP) transfer. (A) The ISP was released from the surrounding tissues. White lines indicate the margin between the ISP and the surrounding tissue. (B) Anterosuperior advancement of the released ISP (white arrow). SSP: supraspinatus.

ternal rotations in a supine position one week postoperatively. Active exercises were subsequently initiated in the sitting or standing position at 8–10 weeks postoperatively. Strength exercises were started at 4–5 months postoperatively, and the patients resumed their previous work activities 6 months postoperatively.

Preoperative and Postoperative Outcome Measures

The functional outcomes were assessed by the Constant-Murley Score (Constant), University of California at Los Angeles (UCLA) Shoulder Score, and Japanese Orthopaedic Association (JOA) scores. Patient-reported outcomes were assessed using the Shoulder Index of the American Shoulder and Elbow Surgeons (ASES), Western Ontario Rotator Cuff Index (WORC), and JOA Shoulder 36 score version 1.3 (Shoulder 36). Range of motion (ROM) was evaluated before the surgery and then again at 12 months postoperatively using the active elevation, external rotation, and internal rotation. The internal rotation was measured as the highest vertebral body that the patient could reach with the thumb of the affected arm. The degree of pain (in motion and at night) was assessed using a visual analog scale (0–100 mm). Muscle strength was evaluated using a handheld dynamometer (MicroFET2; Hoggan Health Industries, Draper, UT, USA) in a sitting position with the hips and knees at 90° flexion. Measurements of the strength of the 40° abductor and the 90° abductor were performed in the shoulder joint's internal and external rotation positions, respectively, along with the external rotation and internal rotation strength in the 0° abduction position. Each measurement was taken three times, and the average value was calculated. These functional evaluations were performed both before and at 12 months after the surgery.

Preoperatively, the tear size was measured by MRI as the maximum anteroposterior tear width on T2-weighted sagittal images and the maximum mediolateral tear length on T2-weighted oblique-coronal images [16]. Preoperative fatty infiltration of the rotator cuff muscles was assessed using the Goutallier Classification [17]. The postoperative cuff integrity was evaluated with MRI 12 months after surgery; images with Sugaya classification Types 4 or 5 were considered re-tears [18]. Subsequently, two observers blinded to this study independently assessed the structural outcomes. Reproducibility between these two observers showed "good" interrater reliability (ICC [3, 1] = 0.85) and "excellent" intrarater reliability (ICC [1, 2] = 0.92).

Statistical Analysis

We used statistical software (R version 2.8.1; R Foundation for Statistical Computing, Vienna, Austria) to analyze the data. After confirming a normal distribution using the Shapiro-Wilk test, a paired t-test or Wilcoxon rank-sum test was utilized. The Wilcoxon rank-sum test was used to compare the Constant, UCLA, JOA, ASES, WORC, and Shoulder 36 scores, ROM, pain level, and muscle strength both before and after surgery. A p-value < 0.05 was considered statistically significant.

RESULTS

Functional Outcomes

Compared with the preoperative scores, the mean scores significantly improved 12 months postoperatively as follows: Constant (53.3 ± 21.1 to 76.8 ± 10.5), UCLA (15.6 ± 3.6 to 27.8 ± 6.7), ASES (51.8 ± 18.3 to 89.1 ± 13.5), and WORC (925.0 ± 436.8 to 480.3 ± 373.2) (all $p < 0.001$). Although the range of motion of active elevation significantly improved after surgery (95.6° ± 51.1 to 146.9° ± 14.5; $p < 0.001$), these improvements were not observed for external or internal rotation (Table 2). Additionally, while 44.1% of all patients exhibited pseudoparalysis before the surgery, they all had improved 1 year after surgery.

This study included 15 patients with preoperative pseudoparalysis (15/34, 44.1%) who experienced significant improvements in their functional and patient-reported outcomes after surgery. We observed no re-tears in these 15 patients. The results also showed that the preoperative pain level while in motion and at night significantly improved after surgery (41.4 ± 25.2 to 6.7 ± 14.9 mm and 21.8 ± 24.8 to 4.3 ± 10.3 mm; $p < 0.001$), respectively (Table 2).

Additionally, the 40° abductor muscle strength during external rotation improved from 53.0 ± 24.4 to 63.3 ± 19.5 N ($p = 0.028$), while the internal rotation improved from 60.9 ± 24.0 to 70.7 ± 20.4 N ($p = 0.042$); however, these improvements were not observed at the other positions. These data are summarized in Table 2.

Postoperative Structural Outcomes

At the 1-year postoperative evaluation, the Sugaya's classifications were type I in 8 patients, type II in 15 patients, type III in 9 patients, type IV in 1 patient, and type V in 1 patient (Table 2). Consequently, postoperative re-tears were noted in two shoulders (5.9%) that were types IV and V.

DISCUSSION

As a muscle advancement procedure for treating irreparable RCTs, Asato et al. [15] developed the IRT technique in which the ISP muscle is fully separated from the surrounding tissues and then advanced to the footprint without creating too much tension. They reported successful outcomes without any postopera-

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Table 2. Clinical outcomes

Variable	Preoperative	Postoperative 12 mo	p-value
Constant-Murley score	53.3 ± 21.1	76.8 ± 10.5	< 0.001
UCLA shoulder score	15.6 ± 3.6	27.8 ± 6.7	< 0.001
JOA score	64.1 ± 10.9	86.8 ± 8.3	< 0.001
ASES score	51.8 ± 18.3	89.1 ± 13.5	< 0.001
WORC score	925.0 ± 436.8	480.3 ± 373.2	< 0.001
Shoulder 36 score			
Pain	2.8 ± 0.9	3.7 ± 0.5	< 0.001
ROM	2.8 ± 0.8	3.6 ± 0.5	< 0.001
Power	2.0 ± 1.0	3.5 ± 0.5	< 0.001
General health	3.2 ± 0.7	3.7 ± 0.4	< 0.001
ADL	2.7 ± 0.8	3.6 ± 0.5	< 0.001
Ability for sports	1.3 ± 1.1	3.0 ± 0.9	< 0.001
Active range of motion (°)			
Elevation	95.6 ± 51.1	146.9 ± 14.5	< 0.001
External rotation	26.8 ± 18.5	30.0 ± 16.9	0.176
Internal rotation	12.9 ± 4.0	12.9 ± 2.0	0.918
Pain (mm)			
Motion pain	41.4 ± 25.2	6.7 ± 14.9	< 0.001
Night pain	21.8 ± 24.8	4.3 ± 10.3	< 0.001
Strength (N)			
Abduction			
40° (ER)	53.0 ± 24.6	63.3 ± 19.5	0.028
40° (IR)	60.9 ± 24.0	70.7 ± 20.4	0.042
90° (ER)	56.2 ± 40.8	57.9 ± 27.6	0.903
90° (IR)	59.2 ± 43.1	66.7 ± 28.7	0.710
External rotation	35.1 ± 26.9	35.6 ± 13.5	0.682
Internal rotation	79.3 ± 22.7	88.2 ± 23.7	0.003
Sugaya classification			
Type 1:2:3:4:5	-	8:15:9:1:1	-

Values are presented as mean ± standard deviation.
UCLA: University of California at Los Angeles, JOA: Japanese Orthopaedic Association, ASES: American Shoulder and Elbow Surgeons, WORC: Western Ontario Rotator Cuff Index, Shoulder 36: JOA shoulder 36 score, ROM: range of motion, ADL: activities of daily living, ER: external rotation, IR: internal rotation.

tive re-tears in the Japanese literature. However, no English literature regarding this technique has been published. The present study investigated the preliminary outcomes of the IRT technique in patients with irreparable posterosuperior RCTs. Both physician-based and patient-based functional outcomes were significantly improved, with a re-tear rate of 5.9% 1 year after surgery, including preoperative pseudoparalysis cases (15/34, 44.1%). Thus, we believe that the IRT technique is a useful surgical option for irreparable posterosuperior RCTs.

Developed by Asato in 2010, IRT focuses on the anatomical restoration of ISP function rather than SSP function. Mochizuki et al. [19] reported that, compared with the SSP, the ISP covers most of the greater tuberosity, indicating the higher importance of repairing the ISP in RCTs. In our series, IRT improved the strength and ROM of elevation after surgery but failed to show significant improvement of the external rotation range and strength at 1 year postoperatively, except for recovery of muscle strength with the arm abducted 40°. This finding may imply that advancement of the ISP leads to a "spacer effect," which helps to exert deltoid function effectively, but not to full recovery of the range and strength of external rotation. In other words, IRT may function to depress and center the humeral head in the glenoid and help the deltoid muscle to elevate the arm, as reported in biomechanical studies of SCR [20] and balloon spacer [21] procedures.

Various alternative procedures for irreparable RCTs have been reported. The lower trapezius transfer technique using an Achilles tendon allograft was reported to improve the clinical outcome

in 90% of patients. However, two patients underwent reverse shoulder arthroplasty, and two experienced traumatic rupture of the transfer at 14 months postoperatively [22]. The latissimus dorsi transfer technique has a high rupture rate of 38% [23]. In this study, when we compared patients aged ≤ 55 years and ≥ 75 years, the re-tear rates were 33% and 26%, respectively, but there was no significant difference in the clinical outcomes and satisfaction rates, suggesting that it is a useful procedure for patients aged ≥75 years [24]. SCR has been increasingly investigated and reported in recent years. In a systematic review, graft tears in the dermal allograft and the autograft fascia lata were reported to be 13.9% overall [25]. A wide range of failure rates has been reported, depending on the type of graft: 5%–32% for the fascia lata autograft and 20%–70% for the human dermal allograft. Irrespective of the tissue source, the clinical results after 12 months postoperatively were reported to be excellent [26]. The present preliminary study successfully demonstrated acceptable functional results with a relatively low re-tear rate (2/34, 5.9%).

For irreparable posterosuperior RCTs, similar procedures have been reported so far (Morihara et al. [14] and Yokoya et al. [27]). Except for the presence of fascial continuity to the surrounding muscles, these two procedures consistently comprise the following techniques: (1) release of the supraspinatus from the supraspinatus fossa; (2) release of the ISP from the ISP fossa; and (3) attachment of these released muscles to the original location. Specifically, the ISP rotation exclusively included the ISP release, after which this tendon was rotated toward the superior to the middle facet because of the supraspinatus tendon's irreparability. In our series, the overall re-tear rate was 5.9%, which decreased to 2.9% when the fatty infiltration level in ISP was Goutallier's stage 3 or less.

IRT uses a relatively low tension at the repair site since the ISP is freed from its attached area and advanced to the footprint. However, re-tearing occurred in 2 of the 34 cases after surgery (5.9%). These results indicate that biological factors of tendon/bone (other than tension) affected the postoperative re-tear rate. Shirachi et al [28]. showed that the procollagen type I and III mRNA expression level at the edge of the ruptured rotator cuff tendon was significantly correlated with the postoperative rotator cuff integrity. Clinical research has also reported that a high signal intensity at the tendon edge on MRI is associated with a high possibility of re-tearing after surgery [29]. The levels of mesenchymal stem cells present in the greater tuberosity of patients with a RCT decreases as a function of a number of clinical factors, including the lag time from the tear onset to the treatment, the tear size, the number of tears, and the stage of fatty infiltration, among others [30]. Thus, biological intervention in the tendon-bone interface may further enhance the healing rate after IRT.

Some limitations were present in this study. First, the study was a retrospective cohort type, where the 1-year postoperative follow-up was conducted with only a few cases. Second, no biomechanical or anatomical support for the Asato technique (the IRT) was found. Finally, this study did not include a control group. However, we believe our preliminary study is worth reporting because no report currently exists like those described in this study.

In conclusion, this preliminary study examined the clinical outcomes of the IRT technique for irreparable RCTs. At 1 year postoperatively, the clinical scores significantly improved, and the re-tear rate was low at 5.9%. Further follow-up studies are needed to determine whether the ISP muscle works as well as the original external rotators after being advanced using the IRT technique.

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Short-term outcomes of two-stage reverse total shoulder arthroplasty with antibiotic-loaded cement spacer for shoulder infection

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Background: The purpose of our study was to investigate short-term outcomes of two-stage reverse total shoulder arthroplasty (RTSA) with an antibiotic-loaded cement spacer for shoulder infection.

Methods: Eleven patients with shoulder infection were treated by two-stage RTSA following temporary antibiotic-loaded cement spacer. Of the 11 shoulders, nine had pyogenic arthritis combined with complex conditions such as recurrent infection, extensive osteomyelitis, osteoarthritis, or massive rotator cuff tear and two had periprosthetic joint infection (PJI). The mean follow-up period was 29.9 months (range, 12–48 months) after RTSA. Clinical and radiographic outcomes were evaluated using the visual analog scale (VAS) score for pain, American Shoulder and Elbow Surgeons (ASES) score, subjective shoulder value (SSV), and serial plain radiographs.

Results: The mean time from antibiotic-loaded cement spacer to RTSA was 9.2 months (range, 1–35 months). All patients had no clinical and radiographic signs of recurrent infection at final follow-up. The mean final VAS score, ASES score, and SSV were significantly improved from 4.5, 38.6, and 29.1% before RTSA to 1.7, 75.1, and 75.9% at final follow-up, respectively. The mean forward flexion, abduction, external rotation, and internal rotation were improved from 50.0°, 50.9°, 17.7°, and sacrum level before RTSA to 127.3°, 110.0°, 51.8°, and L2 level at final follow-up, respectively.

Conclusions: Two-stage RTSA with antibiotic-loaded cement spacer yields satisfactory short-term clinical and radiographic outcomes. In patients with pyogenic arthritis combined with complex conditions or PJI, two-stage RTSA with an antibiotic-loaded cement spacer would be a successful approach to eradicate infection and to improve function with pain relief.

Keywords: Shoulder; Infection; Arthroplasty; Outcomes

INTRODUCTION

The shoulder joint is the third most common location for pyogenic arthritis following knee and hip joints [1]. It can be devastating and difficult to treat because the joint can be rapidly destroyed [2]. Standard management options have included open or arthroscopic irrigation, and debridement in conjunction with antibiotic treatment [2]. However, these classic approaches result in a higher failure rate of infection control with unsatisfactory outcomes when dealing with a combined complex condition

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such as osteomyelitis with joint destruction, massive rotator cuff tear, or advanced degenerative osteoarthritis. Upon systematic review, Memon et al. [1] reported a 28% revision rate and 21% complication rate after primary debridement in pyogenic arthritis of the shoulder.

Successful management of shoulder infection is more difficult to achieve in certain circumstances, including recurrent infection, massive rotator cuff tear, destruction of the joint, or the presence of internal fixation device or prosthesis. Particularly, periprosthetic joint infection (PJI) of the shoulder is one of the most devastating complications for orthopedic surgeons despite rare incidence of 1% to 4% [3-5]. An ideal treatment should secure successful eradication of infection and provide functional restoration with pain relief. Therefore, more aggressive treatment is crucial in these conditions. However, optimal treatment of pyogenic arthritis combined with complex conditions and PJI of the shoulder is not as well established as that in hip and knee joints [6]. For these reasons, treatment options for shoulder infection have been modeled on the management of hip and knee infections, and include antibiotic therapy, open or arthroscopic debridement, resection arthroplasty, and one-stage or two-stage implantation. Among these variety of options, the two-stage approach with temporary antibiotic-loaded cement spacer is well known as one of the standard options in hip and knee infections, and has become a procedure of interest for the treatment of shoulder infection [7,8]. Recently, several studies reported promising results using a two-stage reverse total shoulder arthroplasty (RTSA) with antibiotic-loaded cement spacers in the treatment of primary pyogenic arthritis, as well as PJI of the shoulder [9-12]. However, reports about the treatment of primary pyogenic arthritis using this modality are limited with a small number of patients [9].

The purpose of our study was to investigate short-term outcomes of two-stage RTSA with antibiotic-loaded cement spacer for shoulder infection. We hypothesized that two-stage RTSA with an antibiotic-loaded cement spacer would be a useful option to eradicate infection and to improve function with pain relief in patients with pyogenic arthritis combined complex conditions or PJI.

METHODS

The present study was approved by the Institutional Review Board of Keimyung University Dongsan Hospital with exemption of informed consent (IRB No. 2021-05-082). Informed consent was obtained from the patients for the use of the photographs. We retrospectively reviewed 23 patients who underwent infection control surgery with antibiotic-loaded cement spacer for shoulder infection at a single institution between 2014 and 2020. Indications for infection control surgery with antibiotic-loaded cement spacer included PJI and pyogenic arthritis combined with complex conditions such as recurrent infection, extensive osteomyelitis, advanced degenerative osteoarthritis, or massive rotator cuff tear. Inclusion criteria in this study were as follows: (1) RTSA for the second stage procedure, (2) available medical records and radiographic findings, and (3) a follow-up period more than 12 months after RTSA. Twelve patients with retained cement spacer were excluded, including nine patients that had no infection sign, but refused further surgery, one patient had uncontrolled infection, and one patient was not operable owing to medical reasons. Finally, 11 patients were included in this study (Fig. 1).

Infection was diagnosed based on clinical presentation (erythema, warmth, swelling, tenderness, fever), laboratory markers (white blood cell counts, C-reactive protein, and erythrocyte sedimentation rate), joint fluid analysis, radiographic evaluations (plain radiographs, enhanced magnetic resonance imaging), and tissue culture or biopsy [11].

Surgical Technique

For the first stage, extensive debridement and bone curettage or removal of infected prosthesis was performed by a single surgeon (CHC). After thorough debridement, the humeral head was cut along anatomical neck and the medullary canal was reamed. A hand-made cement spacer loaded with 4 g of vancomycin and a

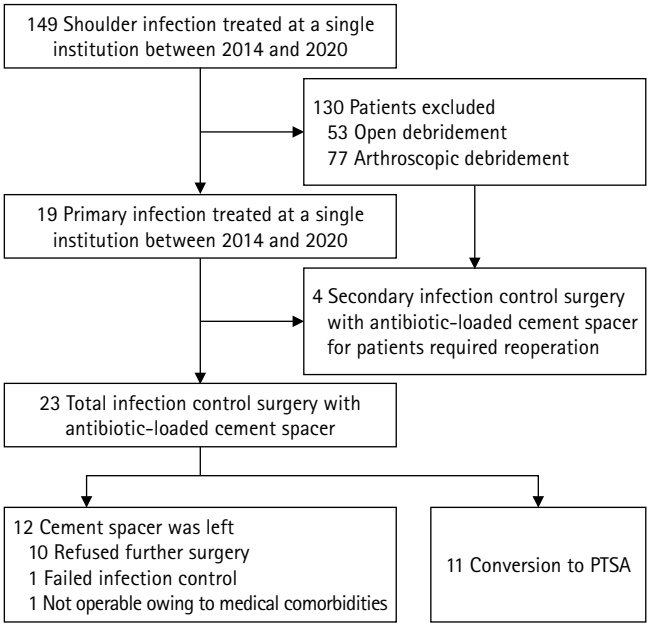

Fig. 1. Flow diagram. RTSA: reverse total shoulder arthroplasty.

2.4 mm Steinmann pin was implanted. The mean duration of intravenous antibiotic therapy after infection control surgery was 3.7 weeks (range, 2–7 weeks). The following oral antibiotic therapy was used according to numerical values of serum inflammatory markers. For the second stage, conversion criteria to RTSA included: (1) no clinical symptoms and signs including resting pain, swelling, warmth, and erythema, (2) no radiographic signs of infection by plain radiographs and follow-up enhanced magnetic resonance imaging before conversion to RTSA, (3) normalization of inflammatory markers at least three times, and (4) intraoperative frozen biopsy or surgeon's assessment. The criterion suggested by Mirra et al. [13] was used, in which <5 neutrophils per high-power field of frozen biopsy sample was considered negative. The Equinoxe Reverse Shoulder System (Exactech, Gainesville, FL, USA) was used in ten shoulders and the Delta Xtend Reverse Shoulder System (Dephy, Warsaw, IN, USA) in one shoulder. The mean time from antibiotic-loaded cement spacer to RTSA was 9.2 months (range, 1–35 months).

Outcome Assessment

The mean follow-up period after conversion to RTSA was 29.9 months (range, 12–48 months). No recurrence of infection was defined as the absence of any clinical signs of infection, normal values of inflammatory markers, and the absence of progressive radiolucency on serial plain radiographs. Clinical outcomes were evaluated using the visual analog scale (VAS) score for pain, American Shoulder and Elbow Surgeons (ASES) score, subjective shoulder value (SSV), and active range of motion (ROM) of the shoulder joint. Radiographic outcomes were evaluated using serial plain radiographs. Radiolucency around prosthesis was classified using the systems described by Gilot et al. [14].

Statistical Analysis

Statistical analysis was performed using IBM SPSS ver. 20.0 (IBM Corp., Armonk, NY, USA). The difference between clinical outcomes before RTSA and after RTSA were assessed using the Mann-Whitney test. A p-value <0.05 was considered statistically significant.

RESULTS

The mean age of patients was 69.7±7.2 (range, 61–81 years). There were six women and five men. Before infection control surgery with antibiotic-loaded cement spacer, three patients had recurrent infection and two patients had PJI. Among the remaining six patients with primary pyogenic arthritis combined complex conditions, three patients had cuff tear arthropathy, two patients had extensive osteomyelitis with joint destruction, and one patient had osteomyelitis with advanced degenerative osteoarthritis. Eight patients had a history of previous surgery, including four arthroscopic rotation cuff repair, two total shoulder arthroplasty, one arthroscopic debridement, and one open debridement for pyogenic arthritis (Table 1). According to enhanced magnetic resonance imaging, all patients had rotator cuff tear with or without degenerative arthritis. Intraoperative histopathology revealed acute or chronic inflammation consistent with infection in all

Table 1. Demographic data

Case	Age (yr)	Sex	Side	Previous OP history (no. of OPs)	Past medical history	Diagnosis	RCT	Culture	Time to RTSA (mo)	Follow-up (mo)
1	69	F	R	ARCR	-	PA, OM, CTA	Massive	NG	3	27
2	70	M	R	-	HTN, ITP	PA, OM	Massive	NG	24	12
3	81	F	R	AS debridement	HTN	PA, OM, OA	Medium	NG	3	30
4	81	F	L	-	HTN	PA, OM, OA	Partial	NG	3	15
5	61	M	R	ARCR	HTN	PA, OM	Retear	MRSA	5	48
6	61	M	L	ARCR, I&D (4)	HTN, DM	PA, OM	Retear	NG	2	38
7	65	F	R	ARCR	MDD	PA, OM, CTA	Massive	NG	1	37
8	73	F	R	-	Cerebral infarction, HTN	PA, CTA	Massive	NG	4	45
9	74	M	L	Open I&D	DM, gout	Multi-joint PA, OA	Medium	*Streptococcus dysgalactiae*	18	21
10	62	M	L	TSA	HTN, DM	PJI	SSC tear	NG	35	20
11	70	F	R	TSA, I&D (1)	Thyroid cancer, HTN, DM	PJI	-	NG	3	36

OP: operation, RCT: rotator cuff tear, RTSA: reverse total shoulder arthroplasty, R: right, L: left, ARCR: arthroscopic rotator cuff repair, PA: pyogenic arthritis, OM: osteomyelitis, CTA: cuff tear arthropathy, NG: no growth, HTN: hypertension, ITP: idiopathic thrombocytopenic purpura, AS: arthroscopic, OA: osteoarthritis, MRSA: methicillin-resistant *Staphylococcus aureus*, I&D: incision and drainage, DM: diabetes mellitus, MDD: major degressive disorder, TSA: total shoulder arthroplasty, PJI: periprosthetic joint infection, SSC: subscapularis.

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shoulders, but positive culture was found in two shoulders at the time of infection control surgery with antibiotic-loaded cement spacer, including methicillin-resistant *Staphylococcus aureus* (MRSA) and *Streptococcus dysgalactiae*. In nine shoulders, no organism was found in any culture from joint aspiration and intraoperative specimen.

At final follow-up evaluation after RTSA, no clinical and radiographic signs of recurrent infection were observed in all patients. The mean VAS pain score was significantly improved from 4.5 ± 2.3 before RTSA to 1.7 ± 1.6 at final follow-up ($p < 0.001$). Three patients had no pain, six had mild pain, and two had moderate pain. The mean ASES score was significantly improved from 38.6 ± 16.3 before RTSA to 75.1 ± 16.2 at final follow-up ($p < 0.001$). The mean SSV was significantly improved from 29.1% ± 17.6% before RTSA to 75.9% ± 16.9% at final follow-up ($p < 0.001$). The mean forward flexion, abduction, external rotation, and internal rotation values were improved from 50.0° ± 31.9°, 50.9° ± 30.8°, 17.7° ± 16.9°, and sacrum level before RTSA to 127.3° ± 34.1°, 110.0° ± 38.2°, 51.8° ± 14.7°, and L2 level at final follow-up, respectively ($p < 0.05$) (Table 2).

Based on the serial plain radiographs, proximal bone resorption by stress shielding was found in two patients (18.1%) and scapular notching was found in two patients (18.1%). No progressive osteolysis was observed around the prosthesis. Two complications (18.1%) among 11 patients were observed, including two periprosthetic humeral fractures. Case 5 with spiral fracture around the stem tip underwent open reduction and internal fixation at 32 months after RTSA. Case 10 had a transverse fracture around the stem tip at 21 months after RTSA and underwent conservative management because of medical comorbidities. At the final follow-up evaluation, both patients had poor clinical outcomes in spite of fracture healing.

DISCUSSION

The present study revealed that two-stage RTSA with an antibiotic-loaded cement spacer yields satisfactory short-term clinical and radiographic outcomes. In all patients, infection was successfully eradicated by infection control surgery using an antibiotic-loaded cement spacer. No clinical or radiographic signs of recurrent infection after two-stage RTSA were observed at final follow-up evaluation. The results presented here indicate that two-stage RTSA with an antibiotic-loaded cement spacer is an effective treatment option for pyogenic arthritis combined with complex conditions such as recurrent infection, extensive osteomyelitis, osteoarthritis, or massive rotator cuff tear, as well as PJI.

Although numerous treatment modalities for PJI of the shoulder have been reported, including long-term use of antibiotics, open or arthroscopic debridement, resection arthroplasty, one-stage implantation, and two-stage implantation, the optimal strategy is still controversial. Use of antibiotics with or without debridement has shown high rates (up to 65%) of recurrent infection that leads surgeons to look for alternative treatment options [3,15]. Resection arthroplasty leads to poor function with residual pain in up to 50% of patients, because the surrounding soft tissues can be irritated by the residual stump during movements [3,16]. Furthermore, it may compromise the potential for revision arthroplasty due to arm shortening, soft tissue adhesion around the joint, weak bone stock, and rotator cuff insufficiency [17]. The rates of recurrent infection after resection arthroplasty

Table 2. Clinical outcomes

Case	Clinical score						ROM							
	VAS		ASES		SSV (%)		Forward flexion (°)		Abduction (°)		External rotation (°)		Internal rotation	
	Preop	Final	Preop	Final	Preop	Final	Preop	Final	Preop	Final	Preop	Final	Preop	Final
1	2	1	43	70	20	70	30	160	30	140	10	70	L5	L3
2	4	2	42	80	40	80	20	90	20	70	5	40	Buttock	L3
3	9	0	12	95	10	100	20	170	20	170	10	80	Buttock	T8
4	2	0	70	95	50	100	70	140	90	120	30	60	Buttock	L3
5	4	4	35	48	40	50	30	90	30	70	10	40	L5	L3
6	6	2	33	75	50	70	30	150	30	130	10	50	Sacrum	L4
7	4	2	50	73	50	70	90	170	70	160	30	60	L5	T10
8	4	2	40	70	30	75	90	100	90	80	60	50	L3	L3
9	5	1	33	82	10	80	70	110	70	90	20	40	Sacrum	L5
10	8	5	15	48	10	50	90	80	90	60	10	30	Sacrum	L5
11	2	0	52	90	10	90	10	140	20	120	0	50	Buttock	L2

VAS: visual analog scale, ASES: American Shoulder and Elbow Surgeons, SSV: subjective shoulder value, ROM: range of motion, Preop: preoperative.

have also been reported up to 30% [3,15]. The one-stage procedure consists of extensive debridement of infected tissue with re-implantation of prosthesis after removal of all implants in the simultaneous step. Beekman et al. [18] reported on 11 shoulders with an infected RTSA treated using one-stage revision RTSA method. They concluded that this approach provides satisfactory results with reliable infection control rate and low cost and duration of treatment. Although this approach included several advantages such as a single anesthesia, low cost, and short hospital stay, surgeons may be afraid of recurrent infection after one-stage revision arthroplasty and may prefer a two-stage procedure that can yield more reproducible rates of infection control.

A two-stage approach with use of a temporary antibiotic-loaded cement spacer has been also used in infected shoulders as a common procedure proven by numerous studies for treatment of hip and knee infections [7-12]. The first stage in this approach consists of thorough irrigation and extensive debridement with implant removal if present, followed by subsequent insertion of a temporary antibiotic-loaded cement spacer with intravenous antibiotic therapy. The second stage is a delayed revision arthroplasty after eradication of infection. Despite the fact that it is difficult to directly translate strategy from hip or knee infection to shoulder infection, the shoulder joint has limited weight-bearing demands compared with the lower extremity [12]. In addition, the patients may tolerate a reduced ROM, because of the ability to compensate with use of the contralateral upper extremity [12,15]. Therefore, this strategy has been shown successfully in the shoulder as well, although published prior studies are not abundant [3,19]. Sperling et al. [3] found recurrent infection in 50% of patients who underwent a one-stage revision for PJI compared to 0% with two-stage revision group at a mean follow-up period of 6.5 years.

In addition, recurrent shoulder infection or primary pyogenic arthritis with combined complex conditions such as extensive osteomyelitis, advanced degenerative osteoarthritis, or massive rotator cuff tear are challenging to treat. Arthroscopic or open debridement for these conditions may result in a high failure rate of infection control. Although RTSA was usually performed in patients with rotator cuff insufficiency, its indications have been consistently expanded with successful outcomes [20,21]. Recently, promising results using a two-stage RTSA with an antibiotic-loaded cement spacer have been reported for the treatment of primary pyogenic arthritis, as well as PJI of the shoulder [9-12].

In the present study, two-stage RTSA with an antibiotic-loaded

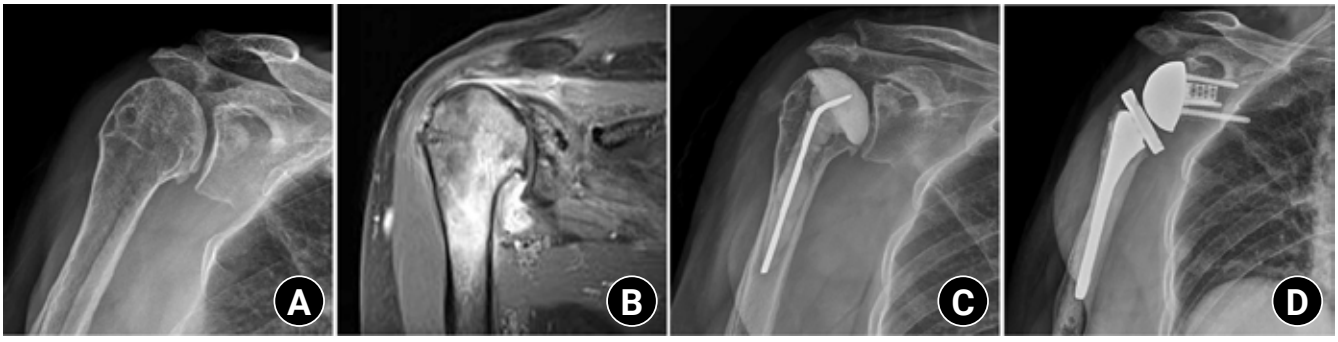

Fig. 2. Case 1. A 69-year-old woman with previous history of rotator cuff repair. Plain radiograph and magnetic resonance imaging show pyogenic arthritis with osteomyelitis and cuff tear arthropathy (A, B). (C) Plain radiograph shows an antibiotic-loaded cement spacer for infection control. (D) Plain radiograph shows reverse total shoulder arthroplasty performed at 3 months after infection control surgery.

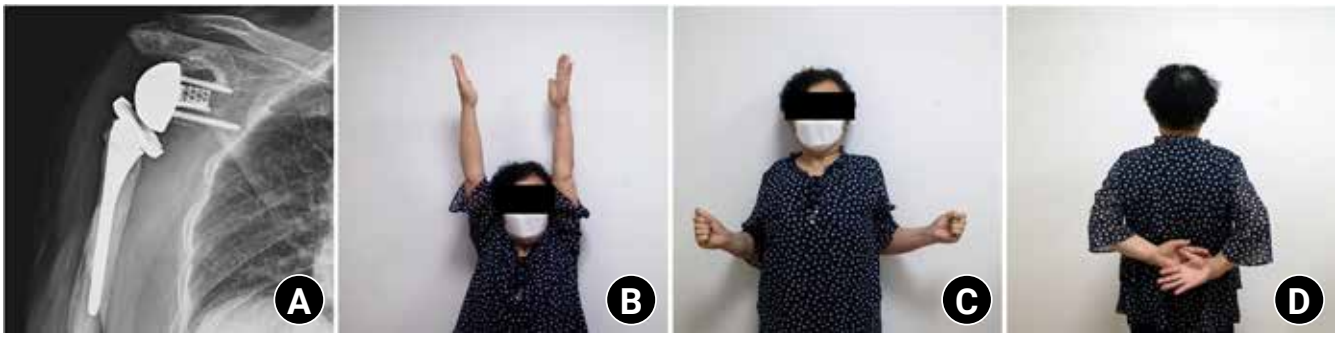

Fig. 3. Case 1. Plain radiograph at 27 months after reverse total shoulder arthroplasty shows proximal humeral bone resorption without any sign of implant loosening (A). Clinical photos at final follow-up show function restoration with pain relief (B-D).

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cement spacer was performed in nine pyogenic arthritis patients with combined complex conditions (Figs. 2 and 3) and two PJI (Figs. 4 and 5). All patients had rotator cuff tear with or without degenerative arthritis. As the first stage, we performed massive irrigation and extensive debridement of the soft tissue and bone. A cement spacer loaded with 4 g of vancomycin and a 2.4-mm Steinmann pin was made and inserted as similar as possible with the cutting head. We believe that this procedure can make further revision RTSA easier by reserving joint space and preventing contracture of surrounding soft tissues. For the second stage, we strictly keep the criteria for RTSA conversion, including no clinical and radiographic signs of infection, normalization of inflammatory markers, and intraoperative frozen biopsy. At final follow-up evaluation, all patients had no clinical and radiographic signs of recurrent infection after RTSA. The present study demonstrated two-stage RTSA with an antibiotic-loaded cement spacer yields satisfactory short-term clinical and radiographic outcomes.

Several studies reported MRSA and *Staphylococcus epidermidis* were the most frequently cultured organisms in patients with shoulder infection [5,22]. However, other studies reported a high incidence of positive culture for *Cutibacterium acnes* in patients with PJI of the shoulder. Buchalter et al. [12] reported on 19 cases with PJI treated by two-stage revision arthroplasty. Eight (61.5%) among 13 positive cultures were *C. acnes* and the patients with *C. acnes* had higher rate of recurrent infection than those without *C. acnes* [12]. Recently, *C. acnes* is becoming recognized as a common pathogen in infected shoulder arthroplasty and requires prolonged incubation of cultures for recognition [11]. In the present study, MRSA and *S. dysgalactiae* were cultured in two shoulders and nine shoulders had negative cultures. A high rate of negative cultures might result from previous use of antibiotics because most patients were referred from local clinics. Also, we did not have positive culture for *C. acnes* in our cases. This result might be attributed to ethnicity and incubation period for the detection of *C. acnes*. East or southeast Asians had the lowest detection rate of *C. acnes* compared with all other ethnicities [23]. The incubation period for organisms was routinely three days only in our institute, although a 13–14 day incubation period is essential for the detection of *C. acnes*

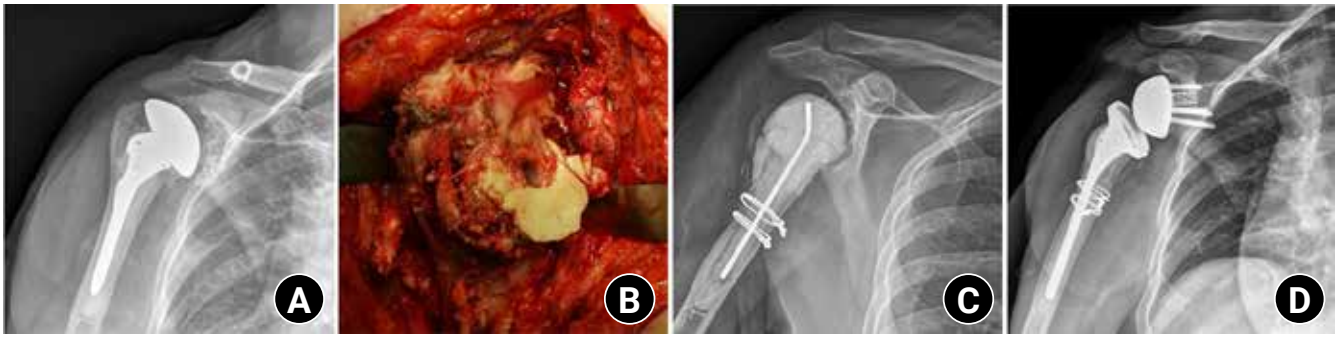

Fig. 4. Case 10. A 70-year-old woman with infected total shoulder arthroplasty. (A) Plain radiograph before infection control surgery shows glenoid component loosening with radiolucency. (B) Intraoperative photo revealed dirty granulation tissue with pus-like joint fluid. (C) Plain radiograph shows antibiotic-loaded cement spacer with implant removal for infection control. (D) Plain radiograph shows reverse total shoulder arthroplasty performed at 3 months after infection control surgery.

Fig. 5. Case 10. (A) Plain radiograph at 36 months after reverse total shoulder arthroplasty shows no evidence of radiolucency or implant loosening. (B-D) Clinical photos at final follow-up show function restoration with pain relief.

[24].

This study has several limitations. First, it was a retrospective study. Second, there was no control group of patients managed with other treatment modalities. Third, the number of patients was small with heterogeneous traits. As a result, subgroup analysis between primary and recurrent infection was not possible. Further prospective, large-scale, comparative studies are needed to clarify the efficacy of two-stage RTSA with antibiotic-loaded cement spacer for shoulder infection.

The present study revealed that two-stage RTSA with an antibiotic-loaded cement spacer yields satisfactory short-term clinical and radiographic outcomes. In patients with pyogenic arthritis combined with complex conditions or PJI, two-stage RTSA with an antibiotic-loaded cement spacer would be a successful approach to eradicate infection and to improve function with pain relief.

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Short-term comparative outcomes between reverse shoulder arthroplasty for shoulder trauma and shoulder arthritis: a Southeast Asian experience

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Background: Reverse shoulder arthroplasty (RSA), first introduced as a management option for cuff tear arthropathy, is now an accepted treatment for complex proximal humeral fractures. Few studies have identified whether the outcomes of RSA for shoulder trauma are comparable to those of RSA for shoulder arthritis.

Methods: This is a retrospective, single-institution cohort study of all patients who underwent RSA at our institution between January 2013 and December 2019. In total, 49 patients met the inclusion criteria. As outcomes, we evaluated the 1-year American Shoulder and Elbow Surgeons (ASES) and Constant shoulder scores, postoperative shoulder range of motion, intra- and postoperative complications, and cumulative revision rate. The patients were grouped based on preoperative diagnosis to compare postoperative outcomes across two broad groups.

Results: The median follow-up period was 32.8 months (interquartile range, 12.6–66.6 months). The 1-year visual analog scale, range of motion, and Constant and ASES functional scores were comparable between RSAs performed to treat shoulder trauma and that performed for arthritis. The overall complication rate was 20.4%, with patients with a preoperative diagnosis of arthritis having significantly more complications than those with a preoperative diagnosis of trauma (34.8% vs. 7.7%).

Conclusions: Patients who underwent RSA due to a proximal humeral fracture or dislocation did not fare worse than those who underwent RSA for arthritis at 1 year, in terms of both functional and radiological outcomes.

Keywords: Arthroplasty, replacement, shoulder; Cuff tear arthropathy; Arthritis; Humeral fractures, proximal

INTRODUCTION

Reverse shoulder arthroplasty (RSA) was first introduced as a management option for cuff tear arthropathy (CTA). Its indication has since expanded to include complex proximal humeral fractures (PHFs), and the proportion of such injuries managed with an RSA has increased by nearly threefold in the past decade [1]. Likewise, evidence of good short-term [2,3] and long-term outcomes supports the use of RSA for PHFs [4-6].

This paper compares the outcomes of RSA by diagnosis (traumatic versus atraumatic) in an Asian population. As outcomes, we evaluated the 1-year American Shoulder and Elbow Surgeons

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(ASES) score, postoperative shoulder ranges of motion, intra- and postoperative complications, 1-year Constant shoulder score, and cumulative revision rate. Our hypothesis was that patients who received RSA for a preoperative diagnosis of trauma would not fare worse than those who received RSA to treat CTA or glenohumeral arthritis (GHOA).

METHODS

This study was approved by Khoo Teck Puat Hospital, Singapore Bioethics Committee (DSRB number 2020/00656). Informed consent was waived. Patients who underwent RSA at our local tertiary institution between January 2013 and December 2019 were included in our study. The main inclusion criterion was primary RSA to treat arthritis or shoulder trauma. The inclusion criteria for the arthritis group were patients who were older than 60 years and suffering from persistently symptomatic and functionally limiting arthropathy of any grade (rotator cuff arthropathy Hamada grade 1–5 or glenohumeral arthropathy Walch type A–D) who had failed on conservative treatment. In the fracture group, the inclusion criteria were patients who were older than 60 years and had a comminuted 3- or 4-part PHF not amenable to fixation; PHFs with head-split; or a PHF-dislocation with a massive rotator cuff tear and significant humeral head bone loss. Other inclusion criteria were primary RSA surgery for any cause and patients with follow-up data for at least 1 year. All procedures were performed by one of four fellowship-trained surgeons (JT, TT, AW, and DT) in the orthopedic surgery department.

Surgical Technique

All patients underwent surgery in the beach chair position using a standard deltopectoral approach. The standard procedures for RSA were followed: glenohumeral dislocation, neck cut, glenoid preparation and baseplate insertion, humeral shaft reaming and stem insertion; and finally, tenodesis and tuberosity re-attachment. For CTAs in which the subscapularis tendon was intact, it was peeled from the lesser tuberosity and repaired using the transosseous technique with drill holes into the humerus in 30° external rotation. This step was aborted when the subscapularis was too short to be re-attached to the humerus. For PHFs, efforts were made to preserve the greater and lesser tuberosity fragments, along with the attached rotator cuff tendons (Figs. 1-3). The tuberosities with their attached tendons were similarly repaired using the transosseous technique with 30° external rotation.

Postoperative Rehabilitation Protocol

No external rotation beyond neutral was allowed for 6 weeks if the subscapularis was repaired. Passive range of motion (ROM) exercises were initiated within the first week after surgery under the supervision of a trained physiotherapist. Shoulder strengthening exercises, including active scapular movements and isometric internal and external motion, were allowed as tolerated by pain. Active assisted exercises were gradually initiated beyond the 6th postoperative week. Isometric exercises could slowly include the deltoids. At the 8th postoperative week, graded resistance band exercises for periscapular and shoulder muscles (including shoulder extension, internal rotation, and external rotation) and dynamic stabilization exercises were introduced. Beyond the 12th postoperative week, gradual resistance pressing and pulling movements were introduced with the aim of being

Fig. 1. (A) Anterior-posterior and (B) Y-scapula views of a patient with a comminuted three-part proximal humeral fracture.

Fig. 2. Three-dimensional computed tomography reconstruction of the same patient showing the three-part proximal humeral fracture with significant head impaction.

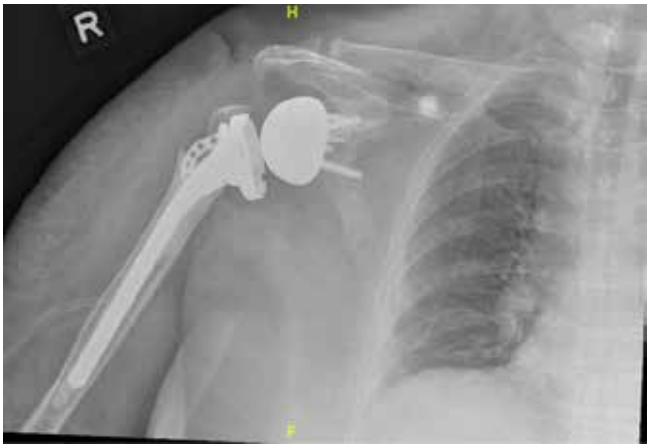

Fig. 3. Postoperative image showing the re-attachment of the greater tuberosity repaired in a transosseous fashion through both the implant and humeral shaft.

functionally independent at light household and work activities.

Data Analysis

The following data were gathered retrospectively from the patients' electronic medical records: age, sex, indication for RSA, preoperative shoulder ROM, implant type, cement use, and subscapularis tendon repair. Serial postoperative radiographs for up to 1-year, which were performed during follow up visits, were reviewed to assess radiological postoperative complications. The following postoperative outcomes were obtained at the last clinical visit: postoperative ROM, pain scores using a visual analog scale (VAS), the Constant shoulder score, and the ASES shoulder score. The patients were grouped based on preoperative diagnosis. The postoperative outcomes after RSA were compared across the two broad etiologies of trauma and shoulder arthritis.

Descriptive analyses were used to summarize the demographic and clinical characteristics of the patients. For categorical data, frequencies and percentages are presented. For continuous data, the median and interquartile range of the data distributions are presented due to the small sample size and a negatively skewed distribution in the outcome measures. The Shapiro Wilk's coefficient (W) was computed to assess whether the data were normally distributed. Data were declared to have a significant skew if the p-value for W was <0.05. Statistical differences in continuous outcomes variables were analyzed using the rank-sum test or Student t-test if the data were non-normally or normally distributed, respectively. For discrete variables, the chi-square test was used to analyze statistical significance unless the number of observations for any category was less than 5; for those categories, Pearson's exact test was used. Statistical significance was declared when a two-sided p-value was <0.05.

RESULTS

A total of 49 patients met the inclusion criteria and was divided into 23 and 26 patients with a preoperative diagnosis of arthritis and trauma, respectively. The groups did not differ significantly by age (72.5 vs. 72.5, $p=0.65$), sex (female, 52.2% vs. 80.8%, $p=0.07$), or race ($p=0.60$). The specific preoperative diagnosis for each group is listed in Table 1. Of the patients who underwent RSA for shoulder arthritis, 82.6% had CTA, and the remaining 17.4% had GHOA. The median follow-up period for the entire cohort was 32.8 months (interquartile range, 12.6–66.6), with no significant difference between the groups (31.2 vs. 27.4 months, $p=0.64$).

The implant used did not differ between the groups ($p=0.73$) (Table 2), though cemented fracture stems were used for the trauma group, and primary press-fit stems were used for the arthritic group. The use of subscapularis repair (78.3% vs. 88.5%, $p=0.45$) was also similar in the two groups. A significantly higher percentage of patients undergoing RSA for trauma required cemented fixation compared to those undergoing RSA for arthritis (52.2% vs. 96.2%, $p<0.001$). The two groups of patients had similar outcomes. The 1-year ASES scores (80 vs. 75, $p=0.93$) and Constant Shoulder Scores (74 vs. 72, $p=0.89$) were similar between the groups (Table 3). VAS scores (3 vs. 8, $p<0.001$) and shoulder ROM scores (abduction angle: 90 vs. 30, $p<0.001$; forward flexion angle: 90 vs. 30, $p = 0.01$) (Table 4) at the time of surgery were poorer for patients with a preoperative diagnosis of trauma. However, at 12 months, the two groups had similar VAS scores and ROM of the shoulder ($p>0.05$ for all outcomes).

In terms of complications, the cumulative 7-year revision rate (17.4% vs. 3.8%, $p=0.17$) did not differ significantly between the two groups. The radiological complications of scapular notching, lucency, and tuberosity migration were similar between the groups ($p>0.05$ for all outcomes). A significantly higher proportion of patients with a preoperative diagnosis of shoulder arthritis had complications (34.8% vs. 7.7%, $p=0.03$), and all the dislocations were in the arthritic group (17.4% vs. 0%, $p=0.04$). A descriptive subgroup analysis was conducted for patients who experienced a complication of any cause. Differences in age; sex; and preoperative ROM in forward flexion, abduction, or external rotation did not account for the higher incidence of complications in the arthritic group ($p>0.05$ for all variables).

Table 5 highlights the profiles of the four patients who had a postoperative dislocation. The direction of dislocation varied; two of the four patients experienced anterior dislocation postop-

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Table 1. Demographics and pathology

Variable	Arthritis	Trauma	p-value
Number of patients	23	26	
Age (yr)	72.5 (65–77)	72.5 (69–77)	0.65
Female	12 (52.2)	21 (80.8)	0.07
Race			0.60
Chinese	15 (65.2)	20 (76.9)	
Indian	3 (13.0)	2 (7.7)	
Malay	5 (21.7)	3 (11.5)	
Others	0	1 (3.8)	
Follow-up time (mo)	31.2 (19.8–51.7)	27.4 (20.6–44.2)	0.64
Etiology			NA
CTA	19 (82.6)		
GHOA	4 (17.4)		
Fracture-dislocation		3 (11.5)	
Proximal humerus fracture		20 (76.9)	
Recurrent dislocations of the shoulder		2 (7.7)	
Locked dislocation		1 (3.8)	

Values are presented as median (interquartile range) or number (%).
NA: not applicable, CTA: cuff tear arthropathy, GHOA: glenohumeral arthritis.

Table 2. Intraoperative findings

Intraoperative finding	Arthritis	Trauma	p-value
Implant type			0.73
Depuy	6 (26.1)	8 (30.8)	
Equinoxe	12 (52.2)	15 (57.7)	
Zimmer	5 (21.7)	3 (11.5)	
Glenosphere size			0.18
36	15 (65.2)	12 (46.2)	
38	8 (34.8)	14 (53.8)	
Cement	12 (52.2)	25 (96.2)	< 0.001
SSC repair	18 (78.3)	23 (88.5)	0.45

Values are presented as number (%).
SSC: subscapularis.

Table 3. One-year outcomes and complications

Complication	Arthritis	Trauma	p-value
All complications	8 (34.8)	2 (7.7)	0.03
Dislocation	4 (17.4)	0	0.04
Intraoperative periprosthetic fracture	2 (8.7)	0	0.22
Postoperative periprosthetic fracture	1 (4.3)	1 (3.8)	1.00
SSI	0	2 (7.7)	0.49
AxN Palsy	2 (8.7)	0	0.22
One-year outcome			
Visual analog scale score	1 (0–1)	1 (0–1)	0.35
Shoulder abduction (°)	140 (90–160)	150 (100–160)	0.70
Shoulder forward flexion (°)	140 (100–160)	150 (100–160)	0.92
Shoulder external rotation (°)	50 (45–70)	60 (45–70)	0.43
Constant score	74 (67–80)	72 (63–80)	0.89
ASES score	80 (68–88.3)	75 (71.7–86.6)	0.93
Radiological outcome			
Notching	5 (21.7)	1 (11.5)	0.45
Lucency	2 (8.7)	1 (3.8)	0.59
Tuberosity migration	0	0	NA
Cumulative outcome			
Revision	4 (17.4)	1 (3.8)	0.17

Values are presented as number (%) or median (interquartile range).
SSI: surgical site infection, AxN: axillary nerve, ASES: American Shoulder and Elbow Surgeons, NA: not applicable.

eratively. All patients had a preoperative diagnosis of CTA. Half of them underwent subscapularis repair during the index surgery, and all used average glenosphere sizes of 36–38. Two of the eight patients (8.7%) who suffered a postoperative complication had partial axillary nerve palsy. One of them had complete spontaneous resolution of symptoms by the third postoperative month. None of the patients in the trauma group experienced an axillary nerve injury.

DISCUSSION

To our knowledge, this is the first retrospective analysis of RSA outcomes from a tertiary institution in Singapore. Regardless of a preoperative diagnosis of arthritis or trauma, the groups had similar demographics at baseline. Patients with a PHF or dislocation had acceptable postoperative results, as did those who suffered from arthritis, in terms of both functional and radiological

outcomes. Our results add support to the short-term non-inferiority of using RSA to treat traumatic compared with its traditional indication of CTA.

Previous case series considered the short-term outcomes of RSA to treat trauma. In Cappellari et al.'s study [4] of 91 primary RSAs for PHFs in the elderly, 12 patients reported complications in the first 6 months. Three dislocations occurred and were the only indications for revision surgery in that study. Scapular notching occurred after 6 months in eight patients and was the most notable radiological complication. The short-term outcomes of RSA for trauma are favorable, and intangible advantages that are often unreported include earlier mobilization and reductions in morbidity and in-hospital mortality [4]. However, few studies have directly compared the short-term outcomes of RSA for trauma versus CTA.

The longer-term outcomes of RSA for trauma versus arthritic conditions remain controversial. Coscia et al. [7] reported the largest systematic review of 47 studies on RSAs stratified by preoperative diagnosis. Except for one study, the minimum follow-up period was 24 months. They found that, although RSA provided significant within-group improvements in all outcomes regardless of indication, the acute PHF and PHF sequelae groups consistently showed significantly lower postoperative means of all four standard planes of shoulder motion, as well as lower patient-reported outcome measures (ASES and Constant shoulder), than the groups with GHOA or massive cuff tear with or without GHOA or CTA. Conversely, one of the few long-term prospective studies on RSA for acute fractures versus rotator cuff deficiencies in the elderly, by Sebastia-Forcada et al. [8], showed no significant differences in mean functional scores or ranges of shoulder motion at the end of a mean 8.4 years of follow-up. Only patient satisfaction was significantly lower after RSA performed for PHF ($p=0.002$). Therefore, it remains debatable whether RSAs used to treat trauma have outcomes comparable to those for arthritic conditions. Moreover, criticizing the use of RSAs to treat trauma would require a holistic comparison of outcomes from the primary fixation of PHFs, and no one has conducted such a study.

The overall complication rate of 20.4% in our cohort is comparable to that in the existing literature [9]. In our series, patients who had a preoperative diagnosis of arthritis had significantly higher rates of complications than those with a preoperative diagnosis of trauma (34.8% vs. 7.7%). Kennedy et al.'s systematic review of 36 studies [10] found that RSAs performed for osteoarthritis of the shoulder had an average pooled incidence of 1.4%, the lowest incidence rate of all pathologies requiring an RSA. However, that finding needs to be interpreted on a background of differing criteria for classification of shoulder pathology that included primary glenohumeral, CTA, and post-traumatic arthritis. Also, the complication rates accumulate as the follow up period becomes longer. Mizuno et al.'s series of 27 RSAs for all-cause GHOA [11], which had an average follow-up duration of 54 months, reported a 15% complication rate. Of the four reported complications in that study, one involved early loosening of the glenoid component, and the remaining three were neurologic complications; no postoperative instability was reported [11]. Existing studies rarely report post-surgical complications stratified by indication. Sebastia-Forcada et al.'s prospective series [8] reported no significant difference in long-term complication rate or 10-year arthroplasty survival between RSA for fracture or for arthropathy. We recognize the higher-than-expected complication rate in the arthritis group in our study. In our series, surgeries were performed by multiple surgeons, so our result could be due to technical error. Overzealous soft-tissue release in arthritic cases can increase the risk of axillary nerve injury and contribute to instability. In one of the cases, part of the anterior acromion was inadvertently excised to facilitate exposure during surgery; in hindsight, that might have precipitated the postoperative dis-

Table 4. Preoperative measurements

Preoperative measurement	Arthritis	Trauma	p-value
Visual analog scale score	3 (2–5)	8 (2.5–8.5)	< 0.001
Shoulder abduction (°)	90 (30–100)	30 (30–45)	0.01
Shoulder forward flexion (°)	90 (30–120)	30 (30–50)	< 0.001
Shoulder external rotation (°)	30 (30–50)	30 (30–45)	0.15

Values are presented as median (interquartile range).

Table 5. Descriptive analysis of patients who had a postoperative shoulder dislocation

No.	Age (yr)	Sex	Etiology	Preoperative FF (°)	Preoperative Abd (°)	Hamada classification	Subscapularis repair	Glenosphere size
1	64	M	CTA	160	80	4b	N	36
2	64	M	CTA	110	90	4b	N	36
3	77	F	CTA	45	45	4a	Y	36
4	75	M	CTA	15	15	1	Y	38

FF: forward flexion, Abd: abduction, CTA: cuff tear arthropathy, N: no, Y: yes.

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location.

Our study's 7-year prevalence of instability after a primary RSA is 7.55%. All four patients who experienced instability had a preoperative diagnosis of CTA, three of them were males, and half required subscapularis repair. Our prevalence is lower than that reported in Cheung et al.'s multivariate analysis of the independent predictors of post-RSA instability [12]; they reported a 4-year prevalence of 9.24%. They found that being male, having a preoperative diagnosis of fracture, and the absence of subscapularis repair were significant predictors of postoperative instability [12]. All cases of postoperative instability were revised in their series. Gallo et al.'s study of risk factors for post-RSA instability similarly [13] reported a 3-year prevalence of 15.7%. All of their patients had compromised subscapularis tendons at the time of RSA, with seven of the nine patients with instability having had a previous shoulder surgery. The only two patients with instability after a primary RSA both had a preoperative diagnosis of CTA. It is clear that exclusion of revision cases in our study lowered the rates of post-RSA instability reported here. Interestingly, CTA seems to be a risk factor for instability after primary RSA, as supported by our study and Cheung et al. [12], whereas Gallo et al. [13] suggest previous trauma as a risk factor for instability after revision RSA. Although the available literature is divided on whether the preoperative diagnosis is a risk factor for instability, sex, body mass index, and surgical technique are established factors. An aggressive humeral cut, superior glenoid positioning, superior glenosphere inclination, subscapularis repair, and subsequent subscapularis integrity are known surgical missteps that can increase the chance of instability after an RSA [14]. Therefore, attention to surgical details such as soft tissue release and intraoperative assessments of stability are important, regardless of the etiology.

ROM improvements are difficult to compare between arthritic and traumatic indications for RSA given the differences in the underlying conditions. It is clear, however, that RSA can improve the ROM even for chronically arthritic joints. Kim et al. [15] reported a doubling of shoulder forward flexion after RSA for arthritis of any known cause. Likewise, Rhee at al.'s study of primary RSA in CTA [16] found that, after a mean follow-up period of 20.6 months, the mean active forward flexion and external rotation increased significantly, from 96.4° to 138.4° and 30.6° to 48.9°, respectively ($p < 0.001$ for both motions). Our outcomes are comparable with those in the existing literature. Some studies have reported worse postoperative ROM and functional outcome scores after RSA for trauma compared with RSA for arthritis [17]. However, the results in our study indicate similar outcomes in the two groups. That might reflect our consistent attempts to reattach the greater and lesser tuberosities when repairing proximal humerus fractures.

Our cohort's combined incidence of notching was 16.3%, less than that reported for the medialized center of rotation (40%–90%) [9] but within the wide range (4.6%–96%) reported for all RSA regardless of center of rotation [18]. Apart from our choice of lateral offset implants, we pay particular attention to our surgical technique and have a tendency to allow an inferior overhang of the glenoid base plate, which reduces the risk of scapula notching [18]. Our study is, however, limited by the length of the follow-up period. A radiographic analysis by Simovitch et al. [19] showed that the average time required for scapular notching to develop was 51.4 ± 24.1 months, and significantly worse clinical outcomes were found in patients with notching.

Our study is limited by its retrospective nature, and postoperative complications might have been underreported. However, the majority of complications after RSA occur in the early period [20]. Despite a minimum of one year of follow up for all patients included in this study, certain complications, such as glenoid or humeral side loosening, might not have occurred yet. Our results could be further confounded by the possibility that patients included in the trauma group had pre-existing arthritis. However, given the age profile of our patients, it would be challenging to include patients without any signs of arthritis. As the indications for RSA expand, future studies need to be more granular in categorizing the indication for the RSA, such as comparing CTA vs. a massive irreparable cuff tear without arthritis. Patients with a PHF or dislocation did not fare worse than those with arthritis in terms of functional and radiological outcomes 12 months after an RSA. Our complication rate of 20.4% is comparable to that in the literature. Longer-term studies will be useful to confirm the non-inferiority of RSA for trauma compared with the traditional indication of arthritis.

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YouTube videos provide low-quality educational content about rotator cuff disease

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Background: YouTube has become a popular source of healthcare information in orthopedic surgery. Although quality-based studies of YouTube content have been performed for information concerning many orthopedic pathologies, the quality and accuracy of information on the rotator cuff have yet to be evaluated. The purpose of the current study was to evaluate the reliability and educational content of YouTube videos concerning the rotator cuff.

Methods: YouTube was queried for the term "rotator cuff." The first 50 videos from this search were evaluated. Video reliability was assessed using the *Journal of the American Medical Association* (JAMA) benchmark criteria (range, 0–5). Educational content was assessed using the global quality score (GQS; range, 0–4) and the rotator cuff-specific score (RCSS; range, 0–22).

Results: The mean number of views was 317,500.7±538,585.3. The mean JAMA, GQS, and RCSS scores were 2.7±2.0, 3.7±1.0, and 5.6±3.6, respectively. Non-surgical intervention content was independently associated with a lower GQS (β=–2.19, p=0.019). Disease-specific video content (β=4.01, p=0.045) was the only independent predictor of RCSS.

Conclusions: The overall quality and educational content of YouTube videos concerned with the rotator cuff were low. Physicians should caution patients in using such videos as resources for decision-making and should counsel them appropriately.

Keywords: YouTube; Quality; Reliability; Patient education; Rotator cuff; Patient resources

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INTRODUCTION

The internet is an increasingly accessed database of information; it has been estimated that 56% of the total world population uses the internet today, compared to only 5% in 2000 [1]. YouTube is considered one of the most popular sources among internet sites with more than 1.9 billion users each month and one billion hours of video watched each day [2]. YouTube videos allow for visual learning of specific content, many of which concern orthopedic information applicable to patient education [3]. Furthermore, it has been demonstrated that decisions made by 75% of patients concerning treatment for their diseases were influenced by the knowledge acquired through online health information searches [4]; therefore, it is essential that these videos provide accurate and reliable information.

Information regarding some of the most prevalent orthopedic conditions encountered in practice, such as anterior cruciate ligament injuries, is often accessed by patients on YouTube to gain a better understanding of their condition despite these videos' low quality [5]. Other studies have also reported the low-quality educational content and reliability of videos concerning various orthopedic conditions [3,5-8]. As YouTube lacks a formal video regulation process for promoting accurate information, it is possible that YouTube videos concerning many other unexplored orthopedic topics are also of low quality [9]. There is growing concern that the educational information on mainstream websites such as YouTube contains a high proportion of uninformed or deliberately deceptive opinions [10].

Among musculoskeletal complaints that present to primary care offices, shoulder pain is the second most common and is observed in 51% of patients [11]. Therefore, the prevalence of rotator cuff tears has been reported to be as high as 62% in some populations [12]. As orthopedic injuries are one of the leading healthcare areas that are searched for on the internet [13], YouTube has a repository of over 177,000 videos regarding rotator cuff disease [2]; however, the quality and reliability of the information contained in rotator cuff videos on YouTube is unknown. The purpose of the current study was to evaluate the reliability and educational content of YouTube videos concerning the rotator cuff. The authors hypothesized that these videos would have relatively low-quality educational content and poor reliability when these metrics were assessed by outcome tools specific to evaluating online videos.

METHODS

YouTube Search

The current study was exempt from Institutional Review Board approval. The YouTube online library (https://www.youtube.com) was queried using the keyword "rotator cuff" on May 4, 2020. In accordance with previous YouTube-based studies in the orthopedic literature [14,15], the first 50 videos sorted by relevance based on this keyword were recorded for evaluation. This search strategy provides an accurate representation of what users will view when searching for the term "rotator cuff" using the default search setting and is the most commonly employed search strategy in health informatics studies of YouTube content [4], which has been reported to be a feasible method of video selection in the literature [3]. If a video populated from the initial search was made in a non-English language or was an audio soundtrack, it was excluded, and the next consecutive video was used instead.

Extracted Video Characteristics

Each video had the following variables recorded for the final analysis: (1) title; (2) video duration; (3) number of views; (4) video source/uploader; (5) type of content; (6) days since upload; (7) view ratio [views/days]; (8) number of likes; (9) number of dislikes; (10) like ratio [like × 100/[like+dislike]; and (11) the video power index [VPI]. The VPI is a calculation derived from the following formula: like ratio × view ratio/100. This measurement is an index of video popularity based on the number of views and likes, which has been used in previous studies [3]. Higher values are indicative of greater video popularity, and there is no upper limit to this metric. The mean VPI for orthopedic videos has ranged from 92.6–301.9 in previous studies [3,6,15].

Video Upload Sources

Video sources/uploaders were categorized by the following: (1) academic (pertaining to authors/uploaders affiliated with research groups or universities/colleges), (2) physicians (independent physicians or physician groups without research or university/college affiliations), (3) non-physicians (health professionals other than licensed medical doctors), (4) trainers, (5) medical sources (content or animations from health websites), (6) patients, and (7) commercial sources.

Video Content Categories

Content was categorized as one of the following: (1) exercise training, (2) disease-specific information, (3) patient experience, (4) surgical technique or approach, (5) non-surgical management, and (6) advertisement.

The Assessment of Video Reliability and Educational Content

The *Journal of the American Medical Association* (JAMA) bench-

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mark criteria was used to assess video accuracy and reliability [16]. The JAMA benchmark criteria (Table 1) offer a non-specific and objective tool consisting of four individual criteria that are identifiable in online videos and resources. To use this tool, an observer assigns one point for each criterion present in a video. A score of four indicates higher source accuracy and reliability, whereas a score of zero indicates poor source accuracy and reliability.

Non-specific educational content quality was assessed using the global quality score (GQS). The GQS [3,17] evaluates the educational value of online content using five criteria (Table 2). One point is assigned for each of the five identifiable criteria present in a video. The GQS has a maximum score of 5, which indicates high educational quality.

To specifically evaluate the quality of educational content for information on the rotator cuff, we created the rotator cuff-specific score (RCSS), which is composed of 20 items based on the guidelines published by the American Academy of Orthopedic Surgeons [18]. The use of novel orthopedic topic-based instruments to assess the educational quality of online video has been demonstrated in previous literature [19]. The RCSS specifically evaluates information on (1) common patient presentations and symptoms, (2) anatomy of the rotator cuff, (3) diagnosis and evaluation of rotator cuff pathologies, (4) treatment options, and (5) the postoperative course and expectations (Table 3). One point is assigned for each present item and may confer a maximum possible score of 22, with a higher score indicating better rotator cuff-specific educational quality. One author scored all

Table 1. The *Journal of the American Medical Association* benchmark criteria

Criteria	Description
Authorship	Author and contributor credentials and their affiliations should be provided.
Attribution	Clearly lists all copyright information and states references and sources for content.
Currency	Initial date of posted content and subsequent updates to content should be provided.
Disclosure	Conflicts of interest, funding, sponsorship, advertising, support, and video ownership should be fully disclosed.

Table 2. The global quality score criteria

Grading	Description of quality
1	Poor quality; unlikely of be to use for patient education
2	Poor quality; limited use to patients as some information is present
3	Suboptimal quality and flow; somewhat useful to patients; important topics missing, some information is present
4	Good quality and flow; useful to patients as most important topics covered
5	Excellent quality and flow; highly useful to patients

Table 3. Rotator cuff-specific score for rotator cuff-specific educational content

Patient presentation	Information about rotator cuff
Describes symptom	Describes anatomy/function of rotator cuff
Describes patient population	Discusses differences between partial tears from full thickness tears
	Discusses acute versus degenerative tears
	Discusses importance of tendons retraction
	Discusses importance of muscular fatty infiltration
	Discusses importance of number of tendons involved
Diagnosis and evaluation	Treatment
Mentions physical examination and findings	Mentions conservative treatment
Discusses inability for X-ray to evaluate rotator cuff tears	Mentions diagnostic arthroscopy
Discusses use of MRI or ultrasound	Describes open repair
Describes surgical candidates	Describes mini-open repair
Postoperative course	Describes complications and outcomes
Mentions physical restrictions	Mentions physical therapy
Outlines return to function timeline	

MRI: magnetic resonance imaging.

studies. A subset of 10 videos was selected for each of the three reliability and quality scores (total, 30 videos) to be analyzed again by a separate author to determine inter-observer reliability. Inter-observer reliability was 0.98 (0.96–0.99) for the JAMA score, 0.97 (0.96–0.98) for the QGS score, and 0.9 (0.88–0.93) for the RCSS.

Statistical Analysis

All statistical tests were performed with Stata ver. 15.1 (StataCorp., College Station, TX, USA). Descriptive statistics were used to quantify the video characteristics as well as the video reliability and quality scores. Continuous variables were presented as means with standard deviations and ranges. Categorical variables were shown as relative frequencies with percentages. One-way analysis of variance (ANOVA) tests (for normally distributed data) and Kruskal-Wallis tests (for non-normally distributed data) were used to determine whether the video reliability and quality differed based on (1) video source and (2) video content. Multivariate linear regression analyses were used to determine the influence of specific video characteristics on video reliability (JAMA score) and educational quality (GQS and RCSS). A two-tailed p-value of <0.05 was considered to indicate statistical significance.

RESULTS

All of the first 50 videos populated by the initial query were included in the final analysis. The video duration ranged between 1 and 23.5 minutes with a mean ± standard deviation video duration of 6.9 ± 4.8 minutes. The mean number of views was 317,500.7 ± 538,585.3, and collectively, the 50 videos were viewed 15,875,035 times. The mean VPI was 296.98 ± 435.3. Other video characteristics are listed in Table 4. Most video uploaders were physicians (46%), while academic institutions accounted for the lowest relative frequency of video uploads at 4%. The video content was primarily classified as being disease-specific (48%), while exercise training content accounted for the lowest proportion of video content at 2%.

Table 4. Video characteristics for included YouTube videos

Characteristic	Mean ± SD	Range
Video duration	412.7 ± 285.1	60–1,407
Views	317,500.7 ± 538,585.3	35–2,298,983
Days since upload	1,639.1 ± 1,171.0	2–3,929
View ratio	297.5 ± 446.2	0.4–1879.2
Comment	224.7 ± 428.0	0–2,301
Like	3,908.3 ± 8,783.4	1–39,000
Dislike	98.4 ± 144.8	0–539
Like ratio	95.3 ± 4.5	83.3–100
VPI	296.9 ± 435.3	0.36–1861.5

SD: standard deviation, VPI: video power index.

Table 5. Mean quality and reliability scores per video content and video source variables

Grouping variable	JAMA	GQS	RCSS
Video content*			
Exercise training	2.1 ± 0.95	3.8 ± 0.9	3.6 ± 1.9
Disease-specific	3.0 ± 0.85	3.8 ± 1.2	7.6 ± 3.8
Patient experience	3.3 ± 0.58	4.2 ± 0.7	6.3 ± 1.2
Surgical technique	2.7 ± 0.95	3.2 ± 0.8	5.2 ± 2.6
Non-surgical	2.2 ± 0.84	2.8 ± 0.5	2.3 ± 0.9
Advertisement	1.3 ± 0.39	1.9 ± 0.3	3.8 ± 2.6
Video source†			
Academic	3.0 ± 1.4	4.5 ± 0.7	9.5 ± 4.9
Physician	3.2 ± 0.7	3.9 ± 0.9	7.1 ± 3.5
Non-physician	2.5 ± 0.9	3.8 ± 1.2	3.3 ± 2.8
Trainer	1.9 ± 0.8	3.6 ± 0.9	3.8 ± 2.0
Medical	2.2 ± 0.4	3.0 ± 0.8	3.5 ± 1.7
Patient	1.8 ± 0.5	2.9 ± 0.6	2.9 ± 1.0
Commercial	2.2 ± 1.0	2.8 ± 1.5	5.8 ± 3.8

Values are presented as mean ± standard deviation. The p-values for video content between-group effects: JAMA = 0.018, GQS = 0.038, RCSS = 0.008. The p-values for video source between group effects: JAMA < 0.001, GQS = 0.17, RCSS = 0.011.
JAMA: *Journal of the American Medical Association*, GQS: global quality score, RCSS: rotator cuff-specific score.
*Range of JAMA, GQS, and RCSS scores by video content: 1–4, 1–5, and 1–15, respectively; †Range of JAMA, GQS and RCSS scores by video source: 1–4, 1–5, and 2–16, respectively.

Video Reliability and Educational Content Analysis

The mean JAMA score was 2.66 ± 0.96; the mean GQS was 3.68 ± 1.04, and the mean RCSS was 5.64 ± 3.56. An ANOVA was used to determine whether the video reliability and the quality of educational content differed by upload source and by content classification (Table 5). Significant between-group effects were observed for the JAMA score based on the content category ($p = 0.018$), with videos concerning patient experiences having the highest mean JAMA score. Significant between-group effects were also observed for the JAMA score based on the video upload source ($p = 0.007$), with videos uploaded by physicians receiving the highest mean JAMA score. Between-group effects were also observed for the GQS, with exercise training and disease-specific content ($p = 0.038$) conferring higher mean scores. There was no association between the upload source and the mean GQS scores ($p = 0.165$). Statistically significant group effects were found for the RCSS with disease-specific content

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($p=0.001$) and academic institution upload sources ($p=0.011$) having the highest mean RCSS.

Predictors of Video Reliability and Educational Content Quality

The influence of video characteristics, the video content category, and the video upload source on the JAMA score, GQS, and RCSS was investigated using multivariate linear regression models. These models did not identify any independent associations between the video characteristics, content category, or upload source and the JAMA score (all $p>0.05$). For the GQS, non-surgical intervention content was independently associated with lower GQS scores ($\beta=-2.19$, $p=0.019$). Disease-specific video content ($\beta=4.01$, $p=0.045$) was the only independent predictor of the RCSS.

DISCUSSION

The main findings of the current study were that (1) the first 50 YouTube videos alone populated by the key word "rotator cuff" accrued a total of 15,875,035 views by users; (2) the mean JAMA score and RCSS of all videos were 2.7 and 5.6, respectively, suggesting low video reliability and rotator-cuff specific educational content quality; (3) the video reliability and educational value as measured by the JAMA score, GQS, and RCSS differed based on the video upload source and the type of video content; and (4) disease-specific video content was a significant independent predictor of a higher RCSS.

The current study suggests that the rotator cuff is of interest to a large online audience, as an analysis of the first 50 videos queried by the simple search term "rotator cuff" were viewed a total of 15,875,035 times. On average, this means that these 50 videos are viewed 297.50 times per day. This finding is unsurprising because YouTube has become a highly utilized source for gathering health information [20]. Interestingly, the mean number of likes of all videos was 3908.27, while the mean number of dislikes for all videos was only 98.42. Furthermore, the mean VPI (a measure of video popularity) was 296.98, reaffirming that videos concerning the rotator cuff are both highly liked and frequently viewed. This value was high in comparison to other common orthopedic conditions, as previously reported YouTube VPIs include values of 92.6 for disc herniation [6], 174.4 for kyphosis [3], and 301.9 for meniscectomy [15]. Despite the popularity of rotator cuff videos, the mean JAMA score was 2.66 ± 0.96, the mean GQS was 3.68 ± 1.04, and the mean RCSS was 5.64 ± 3.56, suggesting poor video reliability, accuracy, and rotator cuff-specific educational content. Taken together, these findings imply that many viewers are satisfied with videos that provide them with unreliable and low-quality information, which may misinform both their motivation to seek treatment and their expectations for outcomes.

Although most videos were uploaded by physicians and the majority of their content was classified as concerning disease information, the reliability, accuracy, and rotator cuff-specific educational content was low. This information is in accordance with previous studies, which have sought to evaluate the quality and content of orthopedic topics on YouTube. Indeed, other orthopedic-specific YouTube studies concerning kyphosis [3], disc herniation [6], the anterior cruciate ligament [5], lumbar discectomy [21], and femoroacetabular impingement [22] syndrome have all concluded that the quality and reliability of YouTube videos discussing these topics are strikingly low. Given that YouTube lacks an editorial process for videos uploaded to their website and that any user can upload any video of their choice, it is plausible that this lack of restrictions allows for video content to be posted that is inaccurate. These findings highlight the need for higher quality orthopedic-based educational content for viewers and patients on YouTube or for the development of a new online platform that only allows peer-reviewed content.

Interestingly, the ANOVA in the current study demonstrated that the mean JAMA score (a measure of video reliability and quality) was higher for videos that discussed patient experiences as well as videos that were uploaded by a physician. This finding may suggest that patient testimonies of their experiences regarding the treatment of rotator cuff pathology are tangible to other viewers, and that physicians who treat these pathologies provide more reliable information. Furthermore, the mean GQS (an objective measure of educational quality) was higher in videos where the content was based on exercise training and disease information; the mean RCSS was higher in videos concerning disease information and those uploaded by academic institutions, and disease-specific video content was a significant independent predictor of a higher RCSS. As both of these measures are concerned with the objective and specific educational content quality, respectively, it is therefore plausible that information about rotator cuff disease provides the best educational quality for viewers and patients. Furthermore, academic institutions that treat or study the rotator cuff would also be expected to produce higher educational value in their videos. Although these associations exist statistically, it is still important to recognize that overall, the quality and reliability of the videos evaluated in the current study were low and that future efforts should be made to increase the quality of such videos. In particular, treating healthcare providers may play a larger role in identifying and counseling patients on which resources are high-quality. Given that there is clearly a de-

mand for online video content as an educational resource, healthcare providers should make efforts to produce high-quality videos for patient education. As more orthopedic surgeons embrace social media for physician-patient engagement and marketing [23], consideration should be given to utilizing these platforms to offer accurate alternatives to unregulated resources, such as YouTube.

The current study had several limitations. The assessment of a small subset of YouTube videos among the many populated with the query "rotator cuff" may not provide a complete representation of all the available videos on this topic. However, selection bias was minimized by systematically analyzing the first 50 videos, and it has been reported that the majority of internet users confine their searches to the first two pages populated by a search [24], which is consistent with the methods employed here. The current study also used reliability and quality assessment tools, which have not been validated despite their widespread use in studies that seek to evaluate these measures for online resources. As these tools have repeatedly demonstrated excellent inter-observer reliability for all three tools in the literature and in the current study, it is likely that the low-quality findings among the included videos are an accurate assessment.

The overall quality and educational content of YouTube videos concerned with the rotator cuff were low. Physicians should caution patients about using such videos as resources for decision-making and should counsel them appropriately.

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Horizontal instability after acromioclavicular joint reduction using the two-hole technique is preferred over the loop technique: a single-blind randomized clinical trial

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Background: Most acromioclavicular joint (ACJ) injuries are caused by direct trauma to the shoulders, and various methods and techniques are used to treat them; however, none of the options can be considered the gold standard. This study examines the horizontal stability of the ACJ after a complete dislocation was repaired using one of two Ethibond suture techniques, the loop technique and the two holes in the clavicle technique.

Methods: In this single-blind, randomized clinical trial, 104 patients diagnosed with complete ACJ dislocation type V were treated using Ethibond sutures with either the loop technique or the two holes in the clavicle technique. Horizontal changes in the ACJ were radiographically assessed in the lateral axial view, and shoulder function was evaluated by the Constant (CS) and Taft (TS) scores at intervals of 3, 6, and 12 months after surgery.

Results: The horizontal stability of the ACJ was better with the two-hole technique than the loop technique at all measurement times. CS and TS changes showed a significant upward trend over time with both techniques. The mean CS and TS at the final visit were 95.2 and 11.6 with the loop technique and 94.0 and 11.9 with the two-hole technique, respectively. The incidence of superficial infections caused by the subcutaneous pins was the same in the two groups.

Conclusions: Due to the improved ACJ stability with the two-hole technique, it appears to be a more suitable option than the loop technique for AC joint reduction.

Keywords: Acromioclavicular joint; Shoulder dislocations; Joint instability; Suturing techniques; Horizontal instability

INTRODUCTION

The acromioclavicular joint (ACJ) is a diarthrodial joint located between the acromion and the clavicle and is supported by the AC and coracoclavicular (CC) ligaments. The AC ligament connects the acromion to the distal clavicle and provides the ACJ with horizontal (anterior–posterior) stability [1-3]. ACJ injury accounts for 9%–12% of shoulder injuries, is most common in

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people aged 20 to 30 years, and occurs five times more often in men than in women [1,2,4-6]. These injuries are often caused by direct trauma to the shoulder during contact sports (such as cycling, skiing, ice hockey, rugby, and soccer) when the arm is in an inclined position or when falling on an inclined arm [1,2,7,8]. ACJ injuries are usually classified by the Rockwood system into six types based on the damage to the AC and CC ligaments. Recommendations for managing these injuries are usually non-surgical for types I and II, surgical for types IV to VI, and controversial for type III [1,2,9].

More than 60 methods for treating ACJ injuries have been proposed in the literature, indicating disagreement about the best surgical procedure for treating them. Many of the methods focus on vertical instability (disruption of the CC ligaments). Horizontal instability (AC ligament disruption) has received less attention [1,9,10]. There is currently no gold standard surgical treatment for any type of AC injury, especially for horizontal ACJ instability [4,8,10,11]. This study examined the effects of two Ethibond suture techniques, the loop technique and the two holes in the clavicle technique, on the horizontal stability of the ACJ following its complete dislocation. These techniques were used because they are cheaper for patients than other techniques in our country.

METHODS

This study was approved by the University Ethics Committee (IR.GUMS.REC.1395.307) and is registered at the Iranian Registry of Clinical Trials (IRCT201704087274N12). All patients signed the consent form, and their personal information was kept confidential.

Study Design

This study was a single-blind, randomized, clinical trial with a parallel design conducted at a referral university hospital. A total of 104 patients aged 18–65 years were included in the study by convenience sampling from 2017 to 2019 after providing informed consent and receiving a thorough examination. The clinical part of the examination looked for symptoms such as hematoma or abrasion on the superolateral border of the shoulder or obvious asymmetry between the two distal clavicle ends, along with tenderness to the touch or positive piano-key sign. A radiographic evaluation was performed in the lateral axial view. Patients diagnosed with acute ACJ dislocation (for less than 3 weeks) of grade V in the Rockwood classification and treated with surgery by the first author were included in the study. Those with chronic dislocation, a history of shoulder joint trauma or associated lesions in the affected arm, psychological disorders, or alcohol or drug abuse were excluded.

Based on the results of previous studies [12] and considering a 95% confidence level and 90% test power, the required sample size was calculated to be 52 per group. Using a 1:1 ratio for the randomized block design, the eligible individuals were randomly allocated into the two Ethibond suture groups, the loop technique or the two holes in the clavicle technique. The website (https://www.sealedenvelope.com) was used to generate a randomization list for allocating the 104 patients to the study groups in randomized blocks of four. After generating the list, each person was assigned a unique code and identified with that code during the study. All participants were blinded to the randomization list; to ensure blinding, consecutively numbered sealed envelopes were used during the randomization process, and the envelope pertaining to each person was opened only after confirming the candidate's eligibility and receiving their signed consent form. The study was single-blind; the subjects were blinded to the type of intervention they received.

Study Groups

The two-hole group

In this group, two holes, 1 cm apart, were made from the superior to the inferior part of the clavicle. An Ethibond 5 suture was divided into two layers, passed through the one hole, and looped around the coracoid to exit through the second hole. After an open ACJ reduction, the sutures were tied together, and the ACJ was stabilized with an additional flat pin from the acromion to the clavicle. The ACJ capsule was then repaired.

The loop group

In this group, the anchor suture was looped around the clavicle and coracoid bone instead of passing through a drilled tunnel, and the two ends of the suture were tied together while open ACJ reduction was being performed. As in the other group, the ACJ was stabilized with an additional flat pin from the acromion to the clavicle, and then the ACJ capsule was repaired (Figs. 1 and 2).

Rehabilitation Protocol

After the operation, the limbs were slinged for 2 weeks in both groups, and the patients were allowed to resume normal daily activities after this 2 weeks. In both groups, after 6 weeks, the subcutaneous pin was removed under local anesthesia, and patients were sent to physiotherapy and allowed further activities. After 3 months, patients were allowed to perform heavy activities, such as lifting, pushing, and pulling.

Data Collection

Data on the patients' demographic characteristics (age and sex) and operation-site infections (serous or pus secretion) were recorded in a checklist. Horizontal stability of the ACJ was recorded by an X-ray device, and shoulder function was recorded by the Constant (CS) and Taft (TS) at 3, 6, and 12 months post-surgery.

Radiographic Evaluation

For the horizontal ACJ evaluation, axillary radiographs were produced. By measuring the distance between the anterior edge of the acromion and the anterior edge of the lateral clavicle, the dislocation was categorized as stable (≤2 mm) or unstable (>2 mm) (Fig. 3) [13-15].

Statistical Analysis

The collected data were analyzed in IBM SPSS ver. 21 (IBM Corp., Armonk, NY, USA) software. The chi-square test was used to compare changes between the two groups in shoulder position as shown on horizontal radiography. Repeated-measures analysis of variance (ANOVA) was used to evaluate the changes in CS and TS before and after surgery, following a normal distribution assessment with Shapiro-Wilk's test. The independent T-test was used for comparisons between the two groups and to compare the age variable. The chi-square test was applied to compare the qualitative variables (sex and infection) between the two groups. A $p < 0.05$ represented statistical significance for all tests.

RESULTS

A total of 104 patients entered the study, but two patients were excluded from the two-hole group due to unavailability. Therefore, 50 patients in the two-hole group and 52 patients in the loop group were evaluated. Among the patients undergoing surgery, 79.4% were male. The mean age of the patients was 29.2 ± 5.5 years. The sex distribution ($p = 0.526$) and mean age ($p = 0.116$) of patients did not differ significantly between the two techniques. The percentage of superficial infections in the form of mild discharge from the wound was 25% (n = 13) in the loop group and 30% (n = 15) in the two-hole group, which was a not significant difference ($p = 0.06$). Each group had one case of loss of reduction, and the loop group had one case of painful ACJ (Fig. 4).

As shown in Table 1, changes in the horizontal stability of the shoulder differed significantly with the two methods ($p < 0.05$) at all the measurement times (3, 6, and 12 months post-surgery), and the incidence of unstable cases with the loop technique was higher than that with the two-hole technique. Repeated-measure ANOVA results are shown in Table 2, along with the effect of time on the scores in the two groups. The CS and TS changes show a significant upward trend over time with both techniques ($p_{time} < 0.001$). The group effect on the CS ($p_{group} = 0.121$) and TS ($p_{group} = 0.126$) was not statistically significant, indicating that the two techniques did not differ. The interaction between time and group for the CS and TS was significant, and those changes were statistically different at some intervals. However, the mean differ-

Table 1. Comparison of horizontal changes in shoulder position between the loop and two-hole methods at three measurement times

Variable	Group			p-value
	Loop	Two holes	Total	
Horizontal 3 mo				0.03
Stable	43 (82.7)	48 (96)	91 (89.2)	
Instable	9 (17.3)	2 (4)	11 (10.8)	
Horizontal 6 mo				0.01
Stable	38 (73.1)	46 (92)	84 (82.4)	
Instable	14 (26.9)	4 (8)	18 (17.6)	
Horizontal 1 yr				0.01
Stable	38 (73.1)	46 (92)	84 (82.4)	
Instable	14 (26.9)	4 (8)	18 (17.6)	

Values are presented as number (%).

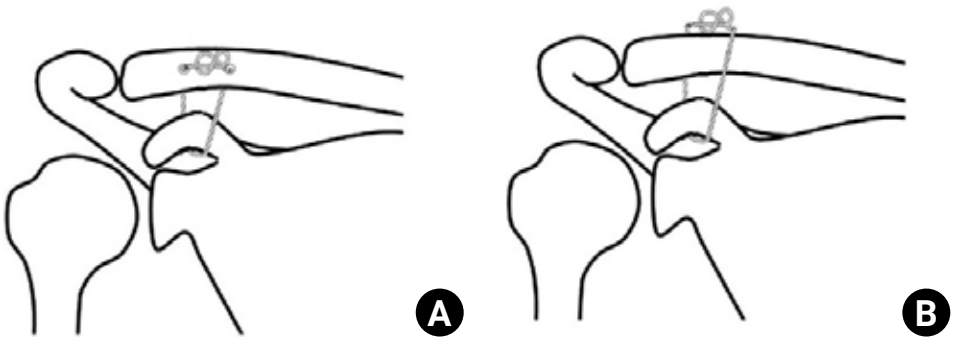

Fig. 1. Schematic diagram of surgery: (A) two holes, (B) loop.

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Table 2. Comparison of the Constant and Taft scores between the loop and two-hole surgery techniques at three measurement times

Variable	Group		p-value
	Loop	Two holes	
Constant score			
Before surgery	33.2 ± 6.4	35.2 ± 6.9	0.108
3 mo	91.4 ± 4.2	89.7 ± 5.0	0.040
6 mo	95.6 ± 4.0	94.4 ± 4.9	0.175
1 yr	95.2 ± 3.8	94.0 ± 4.6	0.136
p-value	$P_{time} < 0.001$, $P_{group} = 0.121$, $P_{int.time \times group} = 0.041$		
Taft score			
Before surgery	4.7 ± 0.8	4.5 ± 0.7	0.455
3 mo	11.7 ± 0.6	11.9 ± 0.4	0.057
6 mo	11.7 ± 0.6	11.9 ± 0.4	0.029
1 yr	11.6 ± 0.7	11.9 ± 0.4	0.023
p-value	$P_{time} < 0.001$, $P_{group} = 0.126$, $P_{int.time \times group} = 0.029$		

Values are presented as mean ± standard deviation.
int, interaction.

ence was not clinically significant.

DISCUSSION

The results show a higher degree of horizontal instability with the loop technique than the two-hole technique. Twelve months after surgery, instability was found in 26.9% of the loop group and 8% of the two-hole group (17.6% overall). The changes in shoulder function reported in the CS and TS were similar with the two techniques. Also, the incidence of superficial infections caused by the subcutaneous pins was the same in the two groups. In this study, horizontal dislocations and joint instability were lower in the two-hole group; at 1-year postoperation, instability was more than three times more common in the loop group than the two-hole group (26.9% vs. 8%). However, with the loop technique, additional instability did not occur after 6 months. In other words, joints treated with the loop technique maintained the stability they had achieved at 6 months after surgery. Although the rates of instability and dislocation differed between the two techniques, the resulting shoulder function did not differ between the groups. Kraus et al. [12] showed that instability existed after shoulder joint reduction for grade V injuries with the double-tightrope technique based on either the V-shaped or parallel drill hole method. Shoulder function did not differ with those two methods either, consistent with the findings of this study. In general, it can be argued that horizontal instability does not affect short- or medium-term shoulder function.

In a review of biomechanical and clinical studies, Jordan et al. [16] showed that simultaneous reconstruction of the ACJ and CC joint produces less horizontal instability than isolated CC reconstruction, although the clinical outcomes did not differ. In other words, horizontal instability appears not to affect the functional outcomes of the shoulder.

In the two-hole group in this study, two holes were made in the clavicle, and an Ethibond suture was passed through the holes and looped around the coracoid so that the two ends of the suture could be tied together. In contrast, in the loop technique, the Ethibond suture was looped around the clavicle and the coracoid. In general, passage of the suture through the holes in the clavicle appears to restrict it. In other words, if the clavicle is fixed by passing a suture through holes in its structure, movement restriction is increased, which reduces the horizontal instability of the clavicle. Beitzel et al. [17] also showed that horizontal instability is limited in CC ligament reconstruction using single or double tunneling, which confirms the results of this study, though their surgical procedural details differed from those used here.

Previous studies have shown that several methods can be used for ACJ reconstruction, and no consensus has been reached on the best methods for diagnosing, evaluating, and treating acute or chronic ACJ horizontal instability. Horizontal instability injuries are often overlooked or not well understood, complicating diagnosis and potentially leading to extensive complications and failure after surgical stabilization [1].

Regarding complications, because subcutaneous pins were used for both techniques in this study, mild infections with small secretions were observed in both groups and were controlled with antibiotics. In a study by Liu et al. [13], a patient developed a superficial wound infection 3 weeks after surgery, which healed after routine care. Theopold et al. [18] reported no intraoperative

Fig. 2. Preoperative (A) and postoperative (B) X-ray.

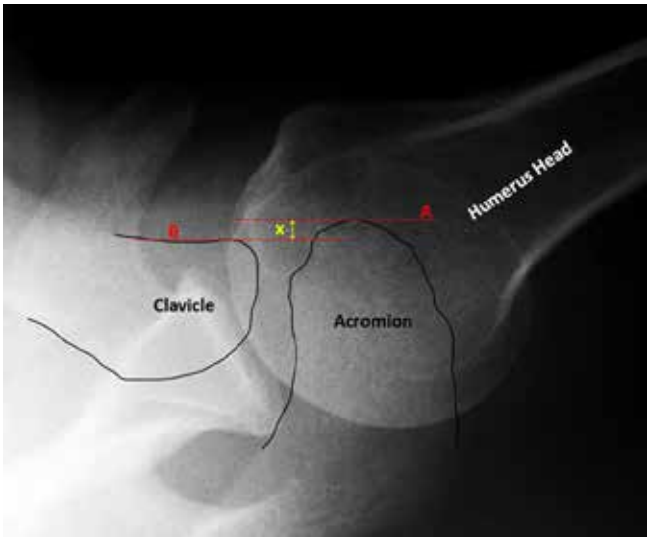

Fig. 3. Axillary shoulder X-ray view. Line A: anterior edge of the acromion, Line B: anterior edge of the lateral clavicle, ×: distance between A and B that determine horizontal stability

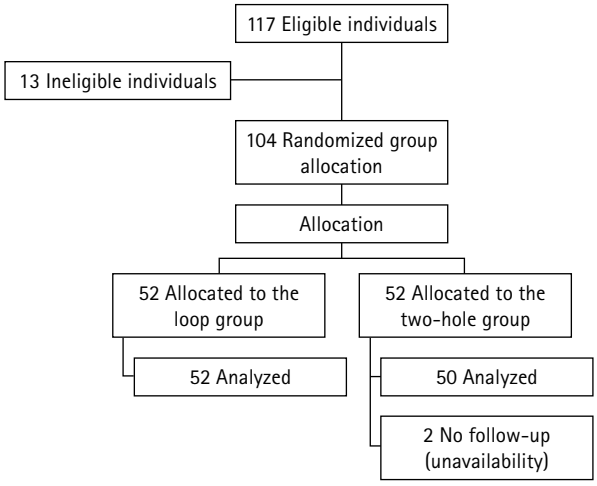

Fig. 4. Participant flowchart.

complications and generally no fractures in the clavicle or coracoid area based on radiological examinations. No postoperative infections or wound healing disorders occurred in their study. In a study by Bostrom Windhamre et al. [19], five superficial infections were reported and treated with oral antibiotics, which is comparable to the results in this study, in which 28 people developed superficial infections. In our study, each group had one case of loss of reduction, and the loop group had one case of painful ACJ. In the study of Tauber et al. [20], a vertical re-dislocation with complete loss of reduction and clinically relevant ACJ deformity was observed in four patients. In general, ACJ reconstruction with various surgical techniques appears to have limited and acceptable complications.

Although horizontal stability differed between the two groups over the course of 1 year, functional outcomes did not differ between the groups. A 1-year follow-up might be too short to evaluate shoulder function, and functional outcomes might vary with longer follow-up periods. Also, clavicle instability could cause ACJ arthritis in the long term. None of the participants in this study were professional athletes or relied heavily on shoulder use. Functional outcomes might also differ in those individuals depending on which of the two techniques is used, and that constitutes one of the limitations of this study.

Although functional outcomes did not differ significantly between the two-hole and loop techniques in the short- and medi-

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um-term, the improved horizontal stability of the ACJ with the two-hole method suggests that technique as a more suitable option for ACJ reduction.

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A modified method of augmented distal clavicle fracture osteosynthesis with a Fibertape coracoclavicular cerclage

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Background: Unstable distal clavicles experience high non-union rates, prompting surgeons to recommend surgery for more predictable outcomes. There is a lack of consensus on the optimal method of surgical fixation, with an array of techniques described in the literature. We describe an alternative method of fixation involving the use of a distal clavicular anatomical locking plate with Fibertape cerclage augmentation in our series of patients.

Methods: Nine patients (8 males and 1 female), with a mean age of 36 years, who sustained unstable fracture of the distal clavicle in our institution were treated with our described technique. Postoperative range of motion, functional and pain scores, and time to radiographic union were measured over a mean follow-up period of 10 months. Incidences of postoperative complications were also recorded.

Results: At the last patient consult, the mean visual analog scale score was 0.88±0.35, with a mean Disabilities of the Arm, Shoulder, and Hand (DASH) score of 1.46±0.87 and American Shoulder and Elbow Surgeons (ASES) score of 94.1±3.57. The mean range of motion achieved was forward flexion at 173°±10.6°, abduction at 173°±10.6°, and external rotation at 74.4°±10.5°. All patients achieved internal rotation at a vertebral height of at least L2 with radiographical union at a mean of 10 weeks. No removal of implants was required.

Conclusions: Our described technique of augmented fixation of the distal clavicle is effective, produces good clinical outcomes, and has minimal complications.

Keywords: Clavicle; Fracture osteosynthesis; Fracture fixation; Orthopedic fixation devices

INTRODUCTION

Clavicle fractures are common, and while most such fractures occur at the mid shaft, approximately 15% involve the distal one-third [1]. The most common classification for distal one-third clavicle fractures is the Modified Neer system based on the fracture site's relationship with the coracoclavicular (CC) ligament [2]. Unstable fractures, such as type 2 and type 5, often experience significant displacement due to deforming forces from the trapezius acting upon the proximal fragment along with the weight of the arm pulling the distal fragment inferiorly. As a result, these fractures experience high non-union rates [3,4], prompting surgeons to recommend surgery [5].

With a lack of consensus on the best surgical option, various techniques have been described, such as anatomical locking plates or hook plate fixation, CC stabilization (with a suture anchor, button device, or screw), Kirschner wire fixation, or arthroscopic assisted procedures. Each of these methods has ad-

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vantages and shortcomings such as the need for implant removal or risk of intraoperative fractures [6]. The purpose of our study is to illustrate an alternative method of fixation involving the use of a distal clavicular anatomical locking plate with Fibertape cerclage augmentation in a series of patients. We hypothesize that our method of augmented fixation will be reliable and produce good outcomes with minimal complications.

METHODS

This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Institutional Ethics Committee of National Health Group (No. NHG 2020/00202). Patient records and radiographs were retrospectively accessed through the patient's electronic medical records upon Institutional Review Board approval.

Nine patients who sustained unstable fracture of the distal clavicle treated by distal clavicle locking plates along with Fibertape (Arthrex, Naples, FL, USA) augmentation from the period of January 2018 to January 2020 in Khoo Teck Puat Hospital, Singapore were included in our study retrospectively. The inclusion criteria of this study were adult patients who suffered an unstable (modified Neer type 2 or type 5) distal clavicle fracture (Figs. 1 and 2). Patients excluded from the study were polytraumatic patients, those who had pathological fractures, patients with a concomitant injury to the ipsilateral upper limb, and those undergoing revision fixation.

Under general anesthesia, the procedures were performed with the patients in a beach-chair position. A longitudinal or saber incision along the distal clavicle was created to allow direct access to the fracture site and coracoid process. The deltotrapezial fascia was split, and the fracture was provisionally reduced under direct visualization and confirmed under fluoroscopy (Fig. 3). A Synthes 3.5 mm LCP Superior Clavicle plate with lateral extension was then applied with as much distal bony purchase as possible using lateral 2.7 mm locking screws (up to six screws). Blunt dissection to the base of the coracoid was performed, and a right-angle curved hemostat was used to guide the Fibertape (Arthrex) around the base of the coracoid process and over the clavicle before being secured using a standard surgeon's knot and square knots over the plate (Figs. 4 and 5). The wound was closed in layers with reconstruction of the deltoid fascia.

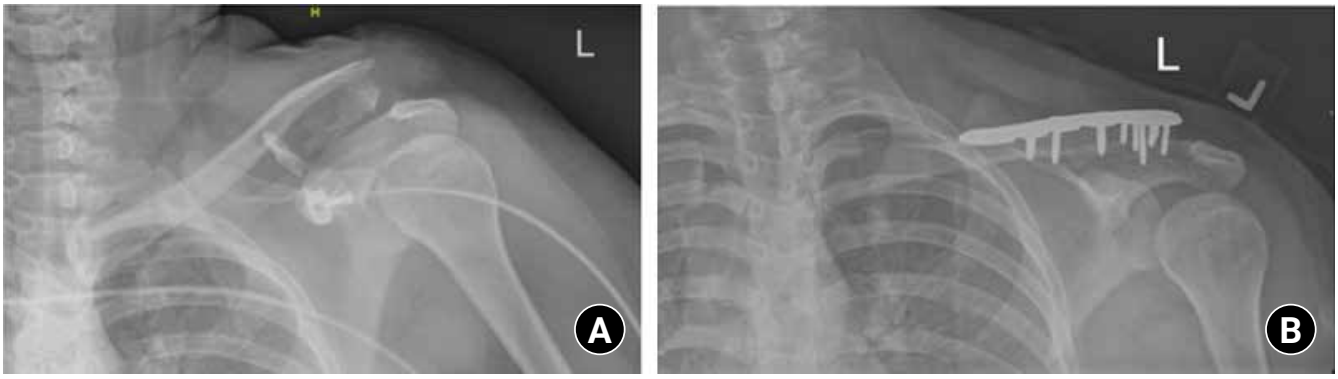

Fig. 1. (A) Plain radiographs of a patient with modified Neer type 2 distal clavicle fracture. (B) Final postoperative radiographs demonstrating healed fracture.

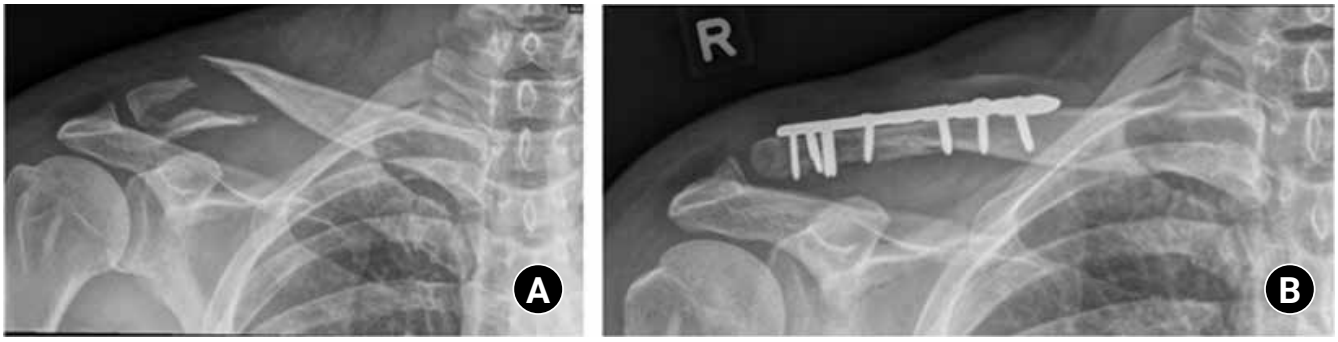

Fig. 2. (A) Plain radiographs of a patient with modified Neer type 5 distal clavicle fracture. (B) Final postoperative radiographs demonstrating healed fracture.

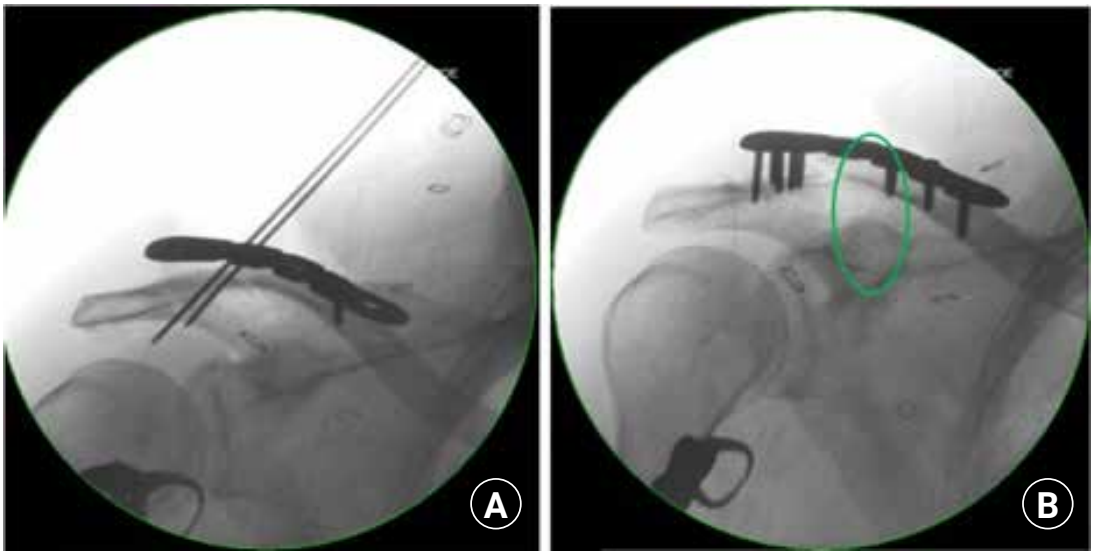

Fig. 3. (A) Intraoperative imaging demonstrating reduction of the fracture and initial positioning of the clavicle plate with Kirschner wires. (B) The location of the Fibertape cerclage (green circle).

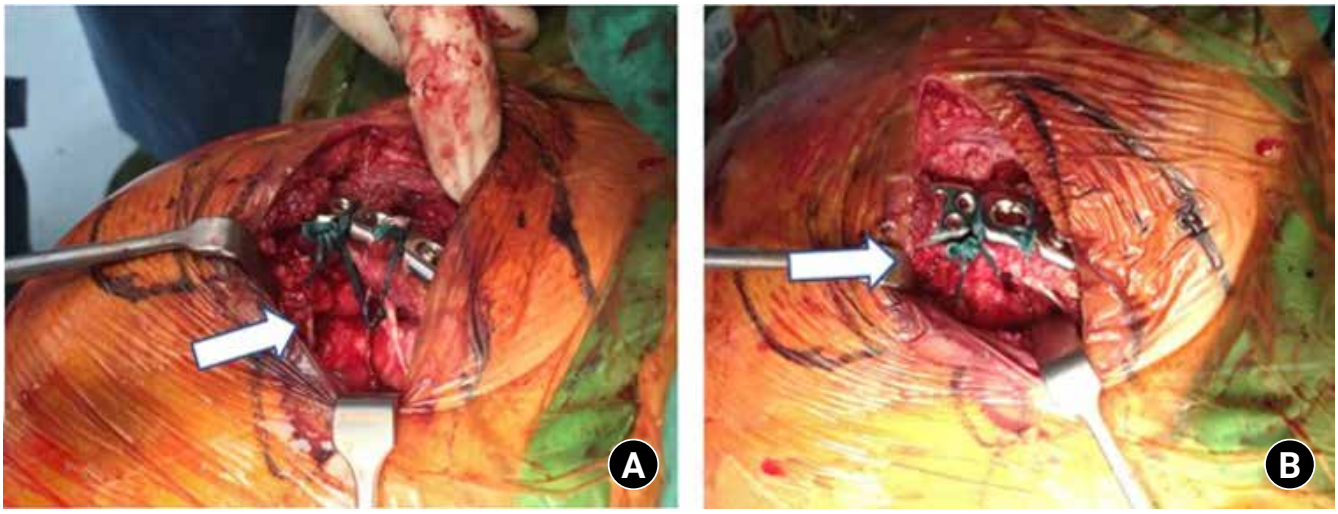

Fig. 4. (A) Arrow depicting where the Fibertape cerclage is employed in an under coracoid and around the clavicle manner. (B) Arrow depicting where the Fibertape knot is secured on the clavicle plate.

The patients were allowed early passive mobilization of the shoulder on postoperative day 1 with the assistance of a physiotherapist. Graduated progression in range of motion and weight bearing status was advised during subsequent visits, and radiographs were obtained in outpatient clinics.

Clinical and radiographical evaluations of the patients were performed at 6 weeks, 3 months, 6 months, and 1 year after surgery. Functional scoring was performed using the Disabilities of the Arm, Shoulder, and Hand (DASH) and American Shoulder and Elbow Surgeons (ASES) questionnaires. The patient's objective range of motion was measured along with injury-residual pain using the visual analog scale (VAS) score, with 0 representing no pain and 10 representing the worst possible pain. Postoperative radiographs (anterior-posterior and axial views of the affected clavicle) were obtained at each follow-up visit. Radiographical union was defined as the presence of bridging callus across the fracture site or healing of the fracture line (Fig. 2). Incidences of postoperative complications such as surgical site infection, non-union, and implant failure were recorded.

RESULTS

The study group involved nine patients, of whom eight were males and one was female, with a mean age of 36 years (range,

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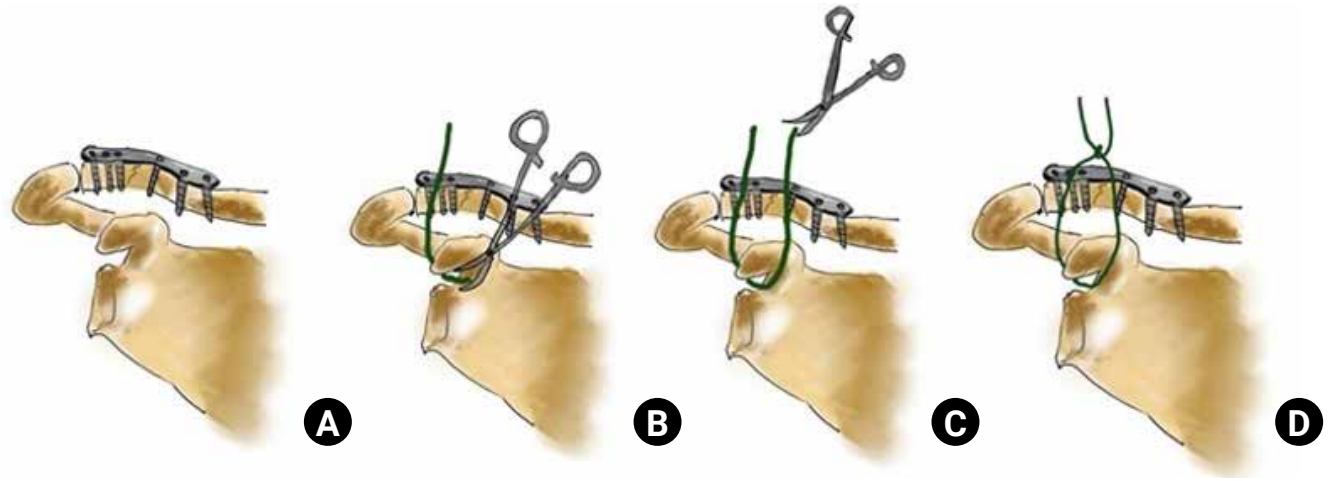

Fig. 5. (A) Illustration showing distal clavicle fracture with plate *in situ*. (B, C) Blunt dissection of base of coracoid performed and the use of a curved haemostat to guide the Fibertape around the coracoid process and over the clavicle. (D) The Fibertape is then secured over the plate with standard surgeon's knot and square knots.

21–66 years) at the time of surgery. The dominant arm was involved in six of the nine patients. In addition, six of the nine patients were smokers, and all had suffered the injury in a road traffic accident. Of the nine cases, one involved bone grafting for a non-united conservatively treated distal clavicle. The mean time to surgical fixation for acute fracture was 14.75 days (range, 7–25 days). One patient was subsequently lost to follow-up, while the remaining eight patients were followed up for a mean of 10 months (range, 8–13 months).

At their last follow-up assessments, the mean VAS score was 0.88 ± 0.35 (range, 0–1) with a mean DASH score of 1.46 ± 0.87 and ASES score of 94.1 ± 3.57. The mean range of motion achieved was forward flexion at 173 ± 10.6, abduction at 173 ± 10.6, and external rotation at 74.4 ± 10.5 (Table 1). All patients achieved internal rotation at a vertebral height of at least L2.

All patients achieved radiographical union on subsequent follow-ups at a mean of 10 ± 0.82 weeks (range, 9–12 weeks) as determined by a consulting orthopedic surgeon. There were no significant postoperative complications noted, although one patient required a second procedure for exchange of a distal locking screw that was backing out at 1 month postoperative. None of the patients complained of plate and/or knot prominence that required implant removal.

Table 1. Mean range of motion and functional outcomes of the patients

Variable	mean ± SD
Forward flexion (°)	173 ± 10.6
Abduction (°)	173 ± 10.6
External rotation (°)	74.4 ± 10.5
Visual analog scale pain score	0.88 ± 0.35
Disabilities of the Arm, Shoulder and Hand score	1.46 ± 0.87
American Shoulder and Elbow Surgeons score	94.1 ± 3.57

SD: standard deviation.

DISCUSSION

The study results suggest that our method of augmented fixation for unstable distal clavicle fractures is reliable with good clinical outcomes, achieved radiographical union, and exhibited no significant postoperative complications. Unstable distal clavicle fractures experience high non-union rates, prompting most surgeons to recommend surgical fixation for more predictable outcomes [5,7-11]. Clavicle hook plates remain a popular option [12,13] as there are concerns of insufficient distal bone purchase with distal clavicle locking plates. However, hook plates have the disadvantage of requiring a subsequent surgery for removal of the implant in order to avoid complications such as subacromial osteolysis, subacromial impingement, and implant fracture [14,15]. Several authors have suggested a combined procedure (clavicle locking plate fixation augmented with CC stabilization) [7,16-20] for added stability [19].

A combined procedure involving a locking plate and CC augmentation has been proposed by various authors to provide greater stability [7,16,17,19]. Xu et al.'s retrospective cohort study [17] comparing distal clavicular locking plates alone with combined use of plates and CC suture anchors exhibited better functional outcomes and a shorter union time with no increase in complications in the combined group. Fan et al.'s study [16] of 28 patients with unstable distal clavicle fracture revealed that anatomical locking plates combined with additional suture anchor fixation resulted in better radiographical and functional outcomes. These results are also supported by biomechanical stud-

ies, such as Madsen et al.'s cadaveric study [19] where CC augmentation added additional stability to the fixation construction when loaded to failure. Similar results were reported in another biomechanical study by Alaee et al. [7], which revealed clear improvements in overall construct stability between various methods of CC augmentation coupled with plate fixation.

Various complications of commonly used supplemental stabilization techniques have been described in the literature. Methods such as suture anchors or tight rope fixation require drilling through the coracoid process, risking potential fracture [20,21]. Technical challenges also can complicate a procedure. For example, drilling a hole in the distal clavicle for Endobutton fixation can be complex in more comminuted fracture patterns. A poorly positioned drill hole in the coracoid process can lead to an increased risk of implant failure or cut out [22].

Our proposed method of using a Fibertape cerclage under the coracoid and around the clavicle does not require drilling and avoids the complications described above. It is also a less expensive alternative to the more costly suture anchors. In addition, as a non-metal implant, it does not introduce hardware that might require a subsequent procedure for removal. We believe that this technique will produce consistently good clinical and radiographical outcomes with low rates of complications. These findings are supported by the good outcomes of Martetschläger et al. [20] with a low rate of complications using a distal radius locking plate and a 1.5-mm braided polydioxanone suture (PDS) cord as a cerclage. We believe that the use of a Fibertape cerclage is a more robust option due to its greater width (2 mm) and higher biomechanical failure load compared to the use of a PDS suture [23,24].

There are disadvantages to the use of a CC cerclage alone that have been highlighted in the literature. Some authors [25] argue that CC cerclage stabilization produces greater anterior-posterior translation compared to other techniques. This is supported by Alaee's biomechanical study [7] showing an increase in anterior-posterior translation with the use of a suture cerclage around the coracoid compared to an intact native CC ligament. However, there was no difference in load to failure or stiffness between the constructs. In the absence of clinical studies comparing the various techniques, this apparent difference might not affect the final functional outcome. Another drawback to this technique is that it relies on the integrity of the coracoid and cannot be performed if the patient has a concomitant fracture of the coracoid.

There are a few limitations to our study. It is a case series with a small group of patients with relatively short follow-up periods. This prohibited us from observing longer term complications of the cerclage technique such as osteolysis and erosion of the distal clavicle [26] or development of AC joint arthritis. However, the development of osteolysis is likely to be averted with our technique as the Fibertape is anchored around the locking plate and not directly on the clavicle. In addition, the follow-up period is sufficient to evaluate bony healing as all cases exhibited union at a mean of 10 weeks. Longer term studies with a larger sample size will be useful to better reflect the long-term outcomes and efficacy of this technique. Studies elucidating circumstances when augmented osteosynthesis is best indicated will also be helpful in guiding treatment.

In conclusion, our modified technique of an augmented distal clavicle fixation is reliable, produces good clinical results, has no significant complications, and did not require subsequent surgery for removal of implants within our period of follow-up.

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Case Report

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Intraoperative pulmonary embolism in shoulder arthroscopy in a patient with previous SARS-CoV-2 infection: a case report

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The objective of this article is to describe intraoperative pulmonary embolism during shoulder arthroscopy in a patient with previous severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection. Further, we describe how the pandemic has influenced the population by increasing the rate of embolisms. Awareness of such cases will help to increase knowledge regarding SARS-Cov-2 and to determine if such patients should receive routine antithrombotic prophylaxis.

Keywords: Shoulder; Arthroscopy; Embolism; SARS-CoV-2; Surgery; Immunoglobulin G

Shoulder arthroscopy has experienced tremendous growth since the first clinical publication on this technique by Andren and Lundberg in 1965 [1]. The complications reported in the literature are scarce and usually limited to case series. Indeed, the first report on complications among 14,329 shoulder arthroscopies by Small in 1986 [2]. Some were classified as anesthesia-related, such as airway compromise, pneumothorax, and air embolism. General surgical complications included infection, neurovascular traction injury, and thromboembolism. Technical complications specific to shoulder arthroscopy were more frequent, including stiffness and fluid extravasation.

Venous thrombosis after shoulder arthroscopy is rare, observed in less than 1% of all cases [3]. There is no substantial evidence to support routine use of anticoagulants after surgery [4]. The current severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) pandemic has raised concern about the increased cases of thromboembolic disease in infected patients. Through microvascular activity, the virus seems to stimulate a strong response that lead to thromboembolic phenomena [5].

In our hospital, 48 hours prior to surgery, patients undergo a nasopharyngeal swab to detect SARS-CoV-2 RNA. This new protocol was established in 2020 and is subject to continuous change as the pandemic evolves. The objective of this article is to describe intraoperative pulmonary embolism during shoulder arthroscopy in a patient with previous SARS-CoV-2 infection.

CASE REPORT

We conducted this study in compliance with the principles of the Declaration of Helsinki. The study protocol was reviewed and

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approved by Reina Sofia University Hospital's Ethics Committee. Written informed consent was obtained.

A 45-year-old male patient with no personal history of interest except morbid obesity (body mass index [BMI], 39.45 kg/m^2) received arthroscopic shoulder surgery. The patient was not receiving anticoagulant therapy, nor had he suffered any previous thrombotic episode. The patient is right-handed and presented with pain in the right shoulder deltoid area, which had been present for one year. Clinical examination showed complete passive and active range of motion. Shoulder flexion range of 120°, extension of 80°, and abduction range of 125° were observed in passive and active motion. The Hawkins and Neer's tests were both positive. The Jobe test was positive, while the Gerber test was negative. Shoulder X-rays showed no acute or chronic alterations. Ultrasound was inconclusive due to poor visualization caused by excessive subcutaneous cellular tissue. Magnetic resonance imaging showed a 6×4-mm-thick partial tear of the articular side of the supraspinatus, with no other alterations except subacromial-subdeltoid and subcoracoid bursitis (Fig. 1). Conservative treatment was performed with physiotherapy for 6 months, and then two injections with corticosteroids were administered without clinical improvement. After exhausting the conservative approach, we performed for surgical intervention once informed consent had been obtained. Preoperatively, the patient showed 43 points on the Constant test and eight of 10 on the visual analogue scale for pain. A polymerase chain reaction (PCR) test for SARS-CoV-2 was performed 48 hours prior to surgery, and the result was negative. In addition, the patient had no symptoms associated with SARS-CoV-2 virus infection.

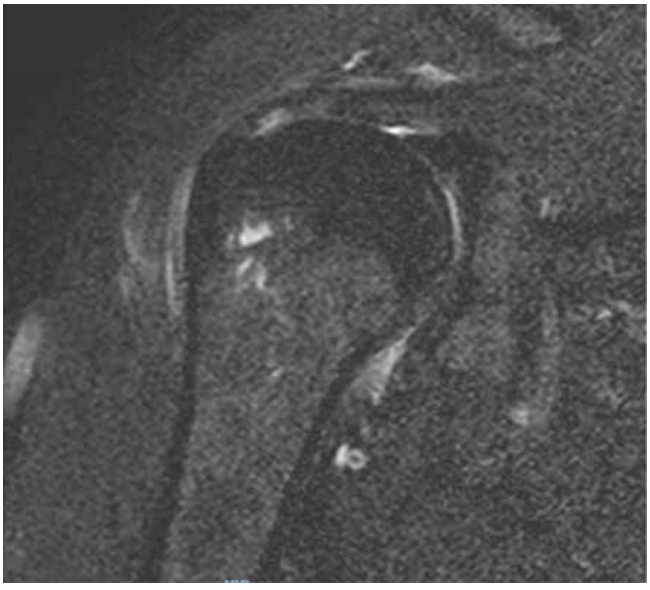

Fig. 1. A 6×4-mm-thick partial tear of the joint margin of the supraspinatus.

Under general anesthesia, we performed arthroscopy with the patient in the left lateral decubitus position, using posterior and anterolateral portals. Debridement of the partially ruptured supraspinatus articular side, bursectomy, and sectioning of the coracoacromial ligament were performed. Operative time was 45 minutes. Anti-thrombotic prophylaxis measures such as compression devices were not used during surgery since they are not established for routine use in our hospital.

During awakening, the patient suffered an episode of low cardiac output with respiratory failure, requiring continuous mechanical ventilation with orotracheal intubation. The patient was transferred to the intensive care unit (ICU). Upon arrival, the patient showed signs of poor perfusion and oxygenation with hemodynamic instability (heart rate of 115 BPM and blood pressure of 50/30 mmHg) despite vasoactive amine perfusion. O_2 saturation was 86%. Electrocardiogram showed negative T waves in V1-V2-V3 and a D-dimer of 16,000 (normal 0–500 ng/mL). Chest computed tomography (CT) angiography showed a contrast repletion defect related to pulmonary thromboembolism in the subsegmental branch of the left upper lobe and subsegmental branch of the right upper lobe (Fig. 2).

The patient required mechanical ventilation, treatment with vasoactive drugs, and anticoagulation with heparin at therapeutic doses. On the fourth day of admission to the ICU, the patient was extubated and presented incoherent speech consistent with motor dysphasia. Follow-up by neurology was requested, and cranial CT scan+angio-CT scan+perfusion CT scan showed no evidence of ischemic lesions; occlusion of large arteries; or atheromatous plaques or stenosis and no asymmetries in the perfusion maps. The patient was diagnosed with encephalopathy of probable toxic metabolic origin.

During the hospital stay, a coagulation study showed no alterations in coagulation, and CT angiography of supra-aortic trunk and upper extremity was normal. SARS-CoV-2 serology was performed 48 hours after surgery, and immunoglobulin G antibodies were positive, indicating prior infection. Tests for immunoglobulin M (IgM) antibodies were negative. The patient had presented no SARS-CoV-2 infection-related symptoms during 2020, nor was he aware of having the disease. The patient had not received the SARS-CoV-2 vaccine. With no clear etiology and no prothrombotic risk factors other than obesity (the patient had no history of thrombotic episodes or family history of thrombosis, and operative time was less than 90 minutes), we suggest that the pulmonary thromboembolism was a result of past COVID-19 infection.

After being treated with a multi-disciplinary approach involv-

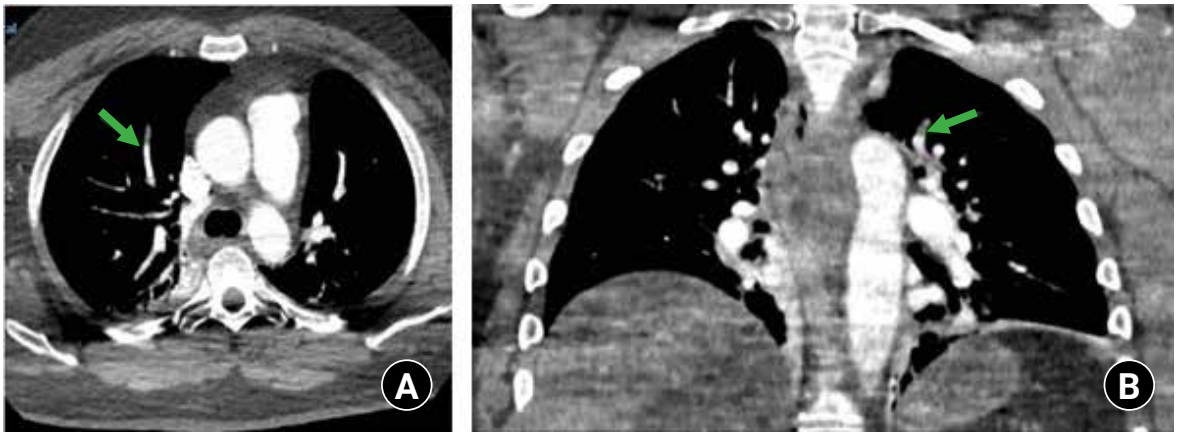

Fig. 2. (A) The green arrow points at a subsegmental branch of the right upper lobe related to pulmonary thromboembolism. (B) The green arrow points at a contrast repletion defect in the subsegmental branch of the left upper lobe.

ing internal medicine, neurology, and traumatology, and when the patient's condition was stable, he was discharged from the hospital. Currently, 6 months after surgery, the patient is undergoing rehabilitation aimed at improving his neurological condition.

DISCUSSION

Emergence of a new coronavirus has triggered major changes in all areas of life, including the hospital setting. Orthopedic surgery and traumatology services in our hospital suspended all scheduled activities, devoting themselves exclusively to emergency pathology. As the incidence rate decreased, new scheduled operations were incorporated following the protocols implemented that year to detect SARS-CoV-2. As we mentioned, all patients preparing for surgical intervention at our center receive a PCR test within 48 hours prior to surgery. The sensitivity and specificity of this test are 71%–98% and 95%, respectively.

The 2020 pandemic has resulted in a vast scope of work, and we found a study similar to ours involving pulmonary thromboembolism in a patient who underwent shoulder arthroscopy and showed a positive PCR result for SARS-CoV-2 at three days after the operation. Unlike in our study, that patient was IgM positive [6]. Numerous studies have shown that hospitalized COVID-19 positive patients are more likely to experience deep vein thrombosis and pulmonary disease than are those who do not have the disease. In addition, such patients have longer ICU stays and a higher mortality rate [7].

There are isolated case reports of thromboembolic disease following shoulder arthroscopy [8,9]. Sager et al. [4] reported that BMI greater than 30 is a risk factor associated with venous thromboembolism after rotator cuff repair. Burkhart [10] reported a case of complete thrombosis of the basilic vein after shoulder arthroscopy. Further evaluation of the patient revealed previously undiagnosed Hodgkin disease. The venous thrombosis was attributed to a hypercoagulable state. Given the rarity of thromboembolic disease, the author recommended evaluation of systemic and local disturbances in cases of occurrence.

Polzhofer et al. [3] reported an isolated case of pulmonary embolism after arthroscopic subacromial decompression. In that patient, neither coagulopathy nor anatomical changes were observed. With no clear etiology, the authors [3] suggested that the cause of the subclavian irritation could have been compression with a powered aspirator.

Although extremely rare, thromboembolic disease can occur after shoulder arthroscopy. Awareness and early detection are the best approach to this serious complication. Currently, antithrombotic prophylaxis is not recommended in shoulder arthroscopy; however, due to the changes in circumstances, prior COVID-19 infection should be considered in selected patients.

We report a case of thromboembolism during shoulder arthroscopy and discuss the increase of such cases during the COVID-19 pandemic. Such cases will help increase our knowledge about the effects of the SARS-CoV-2 virus and reflect on whether or not such patients should receive routine antithrombotic prophylaxis before surgery.

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Technical Note

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The humeral suspension technique: a novel operation for deltoid paralysis

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Isolated deltoid paralysis is a rare pathology that can occur after axillary nerve injury due to shoulder trauma or infection. This condition leads to loss of deltoid function that can cause glenohumeral instability and inferior subluxation, resulting in rotator cuff muscle fatigue and pain. To establish dynamic glenohumeral stability, a novel technique was invented. Humeral suspension is achieved using a double button implant with non-resorbable high strength cords between the acromion and humeral head. This novel technique was used in two patients with isolated deltoid paralysis due to axillary nerve injury. The results indicate that the humeral suspension technique is a method that supports centralizing the humeral head and simultaneously dynamically stabilizes the glenohumeral joint. This approach yielded high patient satisfaction and reduced pain. Glenohumeral alignment was improved and remained intact 5 years postoperative. The humeral suspension technique is a promising surgical method for subluxated glenohumeral joint instability due to isolated deltoid paralysis.

Keywords: Deltoid muscle paralysis; Humeral suspension technique; Brachial plexus neuropathies; Axillary nerve injury; Glenohumeral instability

Isolated deltoid paralysis can occur after axillary nerve injury due to lateral traction on the patient's neck or shoulder trauma. Less common causes are infection leading to brachial plexus neuritis and the quadrilateral space syndrome [1]. The interplay between the rotator cuff muscles and the deltoid enables stability of the glenohumeral joint. In the case of deltoid paralysis with a normal rotator cuff, shoulder function can be maintained, although glenohumeral stability may be reduced. As a consequence, the rotator cuff muscles will be easily exhausted by repetitive shoulder movements [1,2]. This can lead to pain, fatigability in the shoulder region, and positive sulcus sign due to inferior glenohumeral subluxation. In addition, sensibility loss over the lateral aspect of the shoulder can be observed [2]. To clinically diagnose deltoid paralysis, three tests can be used: the Bertelli test, the swallowtail test, and the deltoid extension lag test, of which the Bertelli test is the most reliable [2,3]. Within 2–4 weeks after trauma, electro-

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myography should be performed to confirm the diagnosis and to establish baseline values. After diagnosing deltoid paralysis, conservative treatment with physiotherapy should be started to preserve shoulder strength and mobility [1]. Most axillary nerve lesions recover spontaneously. However, if no clinical improvements are seen after 3 months, neurosurgery should be considered. Neurolysis, neurorrhaphy, nerve grafting, and nerve transfers are described as surgical options and should be performed within 6 months after injury [1,4]. After primary surgical reconstruction, secondary surgical procedures, such as a trapezius tendon transfer [5], biceps tendon transfer [6], pectoralis major inverse plasty [7], and latissimus dorsi tendon transfer [8] may be of added value to improve upper extremity function. Reverse shoulder arthroplasty combined with pectoralis major and trapezius transfer is another surgical option for deltoid paralysis patients [9]. These secondary surgical procedures lead to partial or complete loss of the original function of the transferred muscle. As a last surgical option, glenohumeral arthrodesis can reduce pain and create stability, but does decrease shoulder range of motion [10].

Two male patients aged 47 and 79 years old presented to our institution with shoulder pain and isolated deltoid paralysis combined with glenohumeral subluxation and instability due to traumatic axillary nerve injury (Fig. 1). Their shoulder pain could be relieved by pushing the humerus cranially, thereby aligning the humeral head in an improved glenohumeral position. Glenohumeral alignment and stability were improved by humeral suspension, which leads to less stretching of the brachial plexus and shoulder muscles. To establish dynamic stabilization and suspension of the glenohumeral joint in deltoid paralyzed patients, a novel surgical technique was developed.

The study protocol was approved by the Institutional Review Board of METC Zuyderland Medical Center (File nr. 2021021) and written informed consent was obtained from all patients. In this article, we present this new operation technique and its promising short-term follow-up results.

TECHNIQUE

A standard anterior deltopectoral approach is used. An incision is made from the coracoid process, which extends distally for 8 cm to the upper arm. Subcutaneously, the plane between the deltoid and pectoralis major is opened, whereby the cephalic vein is preserved. Releasing fibrotic adhesions in the subdeltoid space. The humeral head is then moved anterior in a subluxated position, which is not difficult because of glenohumeral laxity. Inspection of the rotator cuff muscles is performed to ensure there are no rotator cuff tears. A second incision 2 cm in length is made at the midline of the lateral border of the acromion medial to lateral with dissection on the acromion bone.

Two bicortical holes 3 mm in diameter are made in the acromion. The two ends of the Fibertape (Arthrex, Naples, FL, USA) are channeled through an AC Dog Bone Button (Arthrex) and then the two ends are channeled from cranial to caudal through the acromion. This step is repeated for the other bicortical hole in the acromion. Divergent drilling of 4 monocortical holes 3

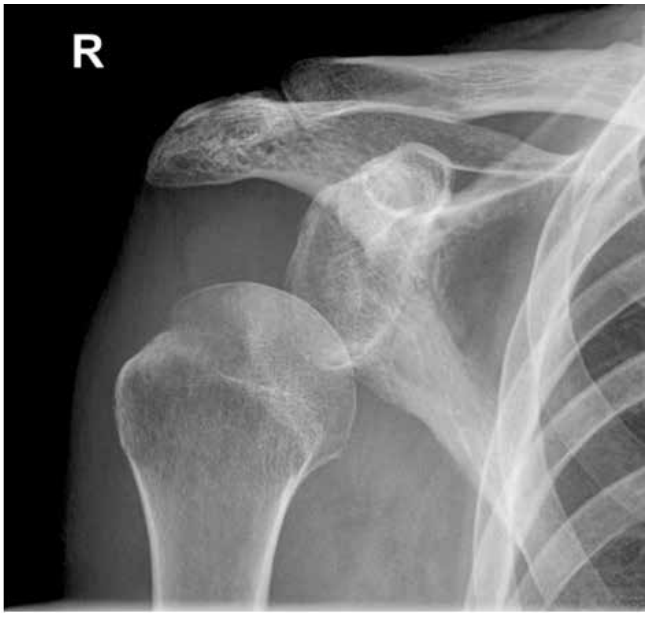

Fig. 1. Preoperative anteroposterior X-ray of the right shoulder of patient 1 with inferior subluxation.

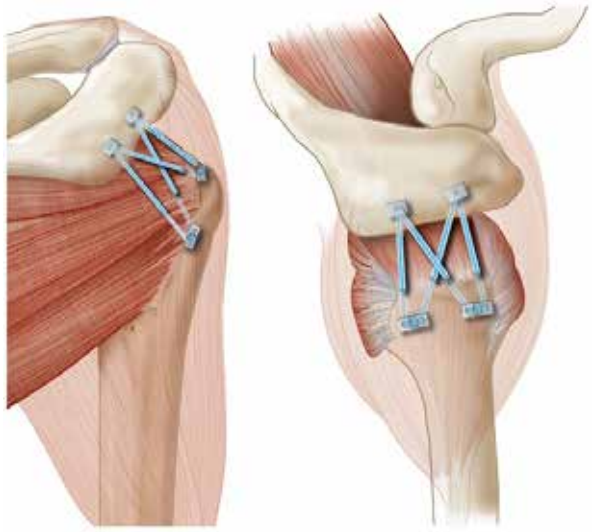

Fig. 2. Anteroposterior and lateral views of the right shoulder with Fibertape channeled through the acromion and proximal humerus.

mm in diameter is performed at the footprint of the greater tubercle. Drill hole is made anterolateral at the insertion of the superior glenohumeral ligament, and drill hole 2 is made 1 cm lateral of hole 1. Holes 3 and 4 are drilled on the posterolateral side of the greater tubercle, whereby hole 4 is made between the insertion of the infraspinatus and supraspinatus and hole 3 1 cm anterior to it. The next step is channeling the Fibertape anterior to posterior through the drill holes. The first Fibertape is channeled through holes 1 and 3 and the second Fibertape through holes 2 and 4, then the ends of the Fibertape are channeled through an AC Dog Bone and tightened from posterior to anterior (Fig. 2). Attention should be paid to alignment of the center of the humeral head with the glenoid fossa to prevent overtightening so that at abduction there is no impingement of the major tubercle at the acromion and internal rotation is still possible to the buttock, while external rotation in adduction is still possible for at least 30º. The glenohumeral anterior-posterior translation is tested, followed by rinsing, closing, and dressing the wound.

Postoperative, the shoulder is immobilized in a sling for 2 weeks without mobilization restrictions. Clinical and radiological evaluation should be conducted at 2, 6 and 12 months postoperative.

DISCUSSION

This novel surgical technique is a method to suspend the humeral head and dynamically stabilize the glenohumeral joint in deltoid paralysis. This technique can improve glenohumeral alignment, which may lead to improved function of the rotator cuff muscles, less fatigue, less pain, and less elongation of the brachial plexus and joint capsule. The basic idea is to reconstruct the function of the glenohumeral ligaments through tensioning of the deltoid. Although native tensioning cannot be imitated, this technique does not disturb the original function of shoulder musculature as is the case in tendon transfers. In addition, the theoretical risk of elongation of the transferred tendon is eliminated. Also, this technique maintains the option for future tendon transfer, shoulder arthroplasty, or glenohumeral arthrodesis if shoulder function is not improved, since no structural changes are made to the original anatomy.

The postoperative results were promising, with a numeric rating scale (NRS) for patient satisfaction of 9 and 8 for patients 1 and 2, respectively. Pain was reduced from NRS 9 to 1 and NRS 8 to 6 for patients 1 and 2, respectively. Both patients reported that they would undergo the operation again if they were in the same situation as before. As is shown in Fig. 3, there was no elongation of the Fibertape, and glenohumeral alignment remained intact after 5 years of follow-up. At the final follow-up, shoulder function was measured using the Disabilities of the Arm, Shoulder and Hand (DASH) and Constant-Murley scores. DASH score was 29 and 32 and Constant-Murley score was 56 and 22 for patients 1 and 2, respectively. No complications were reported.

It should be emphasized that the indication for this novel technique is pain that originates from muscle and tendon fatigue, and not from a neurological cause. If the pain is relieved by manually suspending the upper arm, this novel humeral suspension technique could be of value.

A contraindication for this technique is omarthrosis, since pain will not be reduced with this novel technique in these patients. Whether partial deltoid paralysis should be a contraindication for this technique remains unclear. It is hypothesized that such a muscular imbalance in different parts of the deltoid could affect active and passive shoulder function. Whether patients with anatomical glenohumeral arthroplasty or patients with os acromiale are candidates for this technique remains to be determined.

Possible drawbacks of this technique may be that in time, elongation or rupture of the Fibertape could occur. Another limitation is channeling of the Dog Bone through the acromion due to constant loading. Whether the amount of stabilization and suspension of the glenohumeral joint remains consistent during shoulder abduction is also unclear, since Fibertape tension is reduced due to the position of the upper arm. However, deltoid tension is anatomically reduced in abduction and neither patient

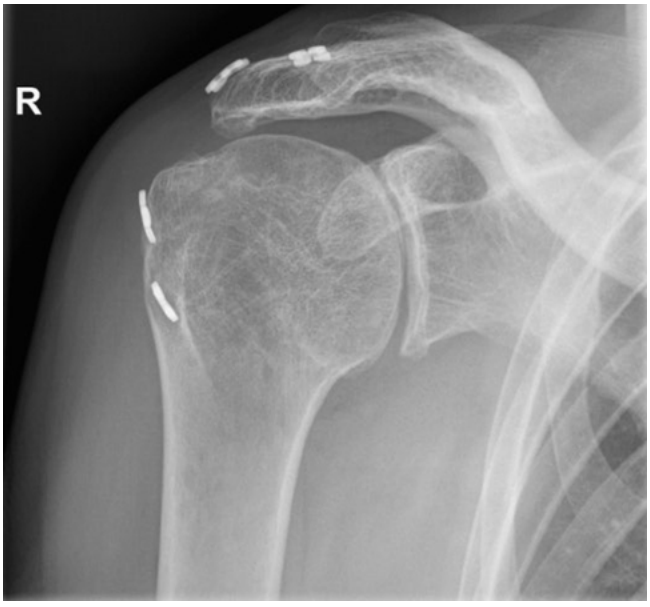

Fig. 3. Anteroposterior X-ray of the right shoulder of patient 1 at postoperative 5 years.

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mentioned a feeling of subluxation during shoulder abduction or flexion. The preliminary outcomes of this new technique are promising; however, more research with a larger study population is needed to identify the short- and long-term results of this technique.

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Current Concept

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Pathogenesis, evaluation, and management of osteolysis after total shoulder arthroplasty

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Radiographic osteolysis after total shoulder arthroplasty (TSA) remains a challenging clinical entity, as it may not initially manifest clinically apparent symptoms but can lead to clinically important complications, such as aseptic loosening. A thorough consideration of medical history and physical examination is essential to rule out other causes of symptomatic TSA—namely, periprosthetic joint infection—as symptoms often progress to vague pain or discomfort due to subtle component loosening. Once confirmed, nonoperative treatment of osteolysis should first be pursued given the potential to avoid surgery-associated risks. If needed, the current surgical options include glenoid polyethylene revision and conversion to reverse shoulder arthroplasty. The current article provides a comprehensive review of the evaluation and management of osteolysis after TSA through an evidence-based discussion of current concepts.

Keywords: Total shoulder arthroplasty; Osteolysis; Complications; Aseptic; Loosening; Shoulder

INTRODUCTION

The annual incidence of primary anatomical and reverse shoulder arthroplasty (RSA) procedures performed in the United States has increased by 103.7% between 2011 to 2017, with the incidence of RSA increasing 191.3% over the same time period [1]. Though reproducible and efficacious procedures for glenohumeral osteoarthritis, rotator cuff arthropathy, and proximal humerus fractures, studies examining the outcomes of both anatomical total shoulder arthroplasty (TSA) and RSA at long-term follow-up report average revision rates of approximately 8%–10% [2-4]. Radiographic osteolysis and glenoid loosening are the most common complications after TSA, accounting for 80% of TSA complications and 7% of revision operations, respectively, while humeral loosening accounts for a much smaller 7% of long-term TSA complications [5]. Therefore, a comprehensive understanding of the mechanisms leading to osteolysis and careful evaluation of patients presenting with osteolysis after TSA is critical.

Gradual osteolysis around the glenoid or humeral components and loosening of either the glenoid or humeral components can result in instability and loss of function [6]. Furthermore, osteol-

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ysis with or without component loosening may be a primary cause of pain, necessitating revision [7]. Therefore, osteolysis around the glenoid or humeral components is not a clinically insignificant entity, as it may lead to additional morbidity and health resource utilization. Despite this knowledge, a comprehensive resource of management options and current concepts in addressing these adverse events is lacking. As such, it is imperative for the most recent literature pertaining to the evaluation and management of osteolysis after TSA to be synthesized and reviewed to better understand the available options for this challenging clinical scenario and optimize patient outcomes.

The purpose of the current article is to present a comprehensive review of the current concepts in the pathogenesis, evaluation, and management of osteolysis after anatomical TSA and RSA. In the first half of this article, the pathogenesis of osteolysis and the evolution in implant design intended to avoid osteolysis are presented. In the second half of this article, we discuss our approach to evaluating and managing osteolysis treatment through an evidence-based analysis of the literature.

This study did not require approval by the institutional review board at the Hospital for Special Surgery. And, consent was not required for any aspects of this study.

PATHOGENESIS OF OSTEOLYSIS

Implant Wear and Immune Response

Implant wear occurs primarily at the articular interface, generating debris that results in the destruction of surrounding tissue secondary to inflammation. The destruction is two-fold: damage to the articulating surface of the prosthesis can be detrimental to implant stability, and the debris generated by implant wear can drive inflammation [8]. Debris may originate from multiple implant compositions, including polyethylene, metal, and cement. Generated debris can then implant on the articular surface of a polyethylene prosthesis, further exacerbating implant wear by enhancing abrasion [9].

Phagocytosis of debris less than twelve 12 μmmicrometers in diameter by macrophages underlies the primary pathogenesis of periprosthetic osteolysis; however, the specific inflammatory response is dictated by the quantity and quality of the particulates regarding size, surface area, and composition. Further, the relative concentration of debris, rather than simply the number of particles, dictates the magnitude of the inflammatory response [10,11]. Macrophage stimulation after debris phagocytosis results in the release of tumor necrosis factor-alpha (TNF-α), interleukin (IL)-1β, and IL-6. TNF-α and IL-6 are catabolic mediators in bone, and IL-1β induces the differentiation of osteoclasts and the production of matrix metalloproteinases that promote bone resorption [11,12]. Polyethylene debris is also associated with complement (CR3) activation, resulting in more macrophage recruitment [13].

Cement debris resulting in larger particulates not amenable to phagocytosis is associated with giant cell recruitment and toll-like receptor (TLR) stimulation, which, in turn, activates the inflammatory nuclear factor kappa-light-chain-enhancer of activated B cells (NF-κB) cascade [14]. The receptor activator of nuclear factor-kappa-B (RANK) and its ligand (RANKL) bind on preosteoclasts, stimulating osteoclastogenesis via the NF-κB transcription factor pathway and, in turn, causing bony resorption. As such, NF-κB is the transcription factor most commonly implicated in osteolysis; it is activated by several mechanisms, including those mediated by TLRs, TNF-α, and IL-1 [15,16]. In summary, periprosthetic osteolysis, characterized by concomitant inflammation, fibrosis, and bony resorption, occurs as an aseptic chronic inflammatory response to intra- and periarticular debris.

Histology

Histologic findings of periprosthetic osteolysis include inflammatory cells (lymphocytes, histiocytes, plasma cells, giant cells, and macrophages), which may contain identifiable particulate debris; clefts containing strongly birefringent polyethylene debris; and scalloped edges where cement has been resorbed. Interestingly, Kepler et al. [9] reported no significant difference in the frequency of polyethylene debris between patients with and without osteolysis after anatomical TSA (62% vs. 67%), indicating that the presence of particles alone is not predictive of osteolysis [9]. In cases of osteolysis in the absence of debris on histologic analysis, the pathogenesis of bone loss is currently unknown.

Detritic synovitis is an inflammatory response to intraarticular debris, which causes more widespread osteolysis beyond the periprosthetic space, resulting in implant loosening or pathologic fracture [17]. Known to cause implant failure in hip, hand, and foot arthroplasty, detritic synovitis leading to osteolysis after anatomical TSA was first described in 2018 [17-19]. Guild et al. [20] described an inflammatory foreign body reaction to polyethylene implant wear resulting in osteolysis; histopathologic analysis found multinucleated giant cell and histiocyte infiltrates and polarizable debris resulting from the destruction of bone and joint tissue. Detritic synovitis and periprosthetic osteolysis share many histological characteristics; however, the scope of their consequences differs given the relative lack of geographic limitation seen in detritic synovitis.

MICROMOTION

High amplitude micromotion increases the abhorrent space between the prosthesis and bone, resulting in fibrous ingrowth [21]. Though the threshold at which micromotion may be of benefit is contested [21-23], the enlarged periprosthetic space seen with higher amplitude micromotion allows for a less coherent bone-implant interface where synovial fluid and wear particles may enter and stimulate inflammation, causing bony resorption, further weakening the bone stock via osteolysis and promoting further implant loosening [24].

Several biomechanical studies have investigated the implications of high amplitude micromotion on the glenoid component in both anatomical TSA and RSA, although *in vivo* analyses are scarce. Sabesan et al. [25] created a biomechanical model to study the influence of increasing glenohumeral implant mismatch on bone-implant interface micromotion. The authors reported that a radial mismatch of greater than 10 mm between glenohumeral components increased the micromotion of an all-polyethylene pegged glenoid component. Bonnevialle et al. [26] reported 20–130 μm of micromotion was found across three separate modern RSA glenoid baseplates, demonstrating that adequate stability was achieved by all models on finite element analysis. Lung et al. [27] found that decreased micromotion of the RSA glenoid baseplate was associated with longer central pegs and longer peripheral screws in general, but no absolute arrangement of screws appears to be superior in optimizing RSA baseplate fixation and decreasing micromotion [28,29]. Chou et al. [30] reported increased micromotion with the use of eccentric glenospheres in RSA when compared to the same-sized concentric design, although eccentric designs were still associated with micromotion amplitudes in the range in which bony ingrowth was possible. Together, these results suggest that, while osteolysis and aseptic glenoid loosening remain the most common reason for failure after anatomical TSA, primary micromotion of the glenoid component is a much less common cause of failure when modern RSA designs are implemented.

NOTCHING

Notching of the inferior border of the scapula was historically a considerable source of osteolysis in RSA, though the development of lateralized glenospheres and increased awareness of the importance of glenoid positioning has decreased the incidence of this phenomenon. Mechanical notching is described as repetitive contact between the humeral implant and scapula, leading to progressive abrasive wear [31]. This wear often leads to biological notching, whereby debris is generated through active osteolysis that may further accelerate notching [32]. With continued notching and osteolysis, catastrophic failure of the glenoid component fixation can occur [33].

Implant Components and Design

Variations in component composition, component positioning, and stem length have been the mainstay approach to reducing implant wear and associated debris, inflammation, and osteolysis. Cemented all-polyethylene glenoid components are associated with 83% or greater survival rates at year 10 of follow-up; however, wear and revision rates vary between polyethylene models [34,35]. Cross-linked polyethylene has been associated with an 85% reduction in wear rates relative to traditional polyethylene components as well as lower revision rates at year 5 of follow-up [36,37]. Metal-backed glenoid components are associated with substantially lower survival rates at long-term follow-up than all-polyethylene glenoid components, with failure attributed to aseptic loosening in the all-polyethylene group and rotator cuff insufficiency and instability in the metal-backed group [38]. Hybrid glenoid implants, which feature porous metal central posts and no metal backing to the glenoid surface, have not been associated with significant differences in complication rates at year 3 of follow-up relative to all-polyethylene implants [39]. Friedman et al. [40] report that the hybrid glenoid component is superior to the all-polyethylene implants with regard to 3-year revision rates, though longer-term investigations on the longevity of these implants are still needed.

Research investigating the means to reduce osteolysis surrounding humeral implants has largely focused on stem length and implant composition. Bell et al. [41] demonstrated decreased rates of radiolucent lines and humeral osteolysis in stemless ceramic humeral components when compared to long-stem metal-head alternatives. Long-stem designs are associated with stress shielding of the proximal humeral metaphysis, resulting in increased bone resorption, while the opposite is true for stemless humeral component designs. Indeed, stemless designs have been demonstrated to better mimic intact bone [42,43]. Investigations of humeral implant composition have demonstrated a decreased wear rate associated with ceramic humeral heads when compared to metallic components [44].

CLINICAL EVALUATION

History and Physical Exam

Comprehensive postoperative follow-up and physical evaluation should be performed in the setting of new-onset pain following

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TSA regardless of the time from the index procedure. The most sensitive indicator of osteolysis following TSA is new-onset or persistent pain [9]. However, postoperative pain is non-specific and should prompt a comprehensive evaluation of other etiologies. Other considerations that may induce pain after TSA include periprosthetic infection, periprosthetic fracture, stiffness, rotator cuff pathology, heterotopic ossification, bursitis, and malalignment. It should be determined whether the pain is associated with weakness or decreased motion, as this may leverage insight into additional shoulder stabilizer involvement and displacement of the glenoid or humeral components.

Importantly, the timing, quality, responsiveness, location, and duration of symptoms can provide more insight into the potential pathology. For example, pain secondary to glenoid or humeral osteolysis is generally experienced when sleeping or first initiating movement (start-up pain) of the shoulder and is diffuse in nature, whereas well-localized pain over the posterosuperior aspect of the shoulder may represent an acromial stress fracture. Pain in the proximal part of the upper extremity can indicate humeral component loosening. Patients should also be asked about wound issues and drainage after the index surgery, as this may elevate indolent infection as a cause of symptoms. Concern for possible osteolysis and aseptic loosening should be raised for patients who report years of symptom-free shoulder function postoperatively followed by new-onset pain or reduced function.

The physical exam should be performed systematically and include inspection, palpation, range of motion, strength, and provocative maneuvers where appropriate. Specifically, the surgical incision and skin around the shoulder should be assessed. The presence of effusion, erythema, or swelling may indicate chronic inflammation or infection. Diffuse tenderness to palpation around all areas of the shoulder in the absence of other findings may signify a chronic pain syndrome.

The extent of passive and active range of motion should be assessed, with particular attention directed towards instability, impingement, or pain along short arcs of motion. Patients with osteolysis that begin to experience early subsidence may experience loss of function. Atrophy or deformity in the setting of a primary anatomical TSA may suggest compromise of the rotator cuff. Finally, a thorough neurovascular exam should be assessed to rule out neurovascular compromise as the etiology of pain and dysfunction.

Though osteolysis is characteristically a chronic process associated with night or start-up pain, it is notable that early osteolysis may manifest non-characteristic symptoms. Therefore, in the setting of painful TSA, early osteolysis should still be considered with a thorough evaluation of routine radiographic imaging. Indeed, early osteolysis that is rapidly progressive without identification and treatment can result in glenoid loosening, subsidence, and early failure.

In all scenarios where a patient presents with a painful TSA, standard laboratory testing including complete blood count, erythrocyte sedimentation rate, and C-reactive protein measurement should be obtained. If these raise suspicion for infection, such as if the synovial leukocyte count exceeds 2,000 and is composed of at least 70% polymorphonuclear leukocytes [45], an ultrasound-guided shoulder aspiration is warranted. However, in cases with a high index of suspicion for infection but negative laboratory and aspiration work-up, arthroscopic or open tissue biopsy is considered a gold standard diagnostic tool for infection. If periprosthetic joint infection has been ruled out, osteolysis and aseptic loosening then rise among the differential diagnoses as the culprit of shoulder pain [46].

Radiographic Evaluation

Postoperative radiographs are the first-line imaging modality to evaluate for osteolysis in the proximity of either the glenoid or humeral components. Standard views of the shoulder, including anteroposterior, Grashey, lateral, and axillary views, should be obtained. The examiner should evaluate radiographs for radiolucencies and stress shielding adjacent to the glenoid and humeral components. Comparison to prior radiographs should be made when available, particularly when monitoring the progression of previously diagnosed osteolysis. The examiner may observe implant loosening, malpositioning, or subsidence. Particular attention should be focused on the location of the humeral head, as proximal migration may indicate a supraspinatus tear, and anterior displacement may suggest a tear of the subscapularis.

In non-cemented humeral components, radiolucent lines often occur at the tip of the prosthesis, whereas radiolucencies commonly develop along the proximal and midbody aspects of the stem in cemented humeral components. In some smaller series with 10 years of follow-up, over 50% of patients developed radiolucencies, most often in association with glenoid wear and polyethylene debris [47]. However, the clinical significance of osteolysis remains unclear in certain populations, as asymptomatic patients with osteolysis do not always require a revision procedure [48].

It also appears that the choice of humeral fixation technique is not associated with osteolysis on radiographs. A recent randomized controlled trial with a mean 38-month follow-up period reported a 0.74% incidence of radiolucencies ≥2 mm in three or more zones, which did not significantly differ between cemented and non-cemented humeral component cohorts [49]. Scapular

notching may be a more obvious finding of progressive osteolysis. In a 10-year follow-up study of patients treated with a Grammont-style RSA, 73% of patients developed scapular notching on radiographs, with 12% having undergone revision surgery [50].

Unfortunately, radiolucent lines on plain radiographs do not always reliably diagnose loosening, particularly during long-term follow-up, as some series report the presence of radiolucent lines in up to 80% of radiographs at 10 years of follow-up [51]. Therefore, it may be more appropriate to evaluate radiolucent line progression over time, as opposed to making a definitive plan of care based on a single observation. Advanced imaging appears to be more sensitive than radiography at detecting radiolucency. Recent studies have demonstrated that the reliability of computed tomography (CT)-based assessments of radiolucencies is three times higher than that of radiographs, and up to 40% of radiolucent lines and 74% of osteolysis cases not observed on radiographs are detectable by CT [51,52].

In cases of osteolysis following RSA, notching of the polyethylene liner against the inferior border of the scapula should be assessed. This mechanical impingement can potentially lead to a high level of particulate debris, leading to osteolysis in both the glenoid and the humerus. In severe cases, significant osteolysis can occur at the inferior glenoid, directly affecting baseplate fixation. In the evaluation of osteolysis after RSA, component malposition should be recognized early and potentially revised to prevent further osteolysis.

TREATMENT OPTIONS AND CLINICAL OUTCOMES

It is important to remember that osteolysis is a biological phenomenon rather than a clinical condition. Osteolysis, in and of itself, is frequently an asymptomatic finding identified in routine postoperative imaging. For patients without clinical symptoms who present with imaging findings of mild osteolysis, nonoperative management with close follow-up is appropriate. Serial clinical and radiographic evaluations are recommended to identify the early development of symptoms and radiographic evidence of osteolysis progression or implant loosening.

Surgical management of osteolysis is reserved for patients who manifest clinical symptoms directly attributable to osteolysis and aseptic loosening, such as pain, dysfunction, or shoulder instability, in the absence of an active or indolent infection. A particular treatment strategy must consider (1) the size, location, and chronicity of osteolysis; (2) the suspected source of loosening (i.e., glenoid vs. humeral component, as well as component malpositioning); (3) the patient's primary subjective complaint; and (4) the patient's functional status. The task of identifying an appropriate treatment is made challenging by the paucity of high-level, direct comparative studies of available treatment options. Given that the existing surgical treatments vary in invasiveness and the anticipated duration of recovery and that revision shoulder arthroplasty outcomes are generally inferior to the outcomes of primary arthroplasty, a shared decision-making process is essential to ensure that the chosen intervention matches the patient's goals and expectations (Fig. 1).

Management of Osteolysis and Aseptic Loosening Following Anatomical TSA

For patients with symptomatic osteolysis and evidence of glenoid loosening following anatomical TSA or RSA, nonoperative treatment is generally reserved only for patients that are poor surgical candidates and medically unfit for surgery. This approach relies on secondary stabilizers to maintain the functional integrity of the shoulder. To solidify the surrounding soft tissue architecture, nonoperative treatment consists of a 4–6-week period of sling immobilization during which active and passive range of motion are deferred. Whereas all surgical treatment options to be discussed in this article carry a significant risk for complications, non-surgical management mitigates the risk of surgery-related complications. In a retrospective analysis of 79 patients diagnosed with aseptic glenoid loosening following RSA, Lädermann et al. [53] demonstrated that a sub-group of 29 shoulders treated nonoperatively had similar clinical improvements and fewer associated complications compared to a group of 27 shoulders that underwent revision. Furthermore, in similar cohorts of patients, nonoperative treatment resulted in better clinical outcome scores than revision to hemiarthroplasty.

Arthroscopic Glenoid Polyethylene Removal

In postoperative anatomical TSA patients with isolated aseptic glenoid loosening and suspected infection, arthroscopic removal of the polyethylene glenoid component offers an appealing surgical option [54,55]. Given the high suspicion for periprosthetic infection and concurrent difficulty in diagnosing indolent *Cutibacterium acnes* infection in this clinical scenario, an arthroscopic procedure enables the clinician to obtain intraoperative tissue samples to aid in diagnosis while performing a minimally-invasive glenoid resection that may provide significant symptomatic relief. Removal of the polyethylene component reduces debris created by contact between the glenoid component and the adjacent metal and bone [54]. To address cavitary bone defects caused by prior osteolysis, bone graft, in the form of corticocancellous bone chips, can be introduced arthroscopically through

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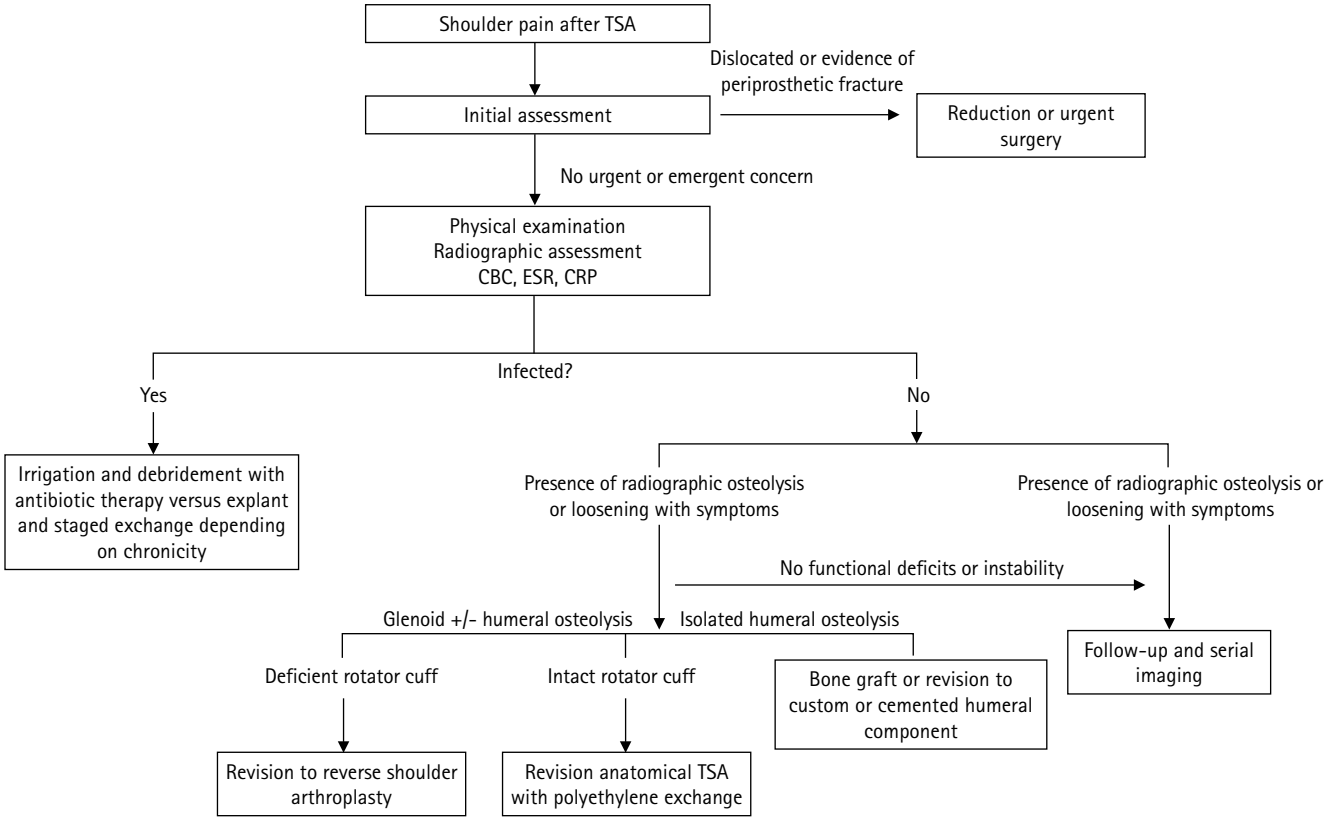

Fig. 1. Proposed treatment algorithm for the evaluation and management of patients with osteolysis after total shoulder arthroplasty (TSA). CBC: complete blood count, ESR: erythrocyte sedimentation rate, CRP: C-reactive protein.

an enlarged anterosuperior portal and tamped into the glenoid cavity until the void is filled [56]. The use of a human dermal allograft patch has been described to help contain the bone graft within the defect [56]. Clinical outcome data regarding dermal allograft procedures have yet to be published. However, the available literature supports the use of isolated arthroscopic glenoid resection. Indeed, a cohort of 15 patients who underwent glenoid component resection with or without bone grafting had comparable pain relief and satisfaction at 2 years postoperatively in comparison to patients that underwent glenoid reimplantation [57]. Given that the authors noted a selection bias in that lower-demand patients were more likely to undergo an isolated glenoid component resection, further evidence is needed to delineate the optimal patient characteristics for this intervention. Nonetheless, in patients whose clinical presentation remains concerning but non-diagnostic for infection, an arthroscopic glenoid component resection with tissue culture procurement is a reasonable temporizing option.

Revision TSA with Polyethylene Glenoid Reimplantation

Another commonly employed surgical treatment option for aseptic glenoid loosening following anatomical TSA is revision anatomical TSA with reimplantation of another polyethylene glenoid [58]. The greater potential shoulder range of motion conferred by an anatomical TSA, in comparison to that of an RSA, has made this an enticing revision option, particularly in younger patients [59,60]. In an early report of outcomes from this intervention, Cheung et al. [61] compared 33 shoulders with glenoid reimplantation to 35 shoulders with glenoid implant removal and bone grafting. Five-year postoperative outcome data demonstrated a 91% reoperation-free survival and higher satisfaction in patients that underwent reimplantation compared to those that underwent implant removal and bone grafting. However, in subsequent work, the authors conceded that these findings might have been confounded by the inclusion of infected arthroplasty cases in their analysis [62]. Subsequent studies have demonstrated that revision anatomical TSA indicated for glenoid loosening has been fraught with complications. In one analysis of 42 patients with symptomatic glenoid loosening following a primary anatomical TSA who underwent an isolated glenoid exchange, 67% of patients had recurrence of glenoid loosening, and 17% required reoperation at approximately year 6 of follow-up [63]. Sheth et al. [64] corroborated the disappointing results of revision anatomical TSA in a cohort of 20 patients, reporting that

35% required reoperation within 3 years of revision surgery. The poor clinical outcomes and increased complications associated with revision anatomical TSA and isolated glenoid component exchange make its contemporary use in the current treatment of glenoid component loosening relatively minimal.

Conversion to RSA

In the setting of a failed anatomical TSA due to osteolysis or glenoid component loosening, conversion to RSA affords several advantages over revision anatomical TSA (Fig. 2). Whereas anatomical TSA requires an intact and functioning rotator cuff for optimal outcomes, RSA outcomes can be satisfactory even with rotator cuff deficiency, which is often present in patients undergoing revision shoulder arthroplasty [65]. Second, on the glenoid side, RSA allows for both stronger fixation with screws and posts, as well as bony ingrowth for greater potential implant longevity [65]. Third, RSA allows the surgeon to not only address the aforementioned bone loss with the increasing popularity of augmented baseplates [66]. The available clinical evidence bores out these advantages. A multicenter study of 37 anatomical TSAs revised to RSA for aseptic glenoid loosening demonstrated an 86% patient satisfaction rate at approximately year 4 of follow-up [67]. The authors reported a 21% reoperation rate and, therefore, cautioned that, despite a high satisfaction rate, patients must be counseled on the elevated risks of reoperation compared with an index operation. Currently, RSA affords the most predictable surgical solution for symptomatic aseptic loosening and osteolysis following shoulder arthroplasty. Further elucidation of optimal patient candidates and long-term clinical outcomes of RSA used in this setting are needed.

Osteolysis Involving the Humeral Component

Humeral component loosening secondary to osteolysis surrounding the humeral implant is exceedingly rare. In a radiographic study of 395 shoulders that previously underwent either hemiarthroplasty or total arthroplasty, 43% of shoulders demonstrated evidence of osteolysis at either the greater tuberosity or calcar [48]. Despite this, humeral component loosening was not observed in any of the uncemented stems, and only one cemented stem was deemed to be at risk for humeral loosening based on the morphology of radiolucent lines surrounding the implant. In the single published case series on the management of humeral component aseptic loosening, Cil et al. [68] reported on 38 cases over a nearly 30-year period. The authors used cancellous bone grafting to treat contained proximal humerus osteolysis in approximately one-third of cases. Due to more extensive bone loss, custom humeral stem implants were employed in two cases. At revision, cement humeral fixation was utilized in approximately 75% of cases. Some authors postulate that the expanded use of stemless humeral implants in shoulder arthroplasty will further minimize the risk of proximal humerus osteolysis; however, further studies are needed to evaluate the impact of stemless humeral designs [69].

Management of Osteolysis and Aseptic Loosening Following RSA

There are limited data available to guide clinicians in the management of aseptic glenoid loosening following RSA. As mentioned, nonoperative treatment should be pursued as a first-line treatment option in minimally symptomatic patients. For patients unable to tolerate nonoperative management, glenoid loos-

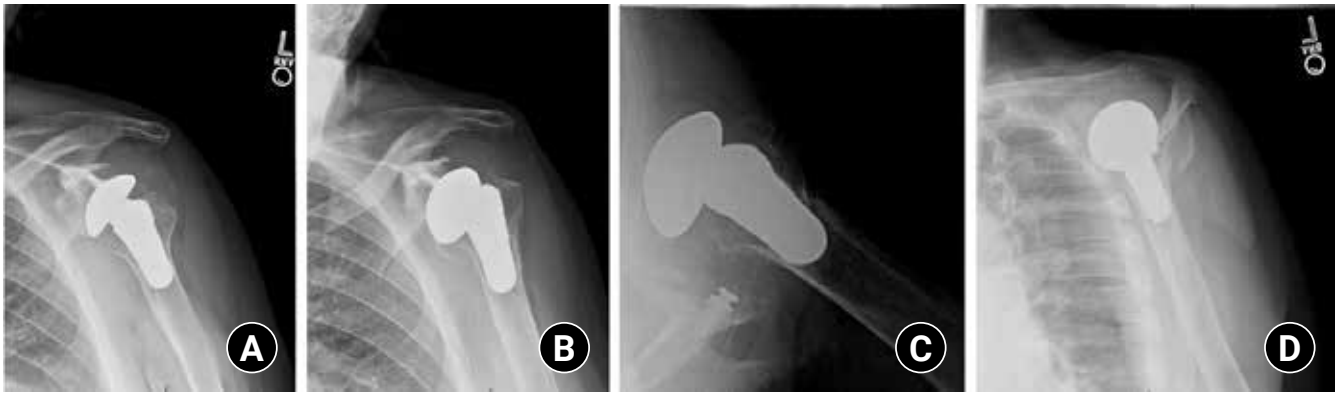

Fig. 2. Eighty-year-old male with a prior surgical history of left anatomical total shoulder arthroplasty (TSA) at an outside hospital in 2018 who presented with 3 years of increasing left shoulder pain and discomfort, especially with physical activity. Physical examination demonstrated the skin over the left shoulder to be intact, and a well-healed surgical incision was observed. The range of motion was 80° of forward flexion, 45° external rotation, and internal rotation to the L4 vertebrae. (A) Internal rotation, (B) external rotation, and (C) axillary, and (D) outlet radiographs at this time demonstrated a previous anatomical TSA with chronic bony remodeling of the glenoid and anterior dislocation of the humeral component with associated proximal humeral osteolysis. The patient was indicated to undergo conversion to an reverse shoulder arthroplasty.

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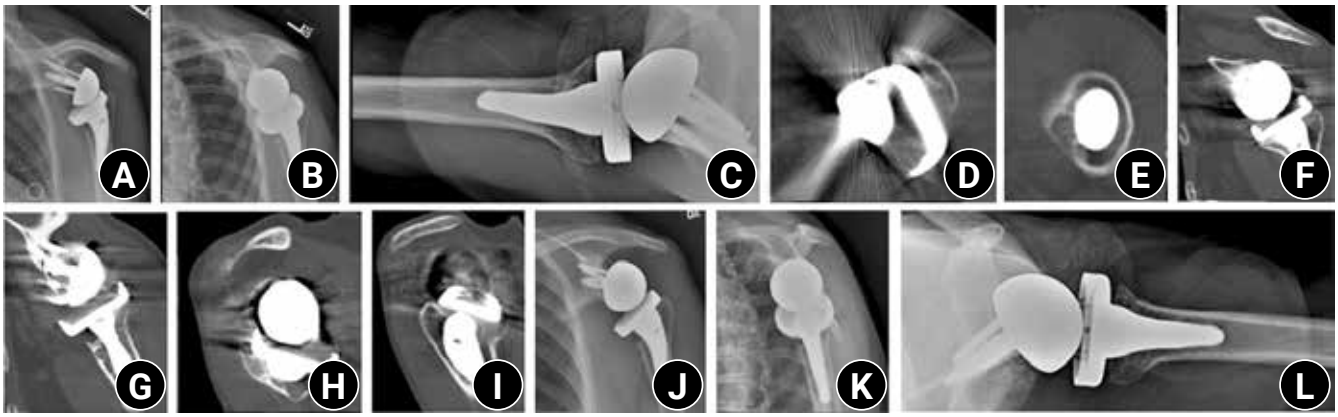

Fig. 3. Eighty-two-year-old healthy female with prior surgical history of a left reverse shoulder arthroplasty (RSA) at an outside hospital on September 24, 2017, and subsequent right RSA at an outside hospital on May 30, 2018, who presented with a chief complaint of left shoulder pain. She stated that the pain began 2 weeks prior to evaluation after being pulled by her dog while holding its leash. She localized the pain to the anterior aspect of the shoulder without radiation. Upon physical exam, the skin over the left shoulder was intact, and a well-healed surgical incision was noted. The range of motion was 140° of forward flexion, 45° of external rotation, and internal rotation to the L1 vertebrae. (A-C) Anteroposterior (A), internal rotation (B), and axillary (C) radiographs at that time demonstrated radiolucencies around the humeral stem and the glenoid baseplate. Though osteolysis was suspected, the decision was made to first rule out low-grade infection and further evaluate the shoulder with a computed tomography (CT) scan. Her erythrocyte sedimentation rate was 6 mm/hr, C-reactive protein level was 0.6 mg/L, and her white blood cell count was 6.8/nL which were not concerning for infection. (D-I) Evaluation of this CT scan on axial (D, E), coronal (F, G), and sagittal (H, I) views demonstrated two separate radiolucencies around the medial aspect of the proximal humeral component, which were concerning for osteolysis with aseptic loosening. On March 9, 2021, the patient underwent revision RSA with a Tornier Ascend Flex lateralized 36 glenosphere and +6 poly with centered 0 tray. (J-L) At 8-week postoperation, she was noted to be recovering well with forward flexion to 130°, external rotation to 30°, and acceptable component positioning on anteroposterior (J), internal rotation (K), and axillary (L) views.

ening should be treated with revision of the glenosphere. Lädermann et al. [53] reviewed 79 patients treated for aseptic glenoid loosening. Among this cohort, patients treated nonoperatively, and those treated with glenoid revision experienced similar improvements in pain, range of motion, and clinical outcomes scores at a minimum 2-year follow-up. As the number of RSA procedures continues to grow, so too will our collective experience with managing its associated complications, including osteolysis and aseptic loosening. A select example demonstrating our institutional experience with the management of osteolysis after RSA is described in Fig. 3.

CONCLUSION

Osteolysis following primary TSA is a challenging clinical entity that causes up to 80% of complications. The pathogenesis of osteolysis is a macrophage-mediated response to debris from the TSA construct that is further facilitated by micromotion. A thorough history and physical examination are essential to rule out other causes of symptomatic TSA—namely, periprosthetic joint infection. Though radiographs remain the gold standard imaging modality in this setting, they remain insensitive for detecting radiolucent lines and early osteolysis, with limited evidence suggesting that CT may be a more efficacious modality for diagnosis. Once confirmed, nonoperative treatment of osteolysis should first be pursued given the potential to avoid surgery-associated risks, and limited data suggesting outcomes may be similar to that of reoperations. Current options for reoperations include glenoid polyethylene revision and conversion to RSA. Future studies are warranted to better define the indications and long-term outcomes of these procedures, though RSA currently appears to be the most reliable option given the evidence available.

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CiSE
Clinics in Shoulder and Elbow

Instructions to authors

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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.

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

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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.

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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.

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ICiSE 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.

- Clinical Trials: CiSE accepts the ICMJE Recommendations for data sharing statement policy. Authors may refer to the editorial, "Data Sharing statements for Clinical Trials: A Requirement of the International Committee of Medical Journal Editors," in the Journal of Korean Medical Science (https://dx.doi.org/10.3346/jkms.2017.32.7.1051).

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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.

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 control 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 Aabstract 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.
- Systematic 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.
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- 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 contin-

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: $^{a)}$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 ICMJE Recommendations (https://www.nlm.nih.gov/bsd/uniform_requirements.html).
- Examples of references are as follows:

Journal article

1. Kim IB, Kim EY, Lim KP, Heo KS, Does the use of injectable atelocollagen during arthroscopic rotator cuff repair improve clinical and structural outcomes? Clin Shoulder Elbow 2019;22:183-9.
2. Kovacevic D, Fox AJ, Bedi A, et al. Calcium-phosphate matrix with or without TGF-β3 improves tendon-bone healing after rotator cuff repair. Am J Sports Med 2011;39:811-9.
3. Nord KD, Masterson JP, Mauck BM. Superior labrum anterior posterior (SLAP) repair using the Neviaser portal. Arthroscopy 2004;20 Suppl 2:129-33.
4. Rohner E, Jacob B, Bohle S, et al. Sodium hypochlorite is more effective than chlorhexidine for eradication of bacterial biofilm of staphylococci and Pseudomonas aeruginosa. Knee Surg Sports Traumatol Arthrosc 2020 Feb 7 [Epub]. https://doi.org/10.1007/s00167-020-05887-9

Book & book chapter

5. Iannotti JP, Williams Jr GR. Disorders of the shoulder: diagnosis & management. 2nd ed. Philadelphia, PA: Lippincott Williams & Wilkins; 2007. p. 66-80
6. Provencher MP, LeClere LE, Van Thiel GS, et al. Posterior instability of the shoulder. In: Angelo RL, Esch JC, Ryu RK, eds. AANA advanced arthroscopy the shoulder. Philadelphia, PA: Saunders; 2010. p. 115-23.

Website

7. American Cancer Society. Cancer facts & figures 2020 [Internet]. Atlanta, GA: American Cancer Society; c2020 [cited 2020

Feb 5]. Available from: https://www.cancer.org/research/cancer-facts-statistics/all-cancer-facts-figures/cancer-facts-figures-2020.html.

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.

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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

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

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