



Risk factors for eccentric glenoid wear after humeral head replacement for cuff tear arthropathy

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Background: In our previous report, glenoid wear (GW) after humeral head replacement for cuff tear arthropathy was classified with modified Goya's classification (grade 0–3), and, among 3 subtypes of grade 3 (glenoid bone erosion), grade 3B (superior eccentric erosion) showed significantly more pain and limited active flexion postoperatively compared to grade 3C (concentric erosion). The purpose of this study was to detect individual risk factors for the progression to grade 3B GW.

Methods: Seventy-nine shoulders in 70 patients who were followed up for a mean of 8.2 years (range, 5.0–13.2 years), including 29 men and 41 women, with a mean age at the surgery of 71.1 years (range, 54–87 years), were reviewed. Atrophy and fatty degeneration of torn cuff muscle, preoperative humeral head displacement (superior translation ratio [STR], anterior translation ratio, and other several parameters) on preoperative magnetic resonance imaging, and other individual factors were analyzed as possible risk factors.

Results: GW at the final follow-up was grade 0: 5 shoulders, grade 1: 17, grade 2: 20, and grade 3: 37 (3A: 4, 3B: 22, and 3C: 11). Preoperative higher STR was defined as a risk factor for grade 3 GW (odds ratio, 35.5; 95% confidence interval, 1.8–693.0; $P = .018$). Comparison among the three subtypes of grade 3 showed that patients with grade 3B GW had larger STR than 3C ($41.4 \pm 14.2\%$ vs. $23.5 \pm 13.3\%$ $P = .006$).

Conclusion: Patients with preoperative high STR are considered to have a risk for grade 3B GW, which possibly relates to poor clinical outcome and future revision.

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Despite the popularity of reverse shoulder arthroplasty (RSA) for the treatment of cuff tear arthropathy (CTA), several long-term follow-up studies after RSA have pointed out a gradual decline in shoulder function, exacerbation of pain,^{8,23} high complication rates,^{1,4,29} and the difficulty in revision surgery after failed RSA.^{1,12} Therefore, RSA must be considered as a final salvage surgery.

Humeral head replacement (HHR) using a small-diameter head with rotator cuff reconstruction has been reported as a useful treatment option for CTA in young and older selected patients,^{7,19,26} considering the lower complication and revision rates compared to those associated with RSA.¹⁹ A previous multicenter study reported that patients experienced satisfactory pain relief and recovery of

reasonable shoulder function after revision RSA from failed HHR¹⁸; therefore, RSA can be considered a salvage surgery after HHR.

Glenoid wear (GW) is a possible complication in the long-term follow-up after HHR and has been reported as one of the major reasons for revision surgery.^{5,9,15} However, we often encounter cases with concentric erosion that have progressive pain but maintain good range of motion (ROM) for flexion and with relief of the pain later in the clinical course. On the other hand, some cases show eccentric erosion and subsequently require revision surgery due to continuous pain. Levine et al¹⁵ reported a cohort of patients undergoing HHR for glenohumeral arthritis, classifying patients into those with concentric GW and those with nonconcentric GW and found that patients with posterior, nonconcentric glenoid erosion had a 63% satisfaction rate compared with 86% in the concentric glenoid erosion group, similar to grade 3C in our results.¹⁴ In a previous report, the pattern of GW that progressed to glenoid bone erosion (grade 3 in our classification) after HHR in detail,¹⁵ and grade 3 GW was classified into three subtypes (Fig. 1). Investigation of grade 3 GW subtypes revealed that 3B had

The institutional review board of Hokushin Hospital approved this study (Study No. 1803).

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significantly more pain and limited active flexion than 3C.¹⁴ This result suggests that more careful follow-up is required for grade 3B cases that tend to have severe pain and limited flexion ROM, as compared to grade 3C cases, which may have less pain and maintain good ROM. However, the risk factors of 3B GW remain unclear. Since the prevention of revision surgery is desirable, it is important to identify the risk factors for the progression of 3B GW. If the relationship between the clinical results and risk factors for GW is clarified, HHR will become a more useful therapeutic option for CTA in patient selection and prognostic prediction.

The purpose of this study was to evaluate GW in patients with CTA who were followed-up for 5 years or more after HHR using a modified classification of GW and to detect individual risk factors for progression to 3B GW.

Material and methods

This retrospective cohort study was conducted to assess GW in patients after HHR for CTA. In all cases, surgeries had been performed because of intractable pain and functional disability secondary to CTA. All patients agreed to participate, and ethical approval was obtained from the institutional review board of Hokushin Hospital (Study No. 1803). Between 2007 and 2016, 142 hemiarthroplasties were performed at our hospital and related facilities. Of these, 79 shoulders in 70 patients were reviewed; 61 shoulders were excluded because they met one of the following exclusion criteria: severe complications unrelated to shoulder surgery, death, or follow-up <5 years. Two patients underwent revision surgery during their clinical course. One patient with grade 3B GW¹⁴ underwent revision anatomical TSA 16 months postoperatively because of pain and functional restriction due to progressive GW. Another patient with grade 1 GW also underwent revision TSA 27 months postoperatively due to pain. These patients were excluded from subsequent evaluations.

The 70 patients enrolled included 29 men and 41 women with a mean age of 71.1 years (range, 54–87 years). The surgeries were performed by three surgeons (N.S., N.O., and N.M.) who had at least 20 years of experience in shoulder surgery. Global Advantage (DePuy, Raynham, MA, USA) was used in 54 shoulders, Comprehensive Shoulder System (AIMM34; Zimmer Biomet, Warsaw, IN, USA) in 13, Trabecular Metal Shoulder System (Zimmer Biomet, Warsaw, IN, USA) in 1, SMR (Lima, San Daniele, Italy) in 1, and Global Unite (DePuy, Raynham, MA, USA) in 10. Rotator cuff reconstruction using tendon transfers according to the cuff defect was performed in all cases. Partial subscapularis transfer was added in 74 shoulders, pectoralis major tendon transfer was performed in 5 shoulders of the anterosuperior cuff defect, anterior transfer of the latissimus dorsi and teres major (LD/TMj) tendons were performed in 2 shoulders of irreparable subscapularis tendon tear, and posterosuperior transfer of the LD/TMj tendons was performed in 14 shoulders of the posterior cuff defect with a positive external rotation lag sign.

Surgical technique

All procedures were performed with the patients in the beach chair position under general anesthesia and with an interscalene brachial plexus block. A superior deltoid splitting approach and deltopectoral approach, if necessary, were employed. The humeral stem was inserted with 40° retroversion, which is larger than the normal retroversion, to prevent the anterosuperior escape of the humeral head. Typically, the size of the humeral head was chosen to be one size smaller and thinner than the original resected humeral head. The final decision regarding the size of the prosthesis was determined by checking the inferior and anteroposterior laxity of

the glenohumeral joint and coverage of the resected surface of the humeral neck during surgery.

Direct repair of the rotator cuff was impossible in all cases, even when using a small HHR; hence, various tendon transfers were performed to reconstruct the rotator cuff tendon based on the tendon defect. In cases where the supraspinatus and infraspinatus tendons were torn, and the subscapularis and teres minor tendons remained intact, two-thirds of the superior aspect of the subscapularis tendon was subperiosteally detached and transferred anterosuperiorly to the cuff defect (modified Cofield's procedure).

If the anterior portion of the rotator cuff (including the subscapularis tendon) was deficient, the LD/TMj tendon was transferred to the lesser tuberosity to cover the defect. If the anterosuperior portion of the rotator cuff was deficient, a pectoralis major tendon was transferred to cover the defect by passing the pars sternocostalis of the pectoralis major tendon under the conjoined tendon. If the posterosuperior portion of the rotator cuff (including the teres minor) was deficient and external rotation reconstruction was necessary, LD/TMj tendon transfers were performed via the axillary approach by suturing the LD/TMj tendons to the remaining tendons and the greater tuberosity. No biologic resurfacing or glenoid reaming was performed in all patients.

Postoperative treatment

Each patient used an abduction pillow for 8 weeks postoperatively. Active elevation in the sitting position was permitted after 10 weeks, and isometric cuff exercises were initiated after 12 weeks. Patients were allowed to resume heavy work or sports if sufficient muscle strength was evident 6 months postoperatively.²⁶

Evaluation and analysis

Patients were regularly monitored for a mean of 8.2 years (range, 5.0–13.2 years). GW was evaluated by serial plane shoulder radiography in true anteroposterior and axillary views at the early postoperative period, at 2 years postoperatively, and at the final follow-up. GW was classified using a modified Goya's classification^{7,14} (Fig. 1) as grade 0: absence of remarkable postoperative changes compared with the preoperative glenoid, grade 1: postoperative glenohumeral joint space narrower than the preoperative glenohumeral joint space because of glenoid cartilage wear, although with no contact between the glenoid and humeral head prosthesis, grade 2: contact between the glenoid and humeral head prosthesis with no glenoid erosion, and grade 3: the presence of glenoid erosion. Grade 3 cases were classified into three subtypes as reported in a previous study¹⁴ as 3A: partial erosion of the anterior glenoid, identified by wear located in the anterior one-third portion of the glenoid in axial views, 3B: partial erosion of the superior part of the glenoid, with wear located in the superior one-third portion of the glenoid, and 3C: concentric erosion of the glenoid (Fig. 1).

Several factors were analyzed as possible risk factors for the progression of GW to grade 3, including (1) age, (2) sex, (3) preoperative ROM (active flexion and external rotation), (4) preoperative pain by Constant-Murley Score, (5) atrophy of torn cuff muscle according to Yamaguchi's classification,²⁸ (6) fatty degeneration of cuff muscle according to Goutallier's classification (average grade four rotator cuff), (7) added muscle tendon transfer (except anterior translation of LD/TMj because of its small number of cases), (8) degree of humeral head displacement by acromiohumeral interval,³ Oizumi's classification²⁰ (Fig. 2A), superior translation ratio (STR), and anterior translation ratio (ATR), which were all measured on preoperative magnetic resonance imaging (MRI) (Fig. 2B and C). Acromiohumeral interval was measured as the narrowest part of the subacromial space (Fig. 2B, length A). To measure STR in a

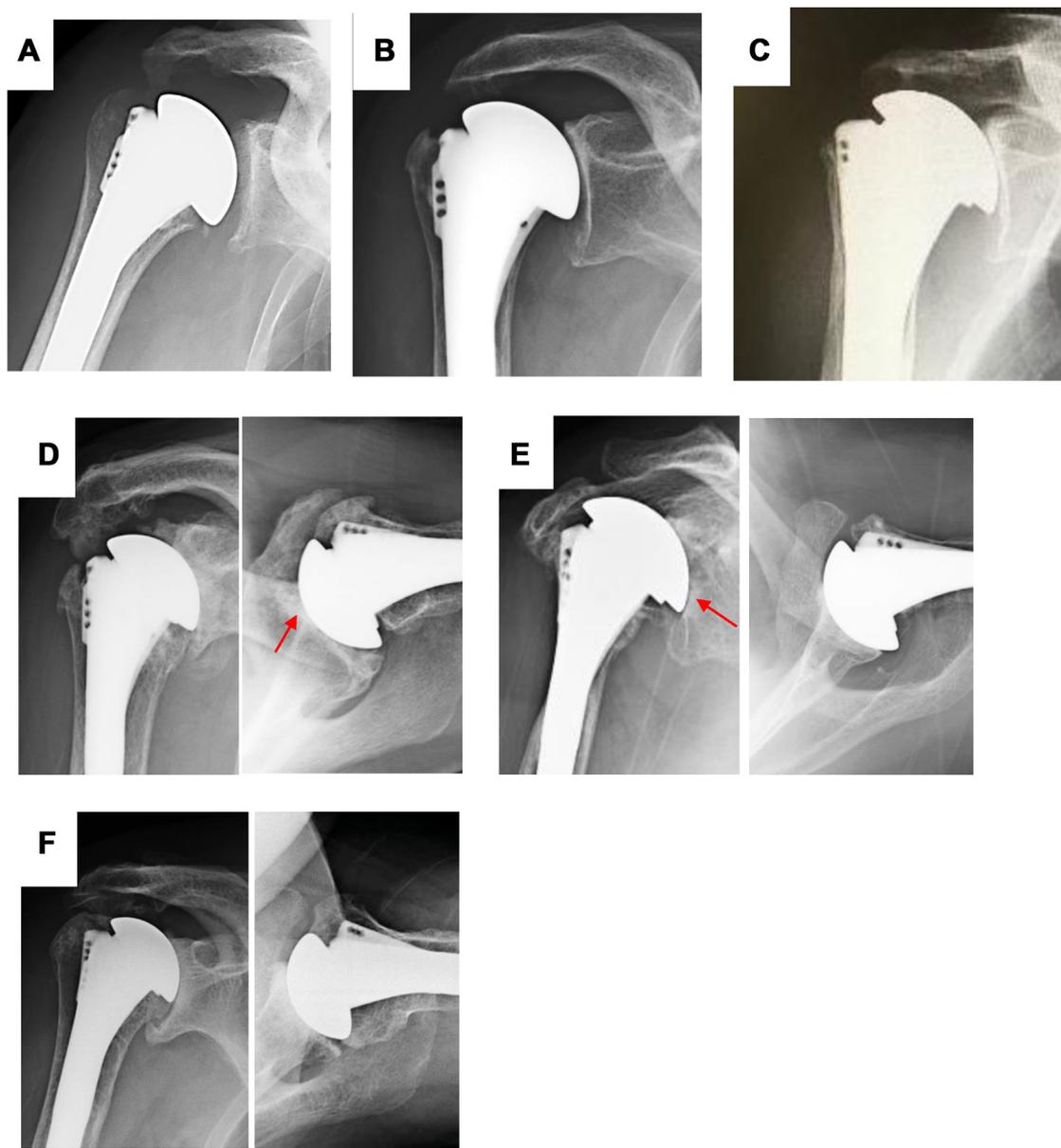


Figure 1 Modified Goya's classification, (A) Grade 0: absence of remarkable postoperative changes compared with the preoperative glenoid; (B) Grade 1: the postoperative glenohumeral joint space was narrower than the preoperative glenohumeral joint space because of glenoid cartilage wear, although there was no contact between the glenoid and humeral head prosthesis; (C) Grade 2: the presence of contact between the glenoid and humeral head prosthesis, although with no glenoid erosion; (D, E, F) Grade 3: the presence of glenoid erosion. Grade 3 cases were classified into three subtypes: (D) 3A: partial erosion of the anterior glenoid; (E) 3B: partial erosion of the superior part of the glenoid; (F) 3C: concentric erosion of the glenoid.

coronal MRI image, length B was defined as the distance between the superior and inferior edges of the glenoid. Length C was defined as the distance between the inferior edges of the glenoid and the inferior corner of the articular surface. STR was defined as the ratio of C to B. To measure ATR in an axial MRI image, the length of line D was defined as the distance between the anterior and posterior edges of the glenoid. Reference line G was drawn vertically to line D through the central point of D. Point H was at the center of the humeral head. The length E was defined as the distance between point H and line G. ATR was defined as the ratio of E to D (Fig. 2C). ATR and STR were measured in the slice that showed the most central point of the glenoid and humeral head. If their central points were not shown in the same slice, each point was translated to another slice, and the distances were measured correctly.

Univariate and multivariate analyses of these factors between groups 0-2 (including grades 0, 1, and 2 shoulders) and group 3 (grade 3 shoulders) were performed to detect individual risk factors for grade 3 GW. Univariate analysis between the three grade 3 subtypes was also performed to detect risk factors for grade 3B GW, previously described as related to poor clinical outcome.¹⁵

Statistics

The Mann–Whitney U test was used to evaluate quantitative data, and Fisher's exact probability test was used for categorical data. Logistic regression analysis was used to compare groups 0-2 and 3 to identify the true association between individual factors. Logistic regression analysis was performed using variables with

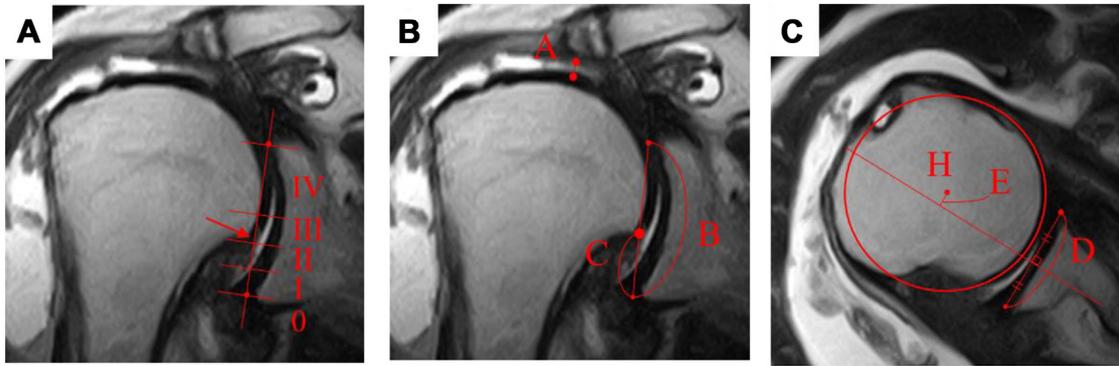


Figure 2 (A) Oizumi’s classification. The inferior half of the glenoid is divided into 3 zones. The grade is defined by the position of the inferior border of the articular surface of the humeral head in the following zones: grade 0: the inferior border of the articular surface of the humeral head is below the lower glenoid rim; grades I, II, and III: the inferior border of the articular surface of the humeral head is in each zone; and grade IV. (B) Length A was measured as the narrowest part of subacromial space (acromiohumeral interval). In a coronal magnetic resonance imaging (MRI) image, length B was defined as the distance between superior and inferior edges of the glenoid. Length C was defined as the distance between inferior edges of the glenoid and inferior corner of the articular surface. The superior translation ratio was defined as the ratio of C to B. (C) In an axial MRI image, the length of line D was defined as the distance between the anterior and posterior edges of the glenoid. Reference line G was a line drawn vertically to line F through the central point of B. Point H was a point at the center of the humeral head. The length E was defined as the distance between point H and line G. Anterior translation ratio was defined as the ratio of E to D.

Table I
Progression of glenoid wear from two years postoperatively to the final follow-up.

	2 years postop	Final follow up
Grade 0	19	5 5
Grade 1	35	7 17
		10
Grade 2	18	6 20
		13 1
Grade 3	7	1 37
		12 17 7

Data are expressed as the number of shoulders.

$P < .10$ on univariate analysis. $P < .05$ was considered significant on univariate and multivariate analysis. Multigroup comparisons and Bonferroni correction were used for comparisons of the results of the three groups. All statistical analyses were performed using R software (The R Foundation for Statistical Computing, Vienna, Austria).

Results

GW at 2 years postoperative was grade 0 in 19 shoulders, grade 1 in 35, grade 2 in 18, and grade 3 in 7 shoulders. The final GW at the last follow-up was grade 0 in 5 shoulders, grade 1 in 17, grade 2 in 20, and grade 3 in 37 shoulders (3A: 4, 3B: 22, and 3C: 11 shoulders, respectively). Table I shows the progression of GW from 2 years after surgery to the final observation. GW progressed in 56 shoulders (70.9% of all shoulders) at 2 years postoperatively, with 30 shoulders (38.0%) progressing to grade 3 GW.

In univariate analysis of individual risk factors for progression of GW to grade 3, grade 3 GW patients had a statistically significantly smaller preoperative ROM of active flexion ($72.5 \pm 42.3^\circ$ vs. $93.0 \pm 48.0^\circ$, $P = .043$) and higher STR ($37.4 \pm 17.0\%$ vs. $27.9 \pm 16.2\%$,

$P = .014$). The two groups had significantly different grades in Oizumi’s classification ($P = .02$) (Table II). In multivariate analysis, preoperative higher STR was defined as a risk factor for progression of GW to grade 3 (odds ratio, 35.5; 95% confidence interval, 1.8-693.0; $P = .018$) (Table III).

A comparison of the univariate analysis of individual risk factors among the three grade 3 subtypes is shown in Table IV. Comparison between the three subtypes of grade 3 showed that patients with grade 3B GW had higher STR than those with grade 3C GW ($41.4 \pm 14.2\%$ vs. $23.5 \pm 13.3\%$, $P = .006$). Grades 3B and 3C showed significantly different grades in Oizumi’s classification ($P = .015$) (Table IV).

Discussion

HHR using a small-diameter head with rotator cuff reconstruction is reported as one of the useful therapeutic option for CTA,^{19,26} considering the lower complication and revision rates. In HHR, GW is a possible complication affecting clinical results^{7,13,17} and has been reported as one of the major reasons for revision surgery.^{5,9,15} A previous report investigated the pattern of GW after HHR in detail¹⁴; grades 0-2 GW showed a maintained ROM and less pain compared to grade 3 (glenoid bone erosion).^{7,14} In other words, even if GW occurs, the clinical outcome is maintained and there is less possibility of revision surgery in cases that do not progress to grade 3. Therefore, we investigated the risk factor of grade 3 GW in this study to understand how to prevent GW progression to grade 3.

Additionally, the pattern of GW that progresses to grade 3 and differences in clinical courses among the three grade 3 GW subtypes (classified according to the erosion pattern) have been studied. In the investigation of grade 3 GW subtypes, 3B (superior eccentric erosion) had more pain and limited active flexion than 3C (concentric erosion).¹⁴ In the current study, GW in patients with CTA who were followed-up for more than 5 years after HHR was evaluated to detect individual risk factors for progression to 3B GW.

In cases of osteoarthritis, the incidence rate of GW reportedly ranges from 42-100%.^{9,21,24,25} In a previous report of more than 8 years of follow-up after HHR in patients with CTA, GW progressed in 70.6% of all shoulders from 2 years postoperatively, and 15 shoulders (44.1%) progressed to grade 3 GW.¹⁴ In the current study with more subjects, GW progressed in 56 shoulders (70.9% of all shoulders) from 2 years postoperatively, and 30 shoulders (38.0%)

Table II
Univariate analysis of epidemiological data (group 0-2 vs. group 3).

Variable	Group 0-II (n = 42)	Group III (n = 37)	P Value
Age (yr)	70.1 ± 6.6	72.2 ± 7.9	.11
Sex (men/women)	16/26	20/17	.18
Constant pain score (points)	0.71 ± 1.8	0.27 ± 1.1	.19
Preoperative ROM (degree)			
Active flexion	93.0 ± 48.0	72.5 ± 42.3	.043*
Active exr.	20.5 ± 19.9	12.8 ± 22.4	.13
Condition of rotator cuff			
Yamaguchi's classification (%)			
Supraspinatus	27.9 ± 13.1	24.9 ± 10.9	.31
Infraspinatus	47.8 ± 30.7	38.8 ± 30.8	.07
Subscapularis	82.2 ± 19.3	70.7 ± 26.9	.10
Teres minor	93.7 ± 17.5	96.6 ± 9.1	.69
Goutallier's classification	2.1 ± 0.5	2.3 ± 0.5	.09
Translation of humeral head			
Oizumi's classification (0/I/II/III/IV)	5/8/14/11/5	0/8/5/15/9	.02*
Superior translation ratio (%)	27.9 ± 16.2	37.4 ± 17.0	.014*
AHI	1.7 ± 2.0	1.9 ± 2.1	.73
Anterior translation ratio (%)	4.0 ± 9.3	0.2 ± 7.5	.23
Muscle tendon transfer			
PM	2 (4.8%)	3 (8.1%)	.66
LD & TMj	8 (19.0%)	6 (16.2%)	.78

ROM, range of motion; exr., external rotation; AHI, acromiohumeral interval; PM, pectoralis major; LD & TMj, latissimus dorsi and teres major.

Data are expressed as the number of shoulders or as mean ± standard deviation.

*P < .05.

Table III
Multivariate analysis of epidermal data (group 0-2 vs. group 3).

Logistic regressive analysis with forward-backward stepwise selection method					
Variable	Group 0-2 (n = 43)	Group 3 (n = 40)	OR	95% CI	P Value
Superior translation ratio (%)	27.9 ± 16.2	37.4 ± 17.0	35.5	1.8-693.0	.018*

ROM, range of motion; OR, odds ratio; CI, confidence interval.

Data are expressed as the mean ± standard deviation.

*P < .05.

progressed to grade 3 GW. The current study had a mean follow-up period of 8.2 years, similar to the aforementioned study and the GW progression rate in both studies was similar.

Several reports have suggested that the risk factor for bone erosion in the shoulder is the female sex,¹⁰ while younger age and high physical activity levels have been demonstrated as risk factors for bone erosion in the hip joint.^{2,22} Our results did not indicate that age or sex were independent risk factors for GW progression. In the current study, grade 3 GW patients had a limited preoperative ROM of active flexion and a higher STR than grades 0-2 patients. A higher preoperative STR (upper migration of the humeral head on supine position) suggests the possibility of preoperative disruption of the force couple of the rotator cuff, which leads to disruption of normal glenohumeral motion and limited active flexion. The pathology may resemble that in a previous report, where preoperative limitation of active external rotation was identified as a risk factor for GW progression to grade 3.¹⁵ In these situations, the normal reactive force was not loaded onto the glenoid, inducing low bone density of the subchondral bone of the glenoid.^{16,27} When the STR value becomes extremely high, it suggests insufficiency of the subacromial arch and absence of dynamic joint stabilization; the final situation will be described as Seebauer's classification type IIB (decentered unstable, anterior superior escape). In cases with extremely high STR, active flexion can be restricted because of the anterosuperior escape of the humeral head. This pathology can explain why patients with grade 3B GW had significantly higher STR than those with grade 3C GW and that grade 3B GW patients tended to be classified as grade 4 in Oizumi's classification preoperatively. This is because, in grade 3B,

the mechanical force of the humeral head in the superior direction is suspected to be the cause of eccentric superior erosion.

It is intuitively plausible that an unbalanced action caused by rotator cuff insufficiency might lead to uneven loading and, thus, destruction of the glenoid cartilage.^{11,13,15} However, preoperative conditions (muscle atrophy and fatty degeneration) of the rotator cuff muscles were not statistically different between groups 0-2 and group 3 and between the grade 3 subtypes. It is possible that rotator cuff reconstruction by muscle tendon transfers restored cuff function and prevented postoperative upper migration of the humeral head in many cases that did not progress to grade 3B GW. The possibility that retear of the reconstructed rotator cuff causes grade 3B GW should be considered in cases that did not show severe upper migrated humeral head preoperatively. From the results of the current study, in HHR for CTA, patients who showed anterosuperior escape of the humeral head due to failure of the coracoacromial arch (ie, Seebauer's classification type IIB) during preoperative examination with plain radiography, computed tomography, and MRI should be carefully considered for this procedure and closely followed-up for possible progression to grade 3B GW and need of revision in the future. In the preoperative evaluation of CTA patients, "limited ROM" should be carefully assessed if it reflects the absence of dynamic joint stabilization, in contrast to "maintained ROM," which may represent maintained dynamic joint stabilization. Additionally, when evaluating the translation of the humeral head preoperatively, it is important to use imaging tools in standing and supine positions because the humeral head is lower in a standing position due to gravity, especially in cases with a

Table IV
Univariate analysis of epidemiological data within each subtype of grade3.

Variable	Grade3A (n = 4)	Grade3B (n = 22)	Grade3C (n = 11)	P Value		
				A vs B	B vs C	A vs C
Age (yr)	73.3 ± 7.7	73.3 ± 8.0	70.0 ± 8.0	1.00	.15	.47
Sex (men/women)	2/2	12/10	6/5	1.00	1.00	1.00
Constant pain score (points)	0.0 ± 0.0	0.5 ± 1.5	0.0 ± 0.0	.54	.31	-
Preoperative ROM (degree)						
Active flexion	61.3 ± 42.5	67.7 ± 36.8	87.5 ± 53.3	.54	.24	.32
Active exr.	7.5 ± 26.3	10.2 ± 18.2	20.5 ± 29.4	1.00	.27	.67
Condition of rotator cuff						
Yamaguchi's classification (%)						
Supraspinatus	16.2 ± 7.0	26.0 ± 9.8	25.6 ± 13.3	.05	.62	.12
Infraspinatus	19.8 ± 9.8	38.6 ± 31.4	46.0 ± 33.2	.27	.43	.19
Subscapularis	55.4 ± 22.4	69.0 ± 29.3	79.6 ± 22.0	.26	.35	.12
Teres minor	95.0 ± 10.0	95.0 ± 10.9	100.0 ± 0.0	.87	.13	.09
Goutallier's classification	2.4 ± 0.6	2.3 ± 0.6	2.3 ± 0.4	.69	.76	.64
Translation of humeral head						
Oizumi's classification (0/I/II/III/IV)	0/0/0/2/2	0/2/4/9/7	0/6/1/4/0	1.00	.015*	.05
Superior translation ratio (%)	53.5 ± 17.0	41.4 ± 14.2	23.5 ± 13.3	.24	.006*	.019
AHI (mm)	2.2 ± 3.7	2.0 ± 2.1	1.6 ± 1.7	.47	.69	.74
Anterior translation ratio (%)	1.3 ± 1.7	-0.6 ± 5.9	0.3 ± 10.8	.19	.87	.40
Muscle tendon transfer						
PM	1 (25%)	0 (0%)	2 (9.1%)	.54	.41	.27
LD & TMj	2 (50%)	2 (18.2%)	2 (9.1%)	.59	.10	.52

ROM, range of motion; exr., external rotation; AHI, acromiohumeral interval; PM, pectoralis major; LD & TMj, latissimus dorsi and teres major.

Data are expressed as the number of shoulders or as mean ± standard deviation.

*P < .0167 after Bonferroni correction.

dynamic (not fixed) upper migrated humeral head. That is the reason why MRI in a supine position was used to evaluate upper migration of the humeral head in this study.

The number of grade 3A GW cases was small; however, the preoperative condition of the subscapularis progressed to atrophy, which may suggest anterior instability due to anterior cuff dysfunction. More reliable results can be obtained using a larger number of cases. As in a previous report,¹⁴ grade 3B GW has the possibility of reoperation with poor clinical results; however, even in those cases, RSA can be used as a salvage.¹⁸ Therefore, HHR with cuff reconstruction remains an option for CTA not only for young patients but also for older selected patients.

Limitations

The first limitation of this study was the follow-up ratio. A medical examination was required of the patients once a year, and an effort for contact to lost patients via telephone or direct mail was made routinely. However, 61 patients had difficulty receiving medical examinations due to proximity to the hospitals, systemic complications, and dementia. Evaluating a larger number of cases in each group will provide stronger statistical support, although some of the results were statistically significant. More grade 3A patients are needed to consider its pathology and risk factors. Second, GW was only evaluated by plain radiography, which might have been affected by differences in arm position at the radiographic examination. However, plain radiographs were repeated to increase reproducibility until they depicted the joint space, and the most accurate depiction was selected after several measurements. Third, although retear of the reconstructed rotator cuff can be a cause of grade 3B GW in cases that did not show severe upper migrated humeral head preoperatively, the post-operative status of muscle-tendon-transfers was not able to be evaluated because MRI is not applicable after inserting metal implants.

In future studies, evaluating the bone quality of the glenoid should be considered an important parameter for predicting postoperative GW. Dual-energy X-ray absorptiometry or alternative screening tools,

such as radiographic absorptiometry, quantitative ultrasound, and conventional and quantitative computed tomography, have also been introduced to assess peripheral bone mineral density.⁶

Conclusions

GW was evaluated in patients who were followed-up for 5 years or more after HHR for CTA using a modified classification of GW. The individual risk factors for progression to 3B GW were detected. Limited preoperative ROM of active flexion and a higher STR on supine position were defined as risk factors for progression to grade 3 GW. Grade 3B GW patients had significantly higher STR than grade 3C GW patients, and grade 3B GW patients tended to be classified into Oizumi's classification grade 4 preoperatively.

When considering the indication of HHR for CTA in patients with severe upper migration of the humeral head and limited active flexion, careful consideration is necessary for progression to grade 3B GW and possible future revision.

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