Comprehensive Arthroscopic Management of Glenohumeral Osteoarthritis

Preoperative Factors Predictive of Treatment Failure

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Background: Patient selection is critical when choosing between arthroscopic joint preservation and total shoulder arthroplasty in young patients with glenohumeral osteoarthritis (GHOA).

Purpose: To identify prognostic factors predictive of early failure in patients undergoing comprehensive arthroscopic management (CAM) for GHOA.

Study Design: Case-control study; Level of evidence, 3.

Methods: A total of 107 shoulders in 98 patients with minimum 2-year follow-up who underwent CAM were identified and evaluated. All shoulders met clinical and radiographic criteria for total shoulder arthroplasty (TSA), but the patients opted for joint preservation with arthroscopic management. Radiographic and preoperative factors were analyzed to determine predictors of early failure, defined as progression to TSA within the study period.

Results: There were 72 men and 26 women with a mean age of 52 years (range, 29-77 years). Seventeen (15.8%) of 107 shoulders progressed to TSA at a mean of 2 years (range, 0.46-8.2 years). Shoulder status for the rest had a mean follow-up of 3.9 years (range, 2-9.4 years). There were a number of radiographic features that were correlated with early failure. Patients who failed had significantly less preoperative joint space than did those who succeeded (1.3 vs 2.6 mm; $P = .004$). Higher Kellgren-Lawrence grades for osteoarthritis and age older than 50 were also associated with failure. Shoulders with Walch type B2 and C glenoid were significantly more likely to fail than were Walch types A1, A2, and B1 ($P < .05$).

Conclusion: The CAM procedure has been shown to reliably improve pain and function in active patients with advanced GHOA; however, it is important to inform patients about the limitations of the procedure. Patients with less joint space and abnormal posterior glenoid shape were significantly more likely to progress to early failure.

Keywords: glenohumeral osteoarthritis; arthroscopic management; Walch glenoid morphology

Glenohumeral osteoarthritis (GHOA) is a common cause of shoulder dysfunction and disability, typically characterized by symptoms of pain, weakness, and decreased range of motion.[17] Initial management consists of nonsurgical modalities such as lifestyle and occupational modifications, physical therapy, nonnarcotic pain relievers, and intra-articular injections of steroid or viscosupplement.[2,6] When these treatments are unsuccessful, surgical options are considered. In elderly or low-demand patients, treatment with total shoulder arthroplasty (TSA) reliably produces excellent clinical outcomes with low revision rates and high patient satisfaction.[28,33] However, treatment of GHOA in young or highly active patients represents a substantial challenge.

Many surgical approaches for GHOA have been described, including open and arthroscopic debridement, hemiarthroplasty, unipolar or bipolar resurfacing, nonprosthetic or biologic interposition arthroplasty, and TSA.[2,9,12,18,19,29,38,39] While it has been shown that TSA provides the most reliable outcomes for patients with advanced GHOA,[31,33] alternative treatments are often sought in younger and more active patients. This may be due to a number of factors, ranging from personal preference to concerns about implant longevity or unwillingness to decrease activity levels postoperatively.[24,39] Furthermore, several studies have shown unacceptable outcomes of TSA in younger patients, including increased rates of component loosening,[33] decreased component survival,[5] and significantly higher risk of revision.[7] A recent Markov decision analysis found that arthroscopic management of GHOA was the preferred treatment strategy for patients younger than 47 years, while TSA was preferred for patients older than 66 years.[34]

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In light of these findings, the senior surgeon (P.J.M.) has developed a joint-preserving arthroscopic strategy termed *comprehensive arthroscopic management* (CAM) for the treatment of young, active patients with symptomatic GHOA.[18,19,22] This procedure addresses many of the potential sources of pain and dysfunction in the osteoarthritic shoulder through a combination of glenohumeral chondroplasty; extensive capsular release; and, when indicated, humeral osteoplasty,[18] osteophyte excision, axillary nerve neurolysis, subacromial decompression, loose body removal, microfracture,[20] and biceps tenodesis. In a previously published article on the first 29 patients (30 shoulders) to receive the CAM procedure, patients were found to have a significant reduction in pain and improved range of motion with increased functional outcome scores.[19] Furthermore, the procedure demonstrated 85% survivorship at 2 years.[19] Glenohumeral joint space of less than 2 mm was found to be predictive of progression to TSA. Midterm results in a similar group of patients also demonstrated encouraging findings with 77% survivorship at a minimum 5-year follow-up, with successful patients noting significant improvements in pain, range of motion, and function.[22]

The promising short- and midterm results suggest that the CAM procedure is effective in managing GHOA and delaying the need for TSA in young, active individuals who wish to extend the life span of their native shoulder joint. However, the data are limited by the small sample size and inability to provide surgeons with definitive preoperative patient selection criteria. Despite this, the data do imply that some patients may be more appropriate candidates for this procedure than others, and despite encouraging preliminary results, identifying the factors that are predictive of early failure is paramount for proper patient selection for those who will do well with joint preservation versus replacement. Differentiating those patients who are less ideal candidates for arthroscopic intervention may also lead to improved long-term results by avoiding multiple surgical interventions. Therefore, the purpose of this study is to examine prognostic factors predictive of early failure in patients undergoing the CAM procedure for GHOA. We hypothesized that radiographic joint space narrowing and lower preoperative patient-reported scores would be predictive of early failure of the CAM procedure. Results from this analysis will assist surgeons in selecting proper candidates for this joint-preserving intervention to optimize durability and long-term outcomes.

METHODS

Patient Selection

Institutional review board approval was obtained before the initiation of this study. Between January 2006 and September 2013, all patients who underwent the CAM procedure were considered for analysis. All patients indicated for the CAM procedure had symptomatic GHOA that met radiographic and objective criteria for TSA with Kellgren-Lawrence grade 2, 3, or 4 changes on either the humeral or glenoid surface. Each failed nonsurgical management with a combination of activity modification, anti-inflammatory medications, physical therapy, viscosupplementation, oral glucosamine, or corticosteroid injections. Patients were excluded from eligibility for the CAM procedure if they were found to have asymptomatic or early-stage osteoarthritis (OA), had not attempted nonsurgical measures, had complete irreparable rotator cuff tears, carried a diagnosis of inflammatory arthropathy or avascular necrosis, had bipolar lesions with flattening of the humeral head on radiographs, or had severe joint incongruity. Patients with "posttraumatic OA" were defined as those patients who had a prior shoulder fracture of the humeral head or glenoid, prior instability surgery, or history of dislocations without surgical intervention.

All patients who underwent the procedure were included, regardless of time to follow-up, to determine the primary outcome measures of survivorship (no further surgical intervention) or early failure (defined as progression to TSA within the study period after the index procedure). The reason for total initial inclusion of all subjects, regardless of time to follow-up, was to confirm the status of the primary outcome measure of survivorship or failure of the procedure. After confirmation of this, all patients who had failed and progressed to TSA were included in the failure limb of the study, regardless of time to follow-up. The remaining patients were included in the survival limb of the study and met the inclusion criteria if they had symptomatic GHOA, had failed nonoperative management, were older than 18 years, and were at least 2 years out from surgery. The logic for including only those patients who had survived for a minimum of 2 years was to ensure that patients were given sufficient time from the index procedure until follow-up to avoid falsely including those who were doing poorly after surgery but were still functionally coping. Four patients refused to participate. Two patients were excluded because they had concomitant

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full-thickness rotator cuff tears that were repaired, and 1 paraplegic patient was excluded, as the patient's condition required excessive dependence on the upper extremities and did not represent the general population.

Demographic Data

All patient data were prospectively collected, stored in an outcomes registry, and retrospectively analyzed. These included demographic information (age, sex, dominant shoulder, affected shoulder), characteristics of the injury (mechanism, duration of symptoms), prior surgeries, treatment history, additional injuries, adjuvant treatments, and operative complications. Postoperative demographic factors and outcome scores were not considered in the analysis as the primary aim of the study was to identify factors predictive of failure before embarking on surgical interventions. Furthermore, postoperative outcome scores for patients who progressed to TSA within the study period would not be truly reflective of their postoperative status before a second intervention.

Radiographic Measurements

All radiographic measurements were examined by 2 independent observers (B.T.W. and M.B.R.). The Kellgren-Lawrence OA grade,[14] presence and size of the glenoid and humeral head osteophytes (mm), and acromiohumeral distance (mm) were determined. Joint space in millimeters was measured from true anteroposterior images at the superior, middle, and inferior aspects of the glenoid, with the smallest joint space noted from the 3 measurements.[19] Critical shoulder angle (CSA) in degrees was measured according to the method described by Moor et al.[23] Walch classification of glenoid type was determined from preoperative axial T1 magnetic resonance imaging (MRI).[26,37] Type A glenoids were identified as central wear or erosion of the glenoid with the humeral head centered in the glenoid (as defined by the center of the humeral head being located 50% of the distance across the anterior to posterior measurement of the glenoid as seen on an axial MRI). Type B1 glenoids were defined as those having posterior joint space narrowing with posterior subluxation of the humeral head, and type B2 glenoids were identified when there was posterior subluxation of the humeral head with a biconcave appearance of the glenoid. Type C glenoids were those retroverted more than 25° (identified by the angle created by intersecting lines drawn down the scapula connecting the root of the scapular spine to the center of the glenoid and one line connecting the anterior and posterior glenoid rim). Interobserver agreement was classified according to Landis and Koch kappa: <0, poor agreement; 0 to 0.2, slight agreement; 0.21 to 0.4, fair agreement; 0.41 to 0.6, moderate agreement; 0.61 to 0.80, substantial agreement; and 0.81 to 1.0, almost perfect agreement.[16]

Operative Technique

Detailed descriptions of the CAM procedure have previously been published.[18,19,28,30] Briefly, patients were placed in the beach-chair position, and diagnostic arthroscopy was performed to identify and treat all intra-articular pathologic abnormalities. Degenerative labral tissue and unstable chondral injuries were debrided, loose bodies when present were removed, and areas of synovitis were addressed with either a mechanical shaver or a radiofrequency device. If a focal chondral defect was noted on either the glenoid or humeral head, microfracture was performed.[20] Next, an accessory posteroinferior portal was established under spinal-needle localization.[4] Through this portal, inferior humeral head osteophytes were resected with a high-speed bur.[3] Curettes were used to remove bone from areas that were difficult (anteroinferior quadrant) to reach with motorized instruments. Fluoroscopy was used to confirm adequate resection. Inferior capsular release was then performed.

If preoperative symptoms and imaging suggested axillary nerve compression, the axillary nerve was identified just inferior to the joint, where it passes from anteromedial to posterolateral toward the quadrilateral space. It was carefully decompressed from proximal to distal, taking great care to identify and preserve all arborizing branches. This procedure was considered if an inferior humeral osteophyte changed the course of the nerve as determined on preoperative MRI,[21] if observed intraoperatively by displacement of the inferior capsule, or if preoperative symptoms consistent with axillary nerve impingement or compression were present (eg, posterior and lateral shoulder pain, atrophy of the teres minor or posterior deltoid, and weakness in external rotation without the presence of a rotator cuff tear). After neurolysis, anterior and posterior capsular releases were performed in standard fashion, and the rotator interval was also released medially until the coracoid and coracoacromial ligament were visualized. A manipulation of the joint was performed after this release, and the improvement in motion was noted.

When indicated, based on preoperative physical examination findings consistent with subacromial impingement or a positive response to the subacromial injection, a complete subacromial bursectomy was performed. Acromial type was assessed, and if deemed necessary, an acromioplasty was performed to create a type 1 acromion. If there was no evidence of subacromial impingement, the acromion was not resected. Finally, the biceps tendon was assessed for pathologic changes; if present, an open subpectoral tenodesis was performed using interference screw fixation. At this point, the glenohumeral joint was once again manipulated to maximize motion, and improvement from preoperative examination was documented. Portals were then closed in standard fashion, and the arm was placed into an immobilizer.

Postoperative rehabilitation was divided into 3 phases, beginning with immediate active and passive range of motion for the first 6 weeks to maintain the gains achieved through osteoplasty, debridement, manipulation, and capsular release. Nonsteroidal anti-inflammatory medications were also used to help reduce inflammation during the initial postoperative period. The second phase began at 6 weeks and progressed until approximately week 12. During this time, rehabilitation focused on strengthening of the rotator cuff, periscapular musculature, and core. The final phase was initiated at 12 weeks and focused on return to normal activities. Maximum recovery was expected by 4 to 6 months.

Data Collection

Patient-centered outcomes scores were collected preoperatively and included the American Shoulder and Elbow Surgeons (ASES); Quick Disabilities of the Arm, Shoulder, and Hand (QuickDASH); Short Form–12 physical component summary (SF-12 PCS); and Single Assessment Numeric Evaluation (SANE) scores. Intraoperative range of motion data gathered during examination under anesthesia were also recorded. The dependent factor used in our analysis was a successful status determined at a minimum 2 years postoperatively. Failures were defined as progression to TSA after the index CAM procedure and were included in the failure limb regardless of time from index procedure to ensure capture of all patients who progressed to TSA.

Statistical Analysis

Statistical analyses were performed using statistical software SPSS version 11.0 (SPSS Inc). Univariate analysis was performed using an independent *t* test, Mann-Whitney *U* tests, or Kruskal-Wallis test, depending on data normality. Bivariate analysis was by chi-square (χ^2) analysis. The Fisher exact test was used to test for association between groups, with relative risk (RR) calculations done using cross-tabulations. Correlations were performed with either a Pearson coefficient (r) or a Spearman rho (ρ) analysis. An interrater reliability analysis using the kappa (κ) statistic was performed to determine consistency among 2 raters for radiologic measurements using 2-way random effect with absolute agreement and Cohen κ for categorical variables. All reported P values are 2-tailed, with a value of <.05 indicating a statistically significant difference.

RESULTS

Between January 2006 and September 2013, a total of 114 shoulders (103 patients) underwent the CAM procedure performed by the senior surgeon (P.J.M.). After exclusion criteria were applied, 107 shoulders in 99 patients were included in the analysis who were able to be contacted for follow-up to determine the primary endpoint of failure or survival (Figure 1). Seventeen (15.8%) of 107 shoulders progressed to TSA at a mean of 2 years (range, 0.46-8.2 years). Shoulder status for the remainder had a mean follow-up of 3.9 years (range, 2-9.4 years). The mean age was 52 years (range, 29-77 years) at the time of surgery in 73 men and 26 women. All shoulders underwent chondroplasty, capsular release, and subacromial decompression. Additional procedures included humeral head osteoplasty/osteophyte excision in 60 shoulders (54%), axillary nerve neurolysis in 35 shoulders (32%), loose body removal in 64 shoulders (58%), and microfracture in 17 shoulders (15%). In addition, biceps injury was identified and treated with a tenodeses in 61 shoulders (55%), tenotomy in 1 shoulder (1%), and debridement only in 2 shoulders (2%). Thirty-four patients had posttraumatic OA. While patients with posttraumatic OA were not associated with progression to TSA, they were significantly younger than those with primary OA (48.3 ± 9.5 vs 53.5 ± 7.6 years; P = .004).

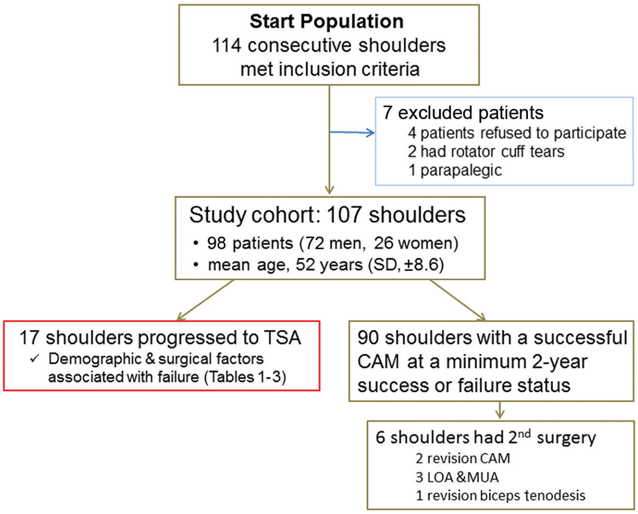

Figure 1. Patient flow diagram representing inclusion of patients for this study. CAM, comprehensive arthroscopic management; LOA; lysis of adhesions; MUA, manipulation under anesthesia; TSA, total shoulder arthroplasty.

For the entire cohort, the mean (±SD) acromiohumeral distance was 10.8 ± 2.5 mm, CSA was 29.8° ± 4.4°, glenoid spur size was 4.7 ± 2.3 mm, and humeral head spur size was 9.6 ± 5.6 mm. Mean joint spaces were 3.8 ± 1.9 mm, 3.0 ± 1.7 mm, and 2.7 ± 1.6 mm at the superior, middle, and inferior aspects of the glenoid, respectively. The mean smallest joint space was 2.4 ± 1.6 mm, and this number was used in the statistical analysis. Osteophytes that were removed were significantly larger than those that were not (11.2 ± 5.1 mm vs 7.5 ± 5.6 mm; P =.002). The interrater agreement for Kellgren-Lawrence osteoarthritis grades of 2, 3, and 4 was $\kappa = 0.573$ (95% CI, 0.422-0.704), indicating fair agreement. The interrater agreement for glenoid type by grouping the Walch classification by MRI of A1, A2, or B2 versus B2 or C grouping was $\kappa = 0.635$ (95% CI, 0.429-0.841), indicating substantial agreement. The interrater reliability for radiologic measurements is listed in Table 1. As presented in Table 2, postoperative range of motion improved for all examined motion parameters ($P < .001$).

Secondary Surgeries and Failures

Of the 107 shoulders that were treated, 17 shoulders (15.8%) failed arthroscopic management and progressed to TSA within 5 years of the index procedure. The decision for progression to TSA was based on patient symptoms and desire, as well as response to the index CAM procedure. Three shoulders had further arthroscopic debridement for stiffness, 2 shoulders underwent revision CAM procedures based on continued symptoms and the patients'

TABLE 1
Interrater Reliability Analysis Using the Kappa Statistic for Radiologic Measurements

	Observer 1, Mean ± SD	Observer 2, Mean ± SD	κ Statistic (95% CI)
Acromiohumeral distance, mm	10.06 ± 2.9	10.66 ± 2.6	0.846 (0.617-0.816); almost perfect agreement
Critical shoulder angle, deg	31.15 ± 4.53	30.00 ± 4.47	0.905 (0.818-0.945); almost perfect agreement
Humeral head osteophyte size, mm	10.0 ± 6.0	9.9 ± 6.3	0.947 (0.920-0.964); almost perfect agreement
Glenoid osteophyte size, mm	4.5 ± 2.3	4.9 ± 3.2	0.753 (0.599-0.748); substantial agreement
Joint space, mm			
Smallest	2.5 ± 1.5	2.4 ± 1.6	0.895 (0.846-0.928); almost perfect agreement
Superior	4.0 ± 1.9	3.8 ± 1.9	0.875 (0.818-0.915); almost perfect agreement
Middle	3.1 ± 1.6	2.9 ± 1.7	0.414 (0.140-0.600); moderate agreement
Inferior	2.8 ± 1.6	2.7 ± 1.6	0.904 (0.859-0.935); almost perfect agreement

strong desire to avoid a TSA, and 1 underwent a revision open subpectoral biceps tenodesis. The 17 shoulders that went on to TSA and failed did so at a mean of 2.0 years (range, 0.46-8.2 years). Preoperative factors that were found to be associated with failure of the CAM procedure were age older than 50 years, radiographically more severe arthritis as measured by the Kellgren-Lawrence grade, narrower joint space, and Walch B2 or C type glenoid anatomy (Tables 3 and 4).

The RR of progression to TSA was nearly 6 times higher in patients with a Walch type B2 or C glenoid compared with patients with Walch A1, A2, or B1 glenoid types (RR = 6.0; 95% CI, 2.2-16.2) (Figures 2 and 3). Besides age older than 50 years, there were no statistical differences in patient demographics between patients who succeeded and those who failed, nor was there an association with the presence or absence of any one of the surgical components of the CAM procedure (Table 4).

Preoperative ASES, SANE, QuickDASH, and SF-12 scores were statistically similar between patients who had a successful CAM procedure and those who failed (Table 5). A descriptive representation of all patients who failed the CAM procedure is included in the Appendix (available in the online version of this article).

DISCUSSION

The techniques and indications related to arthroscopic treatment of GHOA have evolved over time, with prior reports focusing on addressing intra-articular injury through joint lavage, chondrolabral debridement, loose body removal, and synovectomy.[4,11,15,22,25,27,35,38] These studies generally found that patients improved significantly after surgery; however, results were often short-term and patients with more advanced disease had less benefit.[11,15] As arthroscopic treatment and techniques have advanced, some researchers have begun to advocate for the inclusion of additional surgical components to address both intra- and extra-articular causes of shoulder pain and dysfunction, such as capsular releases, osteophyte resection, and subacromial decompression, to improve outcomes and delay the need for more extensive reconstructive procedures. These recent techniques have yielded promising early results but also reveal potential limitations of the CAM procedure in some patients, while lacking the ability to evaluate sufficient data points to predict which specific factors may lead to failure.[19-22] As such, the primary goal of this work was to identify preoperative factors predictive of early failure of the CAM procedure and to provide outcomes-based data to improve patient counseling and physician decision making. Through better patient selection, the success and durability of the CAM procedure will hopefully be improved.

TABLE 2
Representation of Pre- and Postoperative Range of Motion After the CAM Procedure[a]

Range of Motion, deg	Preoperative	Postoperative	*P* Value
Forward elevation	129 (30 to 180)	156 (90 to 180)	<.001
External rotation	39 (–10 to 85)	63 (15 to 90)	<.001
External rotation at 90°	55 (–30 to 100)	78 (5 to 110)	<.001
Internal rotation at 90°	41 (0 to 90)	63 (15 to 90)	<.001

[a] Data are reported as mean (range). Patients demonstrated improved postoperative range of motion in all ranges measured. CAM, comprehensive arthroscopic management.

In this consecutive series of patients undergoing the CAM procedure, 17 of 107 shoulders (15.8%) progressed to TSA. With respect to our hypothesis, patients with a narrower preoperative joint space did fail at a rate that was significantly higher than that of patients with a wider joint space; while several factors were found to be predictive of early progression to TSA, preoperative patient-reported outcome scores did not correlate with early failure. There were a number of independent radiographic factors that predicted progression to TSA within the study period. These included extremely narrowed joint space (1.3 vs 2.6 mm), Kellgren-Lawrence grade of 4, and Walch glenoid type B2 or C. Patients with distorted glenoid type B2 or C were nearly 6.2 times more likely to require TSA. Furthermore, patients younger than 50 years and those with larger increases in postoperative motion compared with preoperative values demonstrated improved survivorship compared with their older counterparts or those with more modest improvements in motion. No other demographic factor or preoperative outcome, function, or pain score predicted failure.

Based on previous work by Millett et al[19] and Mitchell et al,[22] preoperative joint space narrowing is a known risk factor for early progression to TSA in the setting of

TABLE 3
Preoperative Measurements Associated With CAM Success or Failure[a]

Factor	Successful CAM	Failed CAM	*P* Value
Kellgren-Lawrence grade 4[b]	25/85 (29)	12/12 (64)	.016[c]
Critical shoulder angle, deg	30.2 ± 4.1	27.2 ± 5.3	.067
Joint space, mm			
Smallest	2.6 ± 1.5	1.3 ± 1.5	.004[c]
Superior	4.0 ± 1.8	2.5 ± 1.5	.003[c]
Middle	3.2 ± 1.6	1.8 ± 1.7	.003[c]
Inferior	2.9 ± 1.6	1.7 ± 1.5	.008[c]
Walch classification B2 or C[b]	10/75 (13)	8/13 (61)	<.001[c]
EUA FE postoperative	158 ± 22	149 ± 25	.177

[a] Data are reported as mean ± SD, unless otherwise indicated. CAM, comprehensive arthroscopic management; EUA, examination under anesthesia; FE, forward elevation.

[b] Data are reported as n/total (%).

[c] Statistically significant difference between groups ($P < .05$).

TABLE 4
Demographic Data in Patients Undergoing the CAM Procedure[a]

Factor	Successful CAM	Failed CAM	*P* Value
Age ≥50 y	52/90	15/17	.026
Male sex	66/90	13/17	>.999
Humeral acromial distance, mm, mean ± SD	10.7 ± 2.4	11.0 ± 3.1	.713
Surgery on dominant shoulder	44/90	10/17	.598
Prior surgery on shoulder	43/90	8/17	>.999
Posttraumatic osteoarthritis	27/90	7/17	.401
Workers' compensation	15/15	0/15	>.999
Humeral head osteophyte	79/86	14/14	.589
Glenoid osteophyte	49/76	9/15	.367
Osteoplasty	49/90	10/17	>.999
Axillary neurolysis/decompression	28/89	7/16	.392
Loose bodies	52/84	10/14	.564
Synovitis	76/86	14/15	>.999
Biceps treatment	54/87	8/16	.412
Partial rotator cuff tear	20/59	3/12	.739
Microfracture	17/90	0/17	.068
Hardware removal	6/88	1/17	>.999

[a] Data are reported as n/total unless otherwise indicated. Except for age ≥50, there were no statistically significant differences between the success and failure groups. CAM, comprehensive arthroscopic management.

prior CAM procedure, and other studies have similarly suggested this as an independent risk factor for failure. Van Thiel et al[36] found that patients who failed arthroscopic management and progressed to TSA had smaller joint space (average, 1.5 mm) than did those who did not (average, 2.5 mm). Of the 71 shoulders in their study, 16 (22%) progressed to shoulder replacement at a mean of 10.1 months (range, 2.5-27.2 months). The current study confirms these previous findings, but our cohort demonstrated both a lower failure rate and a longer average time to failure than were seen in the aforementioned studies. While it is difficult to speculate why this may be the case, improved results could be due to improved patient selection, shared decision making, the addition of procedural components to address extra-articular causes of shoulder pain, and surgeon preference in our relatively young and active population.

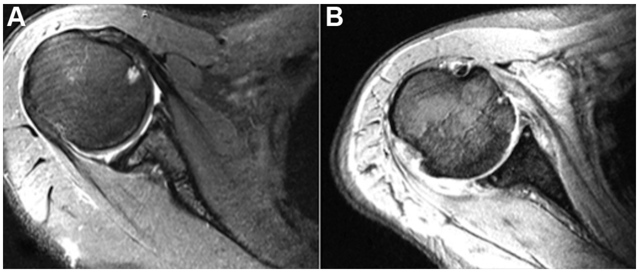

Figure 2. Axial magnetic resonance images of right shoulders demonstrating Walch type A glenoids.[26] (A) An A1 glenoid with central erosion only. (B) An A2 glenoid, which is similar to an A1 glenoid but with increased central erosion.

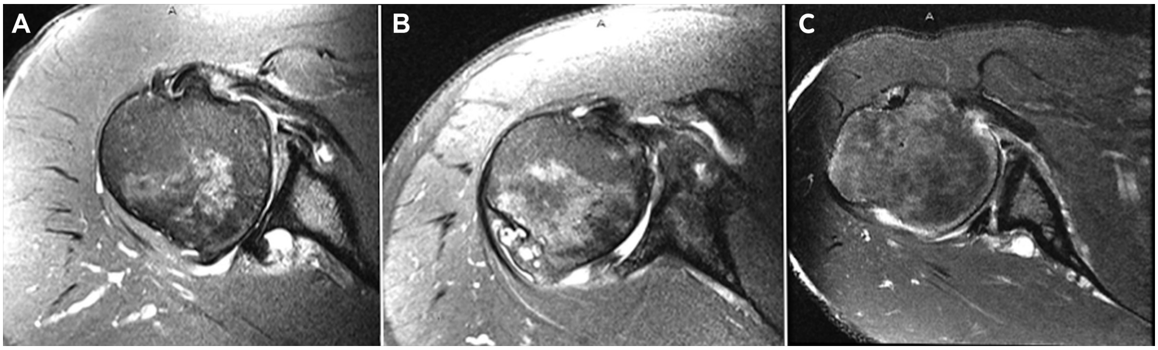

Figure 3. Axial magnetic resonance images of right shoulders demonstrating Walsh type B and C glenoids. (A) A B1 glenoid with posterior wear and slight posterior subluxation of the humeral head on the glenoid. (B) A B2 glenoid with a biconcave shape and posterior subluxation of the humeral head. (C) A type C glenoid with congenital retroversion.

Despite the understanding of radiographic joint space narrowing as an independent risk factor, other radiographic predictors of failure had not previously been fully evaluated. CSA, a relatively new radiographic parameter, described by Moor et al[23] in 2013, is determined by measuring the angle formed by a line drawn from the lateral border of the acromion to the inferior bony margin of the glenoid and a second line connecting the superior and inferior bony glenoid margins. In the original description of the CSA, these authors found that primary GHOA was associated with CSA <30°. They theorized that the combination of a short acromion and inferiorly tilted glenoid—resulting in a small CSA—led to greater compressive loads on the glenoid from a higher compressive deltoid force that predisposed the shoulder to arthritis. This has subsequently been supported by a biomechanical study, which demonstrated that compressive joint forces are decreased (and shear forces are increased) as CSA increases,[8] and a clinical study from Spiegl et al,[34] which also showed that a low CSA was associated with GHOA. In the patients in this cohort, all of whom had GHOA, the mean CSA was 29.9, and a lower CSA was correlated with narrowed joint space, confirming the findings of Moor et al and Spiegl et al. The mean CSA was not significantly different in the shoulders that failed the CAM procedure than those that did not (P = .067).

Another radiographic variable that can be analyzed preoperatively and that may help in surgical decision making is the preoperative glenoid type as described by Walch et al.[37] The Walch classification system is an established scheme for categorizing glenoid type and wear in GHOA.[37] Previous authors have shown that Walch types B2 and C—those with distortion of the posterior glenoid—can lead to difficulties in proper placement of the glenoid component,[13] as well as increase the incidence of periprosthetic radiolucent lines after TSA.[10] In the current study, those with type B2 or C posterior glenoid distortion were at 6 times increased risk of progressing to TSA compared with types A1, A2, or B1. This is certainly a worrisome finding, since these patients appear to do poorly with arthroscopic management while also being at higher risk of complication during and after TSA.[10,33,37] Based on the results of this study, we now advise patients with Walch B2 or C glenoids that the outcomes of the CAM procedure are not as favorable with these types of glenoid deformities. The ultimate decision for what type of surgery a patients proceeds with is then centered on a shared decision-making model.

TABLE 5
Comparison of Preoperative Patient-Reported Outcome Scores in Successful and Failed CAM Procedures[a]

Outcome Measure	Successful CAM	Failed CAM	P Value
Short Form–12			
PCS	44.5 ± 8.5	42.7± 6.53	.525
MCS	53.0 ± 11.1	53.2± 10.5	.924
ASES total score	59.4 ± 17.5	54.8 ± 16.5	.386
Pain	32.0 ± 11.5	32.5 ± 9.7	.841
Function	27.6 ± 9.4	25.0 ± 8.5	.348
QuickDASH	35.5 ± 18.2	35.3 ± 16.4	.978
SANE	50.0 ± 23.8	51.7 ± 29.0	.978

[a]There were no significant differences in these patient-reported outcome scores between groups. ASES, American Shoulder and Elbow Surgeons; CAM, comprehensive arthroscopic management; MCS, mental component summary; PCS, physical component summary; QuickDASH, Quick Disabilities of the Arm, Shoulder, and Hand score; SANE, Single Assessment Numeric Evaluation.

The CAM procedure attempts to address the possible causes of shoulder pain and dysfunction through a series of systematic steps, as previously described. One key component of the CAM procedure is the capsular release. As explained by Richards and Burkhart,[29] capsular tightness leads not only to a decrease in shoulder range of motion, but also to an increase in glenohumeral contact pressures. This occurs through a “wind-up” mechanism of the capsule on the humeral head during motion, which is subsequently relieved when the capsule is decompressed.[25] It has been well described in other joints, such as the hip and knee, that increased joint contact pressures cause pain in the arthritic joint. As such, many authors believe that the capsular release is a crucial component of arthroscopic treatment of GHOA and should always be performed.[26,29]

Cameron et al[1] published a series on 61 patients with arthroscopically confirmed grade 4 chondromalacia of the shoulder. The authors performed joint debridement but also included capsular release in anyone with >15° side-to-side difference in motion in any plane. Partial capsular release in these patients did have positive effects on restoring range of motion but did not apparently affect progression to arthroplasty or patient satisfaction. This may have been because a limited release does not have the same effect on reducing joint contact pressures as a more complete release. The previously referenced study by Van Thiel et al[36] included capsular release in the majority of their patients (44/71), and some also received biceps tenodesis/tenotomy and/or microfracture, making it more similar to our study than many earlier reports. Interestingly, despite noted failures in patients with narrowed joint space, it appears that all 44 patients who received capsular release remained in the "nonarthroplasty" group throughout the study period. This suggests that failure to perform capsular release strongly influences progression to arthroplasty, even when other shoulder conditions are simultaneously addressed. However, a recent study conducted by Skelley et al[32] indicated that debridement and capsular release alone are not sufficient, therefore stressing the importance of performing additional procedures when arthroscopically managing glenohumeral arthritis. Our data reinforce the importance of capsular release as an important component of arthroscopic management of GHOA, as patients who did not gain sufficient forward elevation after manipulation under anesthesia and joint contracture release were significantly more likely to progress to TSA than were those who achieved greater ranges of motion. Those shoulders in which the range of motion did not improve, despite maximal effort to restore motion, also had greater risk of failure. This suggests that bony distortion or severely scarred and noncompliant tissues likely play a role in the progression of GHOA and the success of the CAM procedure. In addition to the inferior capsular release, removal of the inferior humeral head spur can also decompress the inferior pouch and may relieve tension on the axillary nerve.[21] This intervention may, in turn, improve range of motion by decompressing the inferior capsule and alleviate pain caused by spur compression on the axillary nerve.

The present study reaffirms previously published data and defines new parameters associated with early CAM failure.[19,22,37] Our data suggest that patients exhibiting these characteristics may therefore be better served by undergoing TSA as the index procedure if they fail nonoperative treatment. Based on the results of this study, a treatment algorithm has been developed previously, as seen in Figure 4.

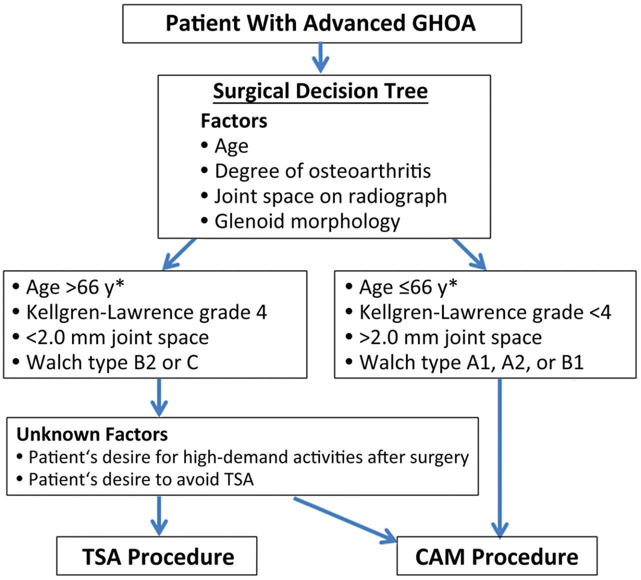

Figure 4. Algorithm for surgical decision making in patients with glenohumeral osteoarthritis (GHOA). *Based on the work of Spiegl et al.[34] CAM, comprehensive arthroscopic management; TSA, total shoulder arthroplasty.

Limitations

This study has several limitations, including many of the inherent limitations of a retrospective study. Although all patients met clinical and radiographic criteria for TSA, they were not considered for arthroplasty due to a combination of young age, physical demands, and/or patient desire. As a result, the findings in this study may not be applicable to all patients presenting with symptomatic GHOA. Some of the patients in this series simply did not want TSA and self-selected to pursue a nonarthroplasty option. Because of this, there may be a patient-induced bias, in that patients included in this series were better able, or more willing, to cope with their underlying GHOA. Because we included minimum 2-year follow-up data, we are not able to comment on long-term durability of the CAM procedure in delaying TSA in all survivors, but aforementioned midterm data do show promising results.[22] Our results may also include a subset of patients who have postoperative shoulder pain or poor function but are "coping" and choosing not to undergo TSA. Such patients could possibly be identified by the inclusion of patient-reported outcome scores; however, because these outcome scores are continuous variables, any cutoff demarcating success or failure would be arbitrary and could create groups above and below the chosen value that are significantly different. Because of this, we chose an objective endpoint for failure that clearly differentiated patients based on a binary variable.

Radiographic measurements were difficult and in some cases secondary to disease-related deformity and/or imperfect radiographs. Best attempts were made to standardize measurements despite these factors. Walch classification was initially described using computed tomography (CT); however, CT scans were not routinely available for the vast majority of our patients.[25] We therefore elected to use T1-weighted MRI scans.[27] Although we do not believe this is likely to have resulted in a significantly different result from CT as our κ values are similar to those reported for CT evaluation, it may have affected the numbers slightly. Finally, it must be noted that the CAM procedure is technically difficult and should be attempted only by experienced shoulder arthroscopists with intimate knowledge of complex shoulder anatomy. In particular, humeral head osteophyte excision, inferior capsular release, and axillary nerve decompression carry the potential risk of nerve damage and should be approached with great caution.[18,28]

CONCLUSION

The CAM procedure has been shown to reliably improve pain and function in active patients with advanced GHOA; however, it is important to inform patients about the limitations of the procedure. Patients with less joint space and abnormal posterior glenoid type were significantly more likely to progress to early failure.

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