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Survivorship and Patient-Reported Outcomes After Comprehensive Arthroscopic Management of Glenohumeral Osteoarthritis

Minimum 5-Year Follow-up

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Background: There are little data on midterm outcomes after the arthroscopic management of glenohumeral osteoarthritis (GHOA) in young active patients.

Purpose: To report outcomes and survivorship for the comprehensive arthroscopic management (CAM) procedure for the treatment of GHOA at a minimum of 5 years postoperatively.

Study Design: Case series; Level of evidence, 4.

Methods: The CAM procedure was performed on a consecutive series of 46 patients (49 shoulders) with advanced GHOA who met criteria for shoulder arthroplasty but instead opted for a joint-preserving, arthroscopic surgical option. The procedure included glenohumeral chondroplasty, capsular release, synovectomy, humeral osteoplasty, axillary nerve neurolysis, subacromial decompression, loose body removal, microfracture, and biceps tenodesis. Outcome measures included the American Shoulder and Elbow Surgeons (ASES), Single Assessment Numeric Evaluation (SANE), Quick Disabilities of the Arm, Shoulder and Hand (QuickDASH), Short Form–12 (SF-12) Physical Component Summary (PCS), visual analog scale for pain, and satisfaction scores. Kaplan-Meier survivorship analysis was performed with failure defined as progression to total shoulder arthroplasty (TSA).

Results: Forty-six consecutive patients (49 shoulders) who underwent a CAM procedure at a minimum of 5 years from surgery were included. Two patients were excluded for refusing to participate before study initiation. The mean age at surgery was 52 years (range, 27-68 years) in 15 women and 29 men. All patients were recreational athletes with 7 former collegiate or professional athletes. Twelve shoulders (26%) progressed to TSA at a mean of 2.6 years (range, 0.5-8.2 years). For survivorship analysis, the status of the shoulder (preservation of the native joint or progression to TSA) at a minimum of 5 years was known for 45 of 47 (96%) shoulders. Survivorship was 95.6% at 1 year, 86.7% at 3 years, and 76.9% at 5 years. For surviving shoulders, minimum 5-year subjective outcome data were available for 28 of 32 (87.5%) shoulders at a mean of 5.7 years (range, 5-8 years). The mean ($\pm$SD) ASES score was 84.5 $\pm$ 17, the mean SANE score was 82 $\pm$ 18, the mean QuickDASH score was 15 $\pm$ 13, the mean SF-12 PCS score was 51.0 $\pm$ 9.1, and median patient satisfaction was 9 of a possible 10 points.

Conclusion: This study demonstrates significant improvements in midterm clinical outcomes and high patient satisfaction after the arthroscopic CAM procedure for GHOA, with a 76.9% survivorship rate at a minimum of 5 years postoperatively. For patients looking for an alternative to TSA, the CAM procedure can provide reasonable outcomes and should be considered an effective procedure in appropriately selected, young active patients. Further studies are warranted to evaluate long-term outcomes and durability after this procedure.

Keywords: shoulder; arthroscopic management; osteoarthritis; 5-year outcomes

Glenohumeral osteoarthritis (GHOA) is a common cause of shoulder pain and dysfunction. The initial treatment typically consists of nonoperative measures including physical therapy, pharmacotherapy, injections, and activity modifications. When nonoperative treatment fails, surgical options include arthroscopic debridement, biological interposition

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arthroplasty, hemiarthroplasty, or total shoulder arthroplasty (TSA). TSA is typically considered the gold-standard treatment for bipolar disease. While TSA offers predictable and reliable outcomes for many patients, concerns regarding the longevity of the implants, potential for revision surgeries, increased patient expectations, and higher patient demands contribute to less desirable outcomes in younger patients.[3,5] Because of this, arthroscopic treatment options have been used in an attempt to delay the need for arthroplasty in younger, more active patients or in those patients in whom arthroplasty is otherwise not an acceptable treatment option.[2,4,6,10,11,13,19,20]

Millett and Gaskill[9] and Millett et al[11] introduced the comprehensive arthroscopic management (CAM) procedure in an attempt to address the known pain generators of the osteoarthritic shoulder. The CAM procedure built on previously reported arthroscopic treatment options for arthritis, which included debridement, chondroplasty, synovectomy, loose body removal, capsular release, and subacromial decompression,[19] but also added inferior humeral osteoplasty, axillary nerve neurolysis, biceps tenodesis, and microfracture (Figure 1).

Outcomes after a minimum of 2 years in 30 shoulders showed promising results.[10,13] Patients who underwent the CAM procedure demonstrated significant improvements in the American Shoulder and Elbow Surgeons (ASES) score and pain levels. Furthermore, survivorship analysis, as defined by progression to TSA, showed a 92% survivorship rate at 1 year and an 85% survivorship rate at 2 years. One of the potential problems with this earlier study was the short follow-up of a minimum of 2 years. At that time point, it was conceivable that some patients might simply be coping with an unsatisfactory result and that, in the longer term, they would convert to TSA.

Given the early promising results of the CAM procedure and the concerns about the potential confounder of a shorter follow-up, the purpose of this study was to report midterm outcomes and survivorship for the CAM procedure for the treatment of GHOA at a minimum 5-year follow-up. We hypothesized that a majority of patients who underwent the CAM procedure would demonstrate sustained improvement in postoperative patient-reported outcomes and maintenance of the native glenohumeral joint without conversion to TSA.

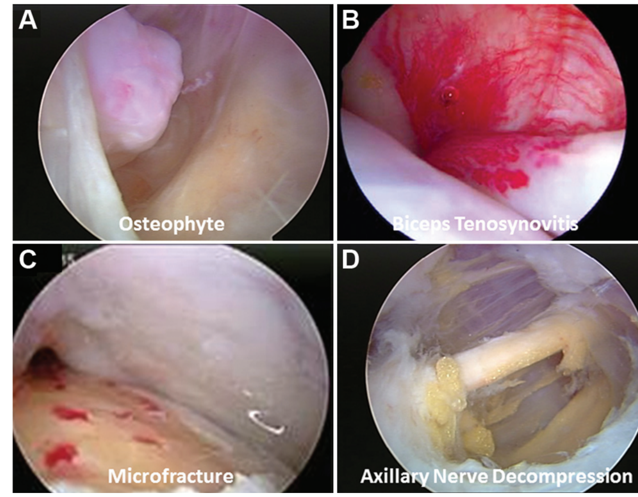

Figure 1. Intraoperative photographs of intra-articular pathological conditions and treatments. (A) Inferior humeral head osteophyte, (B) tenosynovitis of the long head of the biceps tendon, (C) isolated full-thickness cartilage lesion of the humeral head treated with microfracture, and (D) arthroscopic view of the axillary nerve dissected and decompressed during the comprehensive arthroscopic management procedure.

METHODS

Institutional review board approval was obtained before the initiation of this study. Between January 2006 and June 2010, consecutive patients who underwent the CAM procedure for the treatment of GHOA by the senior surgeon (P.J.M.) were included for analysis. All data were prospectively collected within our institutional database and retrospectively reviewed. Demographic data, objective findings, and postoperative patient-reported outcomes were analyzed.

All patients indicated for the CAM procedure had advanced symptomatic GHOA with Kellgren-Lawrence grade 2, 3, or 4 changes on either the humeral or glenoid surface and had failed an extensive course of nonsurgical management including a combination of activity modification, anti-inflammatory medications, physical therapy, viscosupplementation, oral glucosamine, and/or corticosteroid injections. Each patient met clinical and radiographic criteria for TSA but desired a joint-preserving option to avoid or delay joint replacement. Patients were excluded from eligibility for the CAM procedure if they were found to have mild or early-stage osteoarthritis, had not attempted nonoperative measures, had complete irreparable rotator cuff tears, or had bipolar lesions with diffuse flattening of the humeral head on radiographs. On the basis of previous literature, it was also recommended that patients older than

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65 years with less than 2 mm of glenohumeral joint space remaining or with a Walch type B2 or C glenoid shape consider arthroplasty options in lieu of the CAM procedure as outcomes to date in these patients are inferior.[9,10,14,21]

Demographic data collected included age, sex, dominant shoulder, workers' compensation, and treatment history to include any previous surgery. Objective data included the grade of shoulder arthritis classified according to the Kellgren-Lawrence scale. Intraoperative findings, including surgical treatments, were documented along with operative complications. Patient-reported outcome scores were collected preoperatively and included the ASES score, Single Assessment Numeric Evaluation (SANE) score, Quick Disabilities of the Arm, Shoulder and Hand (QuickDASH) score, Short Form–12 (SF-12) Physical Component Summary (PCS) and Mental Component Summary (MCS) scores, and visual analog scale (VAS) for pain score (0 = no pain, 10 = worst pain). These metrics were then collected postoperatively at a minimum of 5 years after the surgical intervention, and patient satisfaction scores were also evaluated (range, 0-10; 10 = very satisfied). Of note, preoperative SANE and QuickDASH scores were not routinely collected before 2010, so analysis was limited to postoperative scores. Patients were evaluated in clinical follow-ups at 2 weeks, 6 weeks, 3 months, and 6 months after the procedure, after which time the patients were invited to follow-up on an as-needed basis. During each clinical visit, range of motion, pain, and patient satisfaction were assessed. Postoperative radiographs were obtained at the 6-week mark and at the final clinical follow-up at 6 months.

In addition, specific questions regarding the level of pain associated with activities including work, recreational athletics, and activities of daily living were asked. Patients who did not return the questionnaire were contacted by telephone or email and asked about further surgery and conversion to TSA for survivorship analysis. These patients were also encouraged by telephone or email to return the follow-up subjective questionnaire for pain and functional assessments. To reduce response bias, no follow-up questions were asked by telephone interview or directly by the physician. The first 30 shoulders in this study had their minimum 2-year data published,[10] so new minimum 5-year data were obtained for this study. Patient-reported outcome scores were collected at a minimum of 5 years postoperatively for the whole cohort.

Surgical Technique

The CAM procedure has been previously described in detail.[9,10,15] To assist with postoperative pain control and allow for early rehabilitation, an interscalene block was used before surgery. The patients were placed in the beach-chair position, and an intraoperative examination of the bilateral shoulders under anesthesia was performed. Capsular contracture was defined as loss of motion of more than 15° when compared with the unaffected healthy shoulder. If a contracture was noted, the plane of the contracture (ie, anterior, posterior, or inferior) was assessed to determine the necessity and location of capsular release. A C-arm was draped sterilely and positioned in the surgical field to allow the visualization of osteophytes and to assist with osteophyte resection.

The surgical procedure began with a diagnostic arthroscopic examination. Degenerative labral tissue and unstable chondral injuries were debrided, loose bodies were removed, and areas of synovitis were addressed with either a mechanical shaver or radiofrequency device. If a focal chondral defect was noted on either the glenoid or humeral head, microfracture was performed.[10] The long head of the biceps tendon was then examined, and if an injury was noted, it was released at its origin and later secured distally utilizing open subpectoral tenodesis. The choice of open tenodesis was chosen based on surgeon preference, previous experience with our active patient population, and prior literature suggesting modest improvements in supination and abduction strength, cosmetic deformity, and cramping when compared with tenotomy.[8,12,16,17,25]

In many cases, an inferior humeral osteophyte was present. Previous literature has shown that this can affect the course of the axillary nerve and may contribute to pain.[13] Therefore, inferior humeral osteoplasty was performed when this deformity was present. An accessory posteroinferior portal was established under spinal needle localization,[15] and through this portal, the symptomatic osteophytes were resected with a high-speed shaver and bur. Curettes were used to remove bone from the anteroinferior quadrant, which can be hard to reach with motorized instruments, and a rasp was used to smooth any remaining bony prominences. Fluoroscopy was used to confirm adequate resection of the inferior humeral osteophyte (goat's beard deformity),[9] with the goal being to restore the normal inferior humeral arch. Importantly, during this step, the resection is assessed dynamically with internal and external rotation of the humerus, and the inferior capsular tissue was preserved to prevent fluid extravasation and to protect the axillary nerve.

After the bony resection, the inferior capsule was released. Axillary nerve neurolysis and decompression were performed if the bony encroachment had changed the course of the nerve as determined on preoperative magnetic resonance imaging (MRI), if observed intraoperatively by displacement of the inferior capsule (the axillary nerve lies, on average, 2.5 mm from the inferior glenohumeral ligament),[18] or if preoperative symptoms suggested nerve compression. Preoperative symptoms considered consistent with axillary nerve impingement or compression were 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. The nerve was carefully decompressed from proximal to distal, taking great care to identify and preserve all arborizing branches.[9] There were instances, however, when axillary nerve compression was not present but a humeral osteophyte occupied a significant portion of the inferior axillary pouch. In these instances, isolated humeral osteoplasty was performed to reshape the humerus to decrease tension on the inferior capsule and to restore mobility and improve kinematics. The anterior and posterior capsules were then released as well. The rotator interval was released, and the subscapularis recess was inspected at this point for loose

TABLE 1
Patient Demographics Noted on Imaging or During Intraoperative Examination[a]

Demographics and Pathoanatomy	n/N (%) or Mean ± SD
Male patient	29/44 (66)
Surgery on dominant arm	23/47 (49)
Prior surgery on index shoulder	19/47 (40)
Workers' compensation claim	3/47 (6)
Kellgren-Lawrence osteoarthritis grade 3 or 4	39/47 (83)
Critical shoulder angle, deg	29.2 ± 4.8
Humeral head spur size, mm	9.6 ± 5.7
SLAP tear grade 2-4	8/47 (17)
Walch type B2 or C	11/47 (23)
Outerbridge classification 3 or 4	45/47 (96)
Loose bodies within joint	24/47 (51)
Humeral head distance to acromioclavicular joint, mm	10.6 ± 2.6
Joint space between glenoid and humeral head, mm	2.3 ± 1.5

[a]SLAP, superior labrum anterior to posterior.

bodies. Subacromial and subcoracoid decompressions were performed next. If the coracohumeral interval was less than 8 mm in women or 10 mm in men, subcoracoid decompression with coracoplasty was then performed.[7] Acromioplasty was performed if a Bigliani type 2 or 3 acromion was present or an impingement lesion was noted. If the long head of the biceps was tenotomized, subpectoral tenodesis was performed with unicortical fixation with a polyetheretherketone (PEEK) tenodesis screw (Arthrex Inc).[10,12]

Postoperative Care

The preoperative placement of a regional block for pain control allowed for the initiation of a rehabilitation program immediately. The main goals were to improve and maintain motion, prevent recurrent scarring, and improve shoulder mechanics. The first 4 to 6 weeks focused on motion restoration with passive- and active-assisted motion. The second phase focused on strengthening from approximately 6 to 12 weeks postoperatively. The final phase was initiated at 12 weeks and focused on return to normal activities. Maximum recovery was expected by 4 to 6 months.

Statistical Analysis

SPSS version 11.0 (SPSS Inc) was used for statistical analyses. An independent t test was used for univariate analysis for normally distributed variables. For variables not distributed normally, the Mann-Whitney or Kruskal-Wallis tests were performed. Bivariate data were analyzed with a chi-square test. Survivorship analysis with progression to TSA as an endpoint was performed using Kaplan-Meier survival curves. The level of significance for univariate analysis, paired t test, Wilcoxon rank-sum test, bivariate chi-square analysis, and correlation analysis was set at $P < .05$.

TABLE 2
Intraoperative Treatments Performed During CAM Procedure[a]

Surgical Treatments	n/N (%)
Chondroplasty with capsular release	47/47 (100)
Removal of prior hardware	4/47 (9)
Removal of loose bodies	24/47 (51)
Humeral head osteoplasty	21/47 (45)
Axillary nerve release/decompression	15/47 (32)
Synovectomy	36/47 (77)
Microfracture of glenoid or humeral head	11/47 (23)
Biceps tenodesis	19/47 (40)

[a]Inferior capsular release was performed in each patient, and further release was conducted based on a preoperative examination. Humeral head osteoplasty and axillary nerve decompression were performed in patients with preoperative symptoms consistent with axillary nerve compression. CAM, comprehensive arthroscopic management.

RESULTS

The first 49 shoulders in 46 consecutive patients who underwent a CAM procedure at a minimum of 5 years from surgery were included. Two patients (2 shoulders) were excluded for refusing to participate before initiation of this study. Because of this, 47 shoulders in 44 consecutive patients who underwent a CAM procedure between January 2006 and June 2010 were included for analysis. Figure 2 demonstrates a flow diagram of the patients included within this cohort. The mean age at surgery was 52 years (range, 27-68 years) in 15 women and 29 men. All patients were recreational athletes with 7 former collegiate or professional athletes, all of whom desired to remain active in recreational activities. Patient demographics with imaging and intraoperative findings are listed in Table 1. Surgical treatments performed are listed in Table 2. Table 3 shows range of motion under anesthesia before and after surgery.

For survivorship analysis, the minimum 5-year shoulder status (defined as preservation of the native shoulder or progression to TSA) was known for 45 of 47 (96%) shoulders. Twelve shoulders (26%), in 9 men and 3 women, progressed to TSA at a mean of 2.6 years (range, 0.5-8.2 years). Survivorship was found to be 95.6% at 1 year, 86.7% at 3 years, and 76.9% at 5 years (Figure 3). Factors associated with failure and progression to TSA were a Walch type B2 or C glenoid shape (P = .006) and preoperative joint space narrowing defined as less than 2 mm of joint space remaining as seen on a Grashey or true anterior-posterior radiograph of the glenohumeral joint (P = .032). Patients who progressed to TSA also presented with significantly lower preoperative ASES scores (53 vs 65, respectively; P = .030). Of note, 2 patients (not considered failures) required secondary arthroscopic surgery; one underwent capsular release for stiffness at 5.6 months, and another underwent a revision CAM procedure at 7.9 years.

Of the 35 shoulders that did not progress to TSA, 3 patients declined completing the subjective survey.

TABLE 3
Intraoperative Range of Motion Before and After CAM Procedure[a]

Range of Motion	Preoperative	Postoperative	*P* Value
Forward elevation, deg	115.6 ± 7.8	155.3 ± 3.8	<.001[b]
External rotation, deg	30.6 ± 4.3	62.4 ± 3.4	<.001[b]
External rotation at 90° of abduction, deg	45.0 ± 5.5	77.5 ± 3.7	<.001[b]
Internal rotation, deg	38.3 ± 3.9	58.5 ± 3.9	<.001[b]

[a]Data are reported as mean ± standard error of the mean. Postoperative range of motion was assessed with the patient anesthetized and after completion of all procedures. CAM, comprehensive arthroscopic management.
[b]Statistically significant difference between preoperative and postoperative values ($P < .05$).

Therefore, 32 shoulders that underwent the CAM procedure were available for analysis, and 28 (87.5%) of these completed patient-reported outcome scores at a mean of 5.7 years (range, 5-8 years). The remaining 4 shoulders were lost to follow-up despite many email and telephone conversations urging the patients to complete the follow-up survey. The analysis group had a mean (±SD) postoperative ASES score of 84.5 ± 17, SANE score of 82 ± 18, QuickDASH score of 15 ± 13, and SF-12 PCS score of 51.0 ± 9.1, all of which improved from the preoperative baseline (Table 4) ($P < .001$). Patients also reported a high median satisfaction of 9 of 10 (range, 2-10). Pain with work, activities of daily living, recreation, sleep, and use of the arms all significantly improved from preoperative to postoperative levels ($P < .001$). Patients reported significant pain relief ($P < .01$) and improved outcome scores at 2 years postoperatively, which they were able to maintain over time (Figures 4 and 5).

Postoperative improvements in the ASES score (r = 0.474; P = .013) and satisfaction (r = 0.397; P = .037) were positively correlated with age. Further, larger critical shoulder angles[20] were significantly correlated with age (r = 0.405; P = .036). In this patient population, no intraoperative or postoperative complications were noted. To summarize, older patients, those with higher preoperative ASES scores, and those with a larger joint space had improved results at a minimum 5-year follow-up.

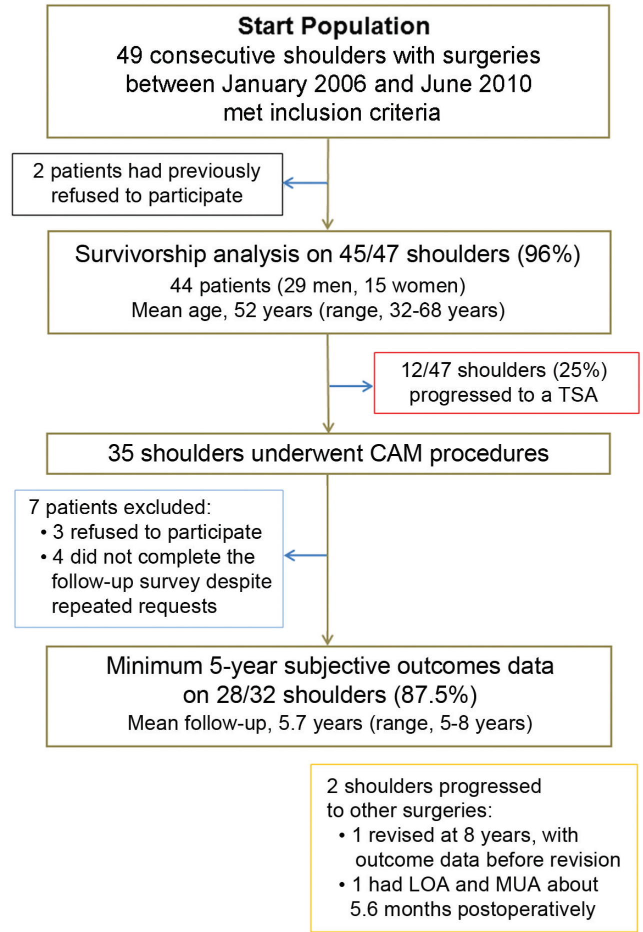

Figure 2. Flow diagram of the patient cohort included in the study. CAM, comprehensive arthroscopic management; LOA, lysis of adhesions; MUA, manipulation under anesthesia; TSA, total shoulder arthroplasty.

DISCUSSION

The results of this study indicate that an aggressive arthroscopic approach may be used in younger patients (the mean age at the time of surgery in this cohort was 52 years [range, 27-68 years]) with advanced GHOA to improve shoulder function, diminish pain, and potentially delay arthroplasty. Patients undergoing the CAM procedure reported significant improvements in pain, range of motion, and patient-reported functional scores, with no perioperative complications and high patient satisfaction (9 of 10). However, 12 patients (12 shoulders) progressed to TSA at a mean of 2.6 years (range, 0.5-8.2 years) after the CAM procedure, and 2 patients (2 shoulders) required further surgery: one was revised at 7.9 years, and one underwent manipulation with capsular release for stiffness at 5.6 months postoperatively. Survivorship was found to be 95.6% at 1 year, 86.7% at 3 years, and 76.9% at 5 years. These outcomes are similar to 2-year outcomes previously reported,[10] and this study goes further to reveal that the results achieved at 2-year follow-up can be sustained at 5-year follow-up. These findings demonstrate that arthroscopic surgery can play an important role in the management of advanced shoulder arthritis, especially in those patients attempting to avoid arthroplasty.

The techniques and indications related to the arthroscopic treatment of GHOA have evolved over time, with prior reports focusing on addressing intra-articular pathological abnormalities through joint lavage, chondrolabral debridement, loose body removal, and synovectomy. These studies generally found that patients improved significantly after surgery; however, results were often short lived, and patients with more advanced disease demonstrated limited benefit.[14,21-24] As arthroscopic treatments and techniques

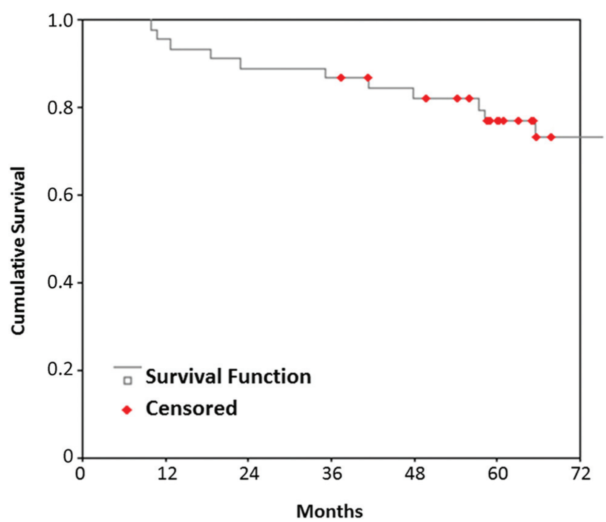

Figure 3. Kaplan-Meier survival analysis curve demonstrating survival at a minimum 5-year follow-up after the comprehensive arthroscopic management procedure.

TABLE 4
Patient-Reported Outcome Scores at Minimum 5-Year Follow-up After CAM Procedure[a]

Outcome	Preoperative	Postoperative	*P* Value
VAS for pain			
Today	3.0 (0-6)	1.3 (0-2)	.003[b]
At worst	7.8 (5-10)	3.4 (0-10)	<.001[b]
ASES	61.3 (33-91.6)	84.5 (30-100)	<.001[b]
SF-12			
PCS	44.3 (35.2-57.6)	51.0 (27.0-59.1)	.004[b]
MCS	55.1 (33.5-64.5)	56.7 (36.4-63.4)	.295

[a]Data are reported as mean (range). ASES, American Shoulder and Elbow Surgeons; CAM, comprehensive arthroscopic management; MCS, Mental Component Summary; PCS, Physical Component Summary; SF-12, Short Form–12; VAS, visual analog scale.
[b]Statistically significant difference between preoperative and postoperative values ($P < .05$).

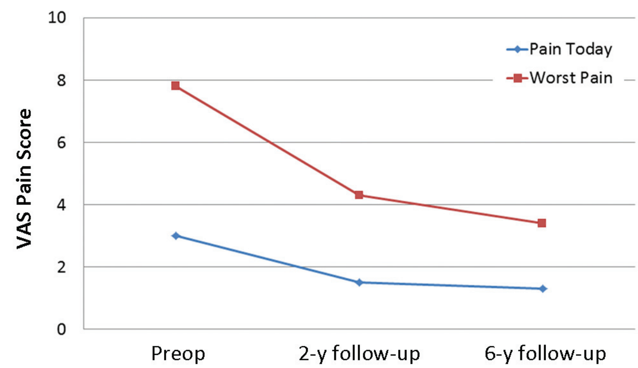

Figure 4. Graphic representation of visual analog scale (VAS) pain scores recorded preoperatively, at 2-year follow-up, and at 6-year follow-up after the comprehensive arthroscopic management procedure. Preop, preoperative.

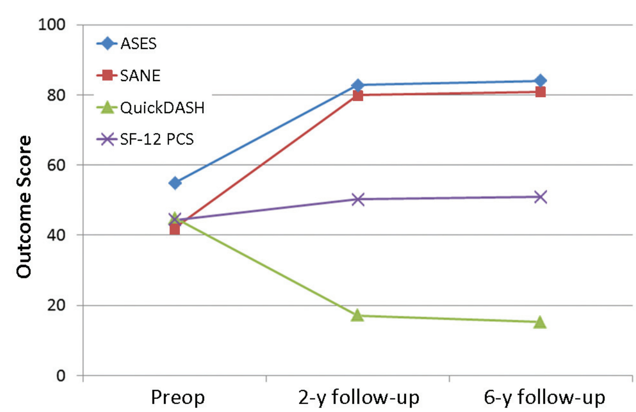

Figure 5. Graphic representation of patient-reported outcome scores recorded preoperatively, at 2-year follow-up, and at 6-year follow-up after the comprehensive arthroscopic management procedure. ASES, American Shoulder and Elbow Surgeons; Preop, preoperative; QuickDASH, Quick Disabilities of the Arm, Shoulder and Hand; SANE, Single Assessment Numeric Evaluation; SF-12 PCS, Short Form–12 Physical Component Summary.

have advanced, some authors have begun to advocate for the inclusion of additional surgical components to address both intra- and extra-articular causes of shoulder pain and dysfunction to improve outcomes and delay the need for more extensive reconstructive or arthroplasty procedures. These recent techniques have yielded promising early results[9,10,15]; however, longer term outcomes have not yet been reported. This study demonstrates results of the CAM procedure for the treatment of GHOA in a group of young active patients at a minimum 5-year follow-up.

In the 1980s, studies investigating the arthroscopic management of GHOA were first reported.[1,6] These early procedures concentrated on glenohumeral lavage, debridement of torn labral tissue, chondroplasty, and removal of loose bodies. However, since the inception of these ideas, more comprehensive and aggressive strategies have been described with promising results. Weinstein et al[24] noted good to excellent results after arthroscopic glenohumeral joint debridement in 80% of patients with mild arthritic changes, but their results were less encouraging in patients with advanced GHOA, particularly when inferior osteophytes were present. More recently, Van Thiel et al[23] published a series of 71 patients treated arthroscopically for GHOA with debridement. They found pain relief and improved function at a mean of 2.25 years postoperatively in 55 of 71 patients. They concluded that significant risk factors for progressing to shoulder arthroplasty included the presence of grade 4 bipolar arthritis as defined by the Outerbridge classification, joint space of less than 2 mm, and large osteophytes.

Important components in the treatment algorithm are proper patient selection and preoperative counseling to manage postoperative patient expectations. A recently published article by Spiegl et al[21] on the role of arthroscopic surgery in the management of GHOA using a theoretical decision model demonstrated that arthroscopic treatment was the preferred treatment strategy for patients younger than 47 years of age, with TSA being the preferred treatment option in patients older than 66 years. Between 47 and 66 years of age, there was no clear advantage for one technique over the other, highlighting the need for individualized treatments based on a number of patient-specific factors in this age group. Our study identified predictive factors associated with the progression to TSA, including Walch type B2 or C, joint space narrowing of less than 2 mm, and patients who presented with significantly lower preoperative ASES scores. Furthermore, postoperative improvements in ASES scores and patient satisfaction were positively correlated with older age; however, our oldest patient was aged 68 years, which makes this a relative comparison in this group of patients. Of those patients who survived past the 2-year time point, there appears to be maintenance of both improved pain and function, which suggests durability of the procedure in the majority of patients. This information can help surgeons who are counseling patients on surgical options for the treatment of GHOA such as arthroscopic management and shoulder arthroplasty. Moreover, it can help provide realistic patient expectations after surgery.

An advantage of the CAM procedure is the ability to address numerous potential sources of pain about the shoulder in a minimally invasive fashion, even in the setting of advanced degenerative changes, such as those demonstrating Kellgren-Lawrence grade 3 or 4 lesions with greater than 2 mm of joint space remaining. This approach allows the excision of large osteophytes; removal of loose bodies; release of the biceps tendon; treatment of chondral defects; and debridement of the labrum, synovial tissue, or other soft tissue injuries. Additionally, a unique feature of the CAM procedure is that the axillary nerve is decompressed both indirectly by resecting the inferior osteophytes from the humeral head and directly from neurolysis. The rationale for this approach is that many patients with osteoarthritis have posterior shoulder pain in the quadrangular space that may be caused by compression of the axillary nerve. In addition, Millett et al[13] have noted that patients with advanced shoulder arthritis and projecting inferior osteophytes have MRI evidence of atrophy of the teres minor. Consideration of the decreased interval between the axillary nerve and the glenohumeral bony structures may suggest that impingement of the nerve is occurring. Although it is difficult to attribute the results of our study to this decompression alone, Skelley et al[20] have found that isolated glenohumeral joint debridement and capsular release without associated procedures yielded only temporary improvement in patient-reported outcomes and did not provide substantial benefit to justify these procedures in isolation. On the basis of these data, as well as our findings, it is certainly plausible to think that the addition of concomitant procedures, such as this step, may play an important role in helping explain why patients who underwent neurolysis had better motion, better subjective outcomes, and less pain.

The findings of this study are consistent with our hypothesis. The majority of patients who underwent the CAM procedure demonstrated sustained improvement in postoperative patient-reported outcomes and maintenance of the native glenohumeral joint without conversion to TSA. While the present study demonstrates promising midterm results after the CAM procedure for the treatment of GHOA, there are several limitations. First, this procedure should only be attempted by an experienced shoulder arthroscopic surgeon because of the technical challenges involved with the excision of osteophytes in an otherwise tight and scarred arthritic shoulder. Second, the patient population in this study was highly active, healthy, and highly motivated to avoid TSA. The results that the authors obtained may not be generalizable because of the unique nature of the patient population that was treated and because of the technical aspects of the procedure. While there were no intraoperative or postoperative complications associated with the procedure in this series, there is a potential risk given the proximity of the axillary nerve. An inherent limitation of this study, which is retrospective, is the lack of a control or comparison group when analyzing patient outcomes. All patients had clinical and radiographic features, other than age, which would make them candidates for TSA. This procedure is designed to extend the life span of the native glenohumeral joint before proceeding with shoulder arthroplasty, and patients in this series were unwilling to be randomized to a TSA treatment arm. While short-term benefits were shown in the earlier studies,[4,9,10,15] it does seem likely that if these effects were short lived or placebo related, outcomes at 5 years would demonstrate a greater diminution in the results. Next, our definition of failure after the CAM procedure in our survivorship analysis was progression to arthroplasty. This may underestimate the true prevalence of dissatisfied patients who are coping with continued pain or limited range of motion about their shoulder without electing to proceed with shoulder replacement. While it is plausible that some patients were simply "coping" with a suboptimal shoulder, our overall median satisfaction at a minimum 5-year follow-up was 9 of 10, indicating that the vast majority of patients continued to be very satisfied with their outcomes.

CONCLUSION

This study demonstrates significant improvements in midterm clinical outcomes and high patient satisfaction after the arthroscopic CAM procedure for GHOA, with 76.9% survivorship at a minimum of 5 years postoperatively. For patients looking for an alternative to TSA, the CAM procedure can provide reasonable outcomes and should be considered an effective procedure in appropriately selected, young active patients. Further studies are warranted to evaluate long-term outcomes and durability after this procedure.

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