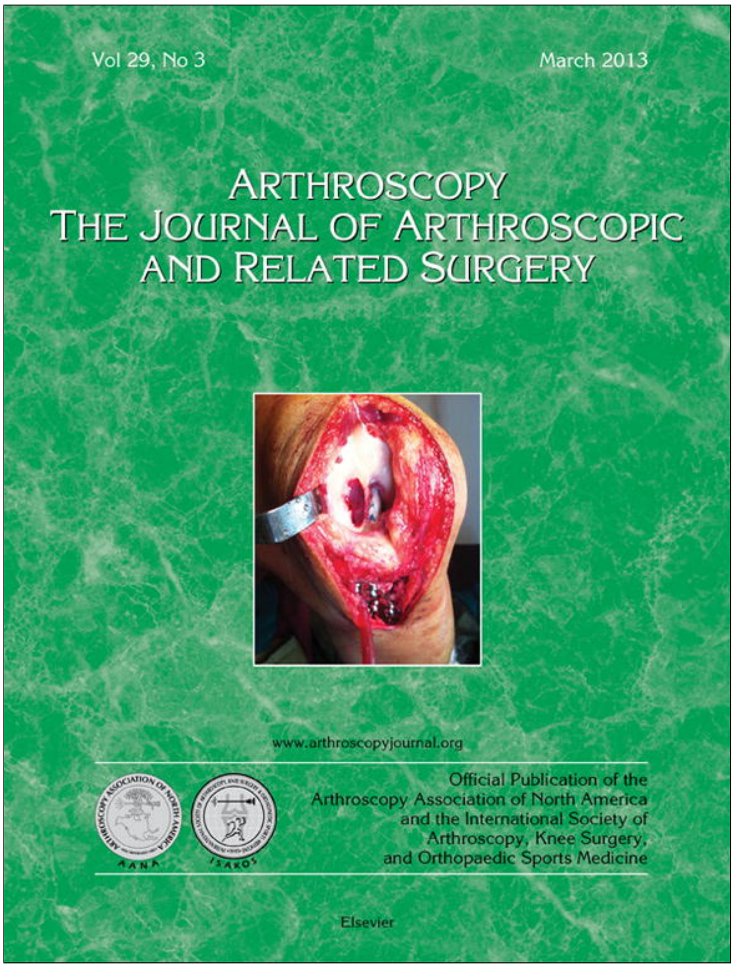
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Original Article With Video Illustration

Comprehensive Arthroscopic Management (CAM) Procedure: Clinical Results of a Joint-Preserving Arthroscopic Treatment for Young, Active Patients With Advanced Shoulder Osteoarthritis

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Purpose: The purpose of this study was to examine the surgical outcomes of 29 active patients (30 shoulders) with end-stage, symptomatic glenohumeral arthritis undergoing the comprehensive arthroscopic management (CAM) procedure. **Methods:** In this institutional review board–approved study, patients with advanced glenohumeral osteoarthritis (OA) underwent the CAM procedure, a joint-preserving arthroscopic treatment. All subjects were candidates for shoulder arthroplasty. The CAM procedure involves the combination of glenohumeral chondroplasty; removal of loose bodies if present; humeral osteoplasty and osteophyte resection (goat's beard deformity); anterior, posterior, and inferior capsular release; subacromial decompression; axillary nerve neurolysis; and biceps tenodesis. Outcome measures included pain, American Shoulder and Elbow Surgeons score, Single Assessment Numeric Evaluation score, QuickDASH (short version of Disabilities of the Arm, Shoulder and Hand questionnaire) score, and satisfaction. For survivorship analysis, failure was defined as progression to shoulder arthroplasty. **Results:** The mean age was 52 years (range, 33 to 68 years), and there were 23 men and 6 women. Of the 30 shoulders, 6 progressed to an arthroplasty at a mean of 1.9 years (range, 0.9 to 3.4 years). Patients with less than 2.0 mm of joint space on radiographs were more likely to undergo arthroplasty ($P = .037$). For shoulders that did not progress to arthroplasty (n = 24), the mean follow-up was 2.6 years (range, 2.1 to 4.7 years). The American Shoulder and Elbow Surgeons scores significantly improved from 58 points (SE, 2.4) to 83 points (SE, 3.3) ($P < .001$), and pain levels decreased with activities of daily living, work, recreation, and sleep ($P < .05$). The median patient satisfaction rating was 9 (range, 3 to 10). Survivorship analysis showed a 92% survival rate at 1 year and 85% at 2 years. Patients with larger osteophytes had greater improvement in postoperative range of motion but were less satisfied ($r = 0.479$, $P = .038$). **Conclusions:** The CAM procedure reduced pain, improved function, and provided reasonable short-term durability for our cohort of young, active patients with advanced shoulder OA and may serve as a joint-preserving alternative to arthroplasty. Patients with less than 2 mm of joint space had a significantly higher failure rate. The CAM procedure is a viable surgical option in young, active patients with advanced OA, showing survivorship of 85% at 2 years. **Level of Evidence:** Level IV, therapeutic case series.

Osteoarthritis (OA) of the glenohumeral joint is a frequent and disabling cause of shoulder pain and dysfunction. Joint space narrowing, stiffness, and osteophyte formation are associated with symptomatic OA. Although the exact incidence of shoulder OA is unknown, it has been associated with increasing age and with prior shoulder trauma.[1,2] In our referral practice, we treat a very active patient population and, unfortunately, see a number of young and active patients with advanced OA of the shoulder. Currently, nonoperative modalities including physical therapy, pharmacotherapy, steroid injections, viscosupplementation, and activity modification are the initial treatment of choice.[3,4] When these approaches fail, many surgical options are considered, including arthroscopic and open debridement, nonprosthetic or biologic interposition arthroplasty, hemiarthroplasty, and total shoulder arthroplasty.[3-10]

Although total shoulder arthroplasty provides the most predictable outcomes for many patients with advanced degenerative joint disease, young or active patients may wish to avoid or delay arthroplasty because they want to maintain a high level of activity.

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Furthermore, the increased morbidity of arthroplasty procedures and durability concerns make these procedures less desirable for younger patients.[11] For this reason, we have developed a joint-preserving arthroscopic treatment approach for young, active patients with advanced shoulder OA. We have called this the CAM procedure, which is an acronym for comprehensive arthroscopic management. Because patients with advanced OA frequently have a number of different pain generators and various pathoanatomic features that lead to functional deficits, such as limited motion, all of these pathoanatomic factors need to be considered and addressed to optimize outcome. The CAM procedure therefore entails similar arthroscopic debridement procedures such as chondroplasty, synovectomy, loose body removal, and subacromial decompression as has been described previously.[10,12] In addition, the CAM procedure also involves (1) an extensive capsular release to restore glenohumeral motion; (2) humeral osteoplasty and osteophyte excision to recontour the humeral head, restore abduction, and potentially decompress impingement on the axillary nerve; (3) axillary nerve neurolysis when scarring is seen around the nerve or there is significant compression from an inferior humeral osteophyte; and (4) biceps tenodesis when there is significant biceps tenosynovitis, a degenerative SLAP tear, an hourglass deformity, or a pulley lesion. These are the features that distinguish the CAM procedure from previously described debridement procedures.

The purpose of this study is to examine the surgical indications, technique, and early outcomes in a cohort of patients who have undergone the CAM procedure. We hypothesized that patients undergoing the CAM procedure for advanced glenohumeral OA would have improved function, diminished pain, and low rates of conversion to arthroplasty.

Methods

Between January 2006 and September 2009, 147 patients had surgical treatment for glenohumeral OA. Approximately 20%, or 29 patients (with 30 shoulders), underwent the CAM procedure for their shoulders. All patients had advanced glenohumeral OA and wanted an alternative treatment to potentially delay arthroplasty. Institutional review board approval was obtained before we conducted this study. In all cases, the diagnosis of moderate to advanced glenohumeral OA was made based on preoperative radiographs and confirmed at the time of surgery. All patients had either Kellgren-Lawrence grade III or IV changes on 1 or both glenohumeral surfaces.[1,13,14] All patients had previously been treated conservatively including activity modification, anti-inflammatory medications, physical therapy, viscosupplementation, oral glucosamine, and corticosteroid injections. Exclusion criteria were patients with only mild OA and those with complete rotator cuff tears. Sizes of osteophytes (in millimeters) and glenohumeral joint space (in millimeters) were obtained on preoperative radiographs by use of a calibrated measurement system (Stryker OfficePACS Power Viewer; Stryker, Flower Mound, TX). Joint space measurements were performed on the anteroposterior (AP) radiographic view for AP-superior, AP-central, and AP-inferior aspects from the glenoid to the humeral head.[15] For final analysis, the smallest joint space measurement was used.

Operative Technique

The CAM procedure consists of several distinct steps (Video 1, available at www.arthroscopyjournal.org).[3,6,16] The procedure was performed with patients under general anesthesia augmented with an interscalene block. All patients were examined under anesthesia and range of motion was compared with the opposite side. Capsular contracture was defined as loss of motion of more than 15° compared with the contralateral shoulder. The plane of contracture (anterior, posterior, or inferior) was carefully assessed to plan the amount of capsular release. Patients were positioned in the beach-chair position so that the arm could be freely moved to help identify whether an osteophyte was hindering motion and to visualize the osteophyte during its arthroscopic excision. After standard posterior and anterosuperior portals were established, a diagnostic arthroscopy was performed. Of the shoulders, 21 had diffuse Outerbridge grade IV changes[17] to the humeral head cartilage surface and 5 had grade III changes (Fig 1). The glenoid showed Outerbridge grade IV changes in 20 shoulders and grade III changes in 6 shoulders. Degenerative labral tissue and unstable cartilage, which were present in all 30

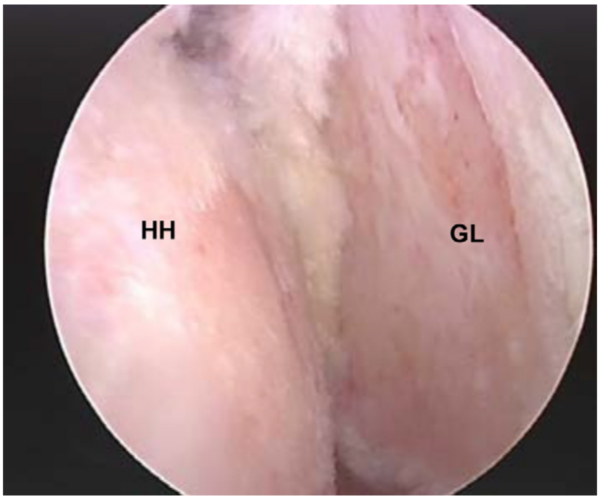

Fig 1. Arthroscopic view of diffuse Outerbridge grade IV glenohumeral OA on both the humeral head (HH) and glenoid (GL) surfaces.

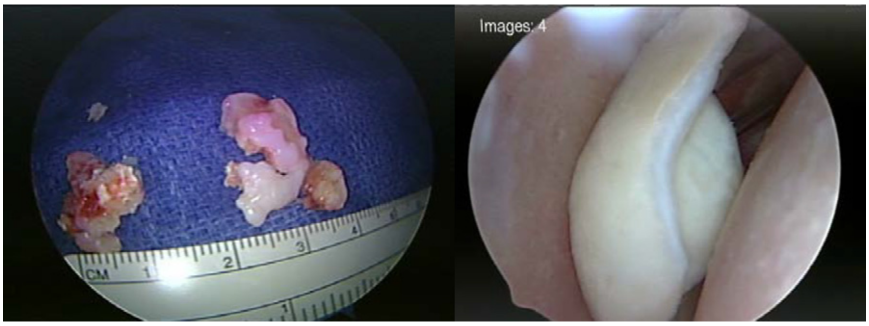

Fig 2. Loose bodies within the glenohumeral joint.

shoulders, were meticulously debrided back to a stable border, and any loose bodies encountered were removed. Arthroscopic debridement of the glenohumeral joint, articular surfaces, and labral tissue was performed in all cases. For synovitis, we performed excision with a shaver or ablation with a radiofrequency probe. Microfracture was performed in 4 shoulders when a focal chondral lesion that had a stable defined border was identified on either the glenoid (4) or humeral surface (2). Nine shoulders had loose bodies removed (Fig 2). Advanced synovitis was found in 20 shoulders and was treated by ablation with a thermal radiofrequency probe (Table 1).

A posteroinferior portal was then established under direct visualization by use of a spinal-needle localization technique. This portal provided superior visualization of the axillary pouch, inferior osteophyte, inferior capsule, and axillary nerve (Fig 3). If an inferior osteophyte (goat's beard deformity) was identified, it was excised with a high-speed bur and arthroscopic shaver (Fig 4). The arm was rotated into internal and external rotation to help to ensure that the spur could be excised. In some cases the spur could only be partially excised. Fluoroscopy was used in all cases during the osteophyte excision to ensure adequate bony resection. After the excision of the osteophyte, an inferior capsular release was performed. The capsule was released under direct vision with arthroscopic scissors and a monopolar radiofrequency probe (OPES; Arthrex, Naples, FL). The inferior capsule was released only after osteophyte excision and humeral osteoplasty because the inferior capsule helped to protect the axillary nerve. Keeping the capsule intact also improved visualization in the axillary pouch.

Table 1. Co-pathologies and Other Surgical Treatments

Surgical Treatment	No. of Shoulders Receiving Treatment
Glenohumeral debridement with global aggressive capsular release	30 of 30
Loose body removal	9 of 30
Synovectomy	20 of 30
Microfracture	4 of 30
Osteoplasty	14 of 30
Axillary nerve release	7 of 30
Arthroscopic subacromial decompression	10 of 30
Biceps tenodesis	8 of 30

If patients complained of posterior or lateral shoulder pain on preoperative physical examination, if there was encroachment on the nerve on the preoperative magnetic resonance imaging (MRI) studies (Fig 5), or if the spur appeared to be directly encroaching on the axillary nerve during the arthroscopic evaluation, then an axillary nerve decompression was performed.[6,16] The axillary nerve was identified after the surgeon performed the inferior capsular release by bluntly dissecting the nerve from the soft tissues. Neurolysis was performed from proximal to distal with a blunt probe and arthroscopic punches. The release was performed from proximal to distal to avoid injury to the nerve which frequently arborized with a number of branches (Fig 6).

Anterior and posterior capsular releases were then performed in a systematic fashion. The soft tissue in the rotator interval medial to the biceps sling and inferior to the superior glenohumeral ligament was released by use of a combination of a mechanical shaver and an electrocautery probe. The anterior and posterior capsular releases were typically performed after the humeral osteoplasty and excision of the inferior osteophyte to prevent fluid extravasation. In a right shoulder, the anterior capsule was released from the rotator interval inferiorly to the 5-o'clock position, staying just lateral to the labrum. Care was taken to avoid damaging the subscapularis tendon. The arthroscope was then placed in the anterosuperior portal and a posterior release was performed from the 7- to 11-o'clock position using the posterior portal for instrumentation. Gentle manipulation was then performed after the capsular release to determine how much motion had been restored.

The arthroscope was inserted into the subacromial space through the posterior portal. A thorough bursectomy was performed to assess the integrity of the rotator cuff. If an impingement lesion was found (scuffing or fraying of coracoacromial ligament) or a type III acromion was present, a formal acromioplasty was performed with an arthroscopic bur through a lateral portal. Thirty shoulders underwent subacromial bursectomy, with 10 having a formal decompression with an acromioplasty. A biceps tenodesis was performed in 8 shoulders through a subpectoral technique with a polyetheretherketone (PEEK) tenodesis screw (Arthrex, Naples, FL) in all cases.

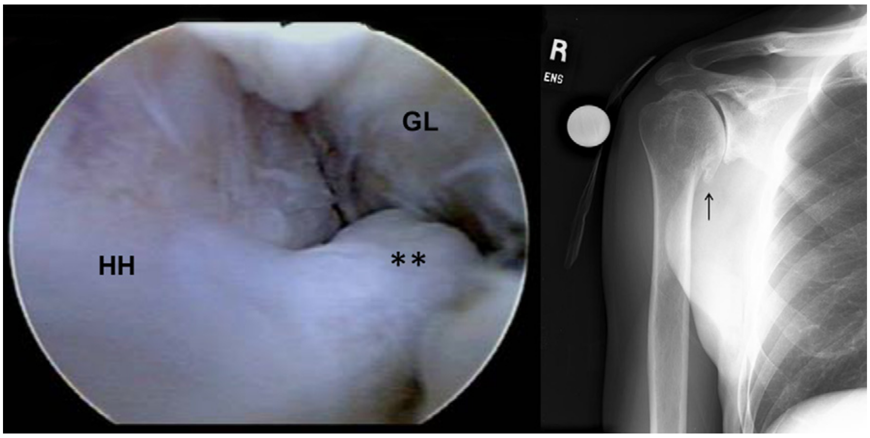

Fig 3. Arthroscopic image of an inferior osteophyte (asterisks) and corresponding preoperative radiograph, showing an intra-articular osteophyte (arrow). (GL, glenoid; HH, humeral head.)

Indications for biceps tenodesis included severe tendinopathy, tenderness at the groove, subluxation of the tendon, tendon tearing, or a degenerative SLAP tear. Biceps tenodesis was preferred over simple tenotomy given the patients' young age and desired activity level.

Postoperative Care

The principal goals of the rehabilitation program included the maintenance of joint motion, prevention of scar formation, and improvement of shoulder kinematics. All patients progressed through a 3-phase rehabilitation protocol, however, individual tailoring of the program was performed when necessary. The initial phase was characterized by passive and active-assisted range-of-motion and stretching exercises. Patients proceeded with caution while stretching to avoid joint inflammation and pain. The second phase consisted of early strength training and continued stretching. Around 6 weeks postoperatively, patients progressed to functional strengthening including elastic resistance exercises. The final phase was initiated at approximately 3 months after surgery with the goals of advanced strength training and return to sport. Patients typically underwent clinical follow-up at 2 weeks, 6 weeks, and 3 to 4 months postoperatively.

Outcome Analysis

The data were prospectively collected and stored in a patient data registry that included demographic factors, surgical findings, mechanism of injury, prior injuries, and preoperative and postoperative objective and subjective outcome measures. Range-of-motion data were recorded in degrees. Postoperative range-of-motion data were documented from examination under anesthesia at surgery and from clinical examinations at the latest follow-up but no earlier than 2 months postoperatively. At the initial presentation, patients completed a self-administered questionnaire that assessed their pain and function. Postoperatively, patients completed the same questionnaire for the evaluation of pain, function, and satisfaction with the surgical outcomes. Functional outcomes were measured with the American Shoulder and Elbow Surgeons (ASES)[18] score, the Single Assessment Numeric Evaluation score,[19] and QuickDASH (short version of Disabilities of the Arm, Shoulder and Hand questionnaire) score.[20] Patient satisfaction (on a scale from 1, very unsatisfied, to 10, very satisfied), VAS pain (on a scale from 0, no pain, to 10, worst pain), and both the physical and mental components measuring general health, the Short Form Health Survey (SF-12) were also recorded, along with the need for additional surgeries and

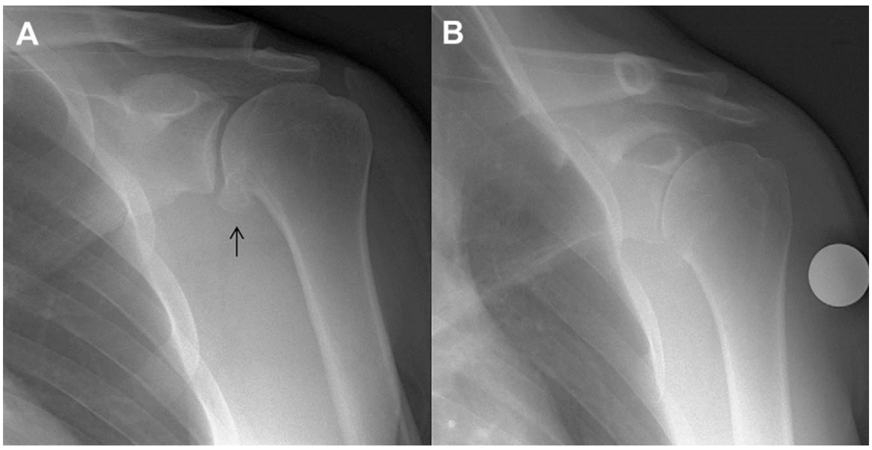

Fig 4. (A) Preoperative image of humeral head osteophyte (goat's beard deformity) (arrow). (B) Postoperative image showing resection. The demarcation of the inferior humeral head is noted, indicating bone loss from the osteophyte removal.

Fig 5. Preoperative MRI showing encroachment on axillary nerve of osteophyte. The circle highlights the proximity of axillary neurovascular bundle to the osteophyte. A humeral cyst (asterisk) is also visible.

any complications. Patients who did not return the questionnaire were contacted by phone or e-mail and asked about further surgery for the survivorship analysis. These patients were also encouraged to return the follow-up subjective questionnaire for pain and functional assessment. To reduce bias, no follow-up questions were obtained by phone or email interview. When contacted, 2 patients declined to complete the follow-up questionnaires, so they were listed as "refused to follow-up." However, we still used the preoperative, surgical, and survivorship data that had already been obtained. For survivorship analysis, progression to shoulder arthroplasty was defined as failure.

Statistical Analysis

We performed survivorship analysis for failure rate of the CAM procedure using Kaplan-Meier survival analysis taking into account censored data. Interclass and intraclass correlation was measured for osteophyte size by use of the κ coefficient.[21] All continuous variables were normally distributed, so comparisons were performed with an independent *t* test. The level of significance for univariate, paired *t* tests; the Wilcoxon rank sum test; bivariate χ^2 analyses; and correlations analysis was set at $P = .05$. Statistical data analysis was performed with SPSS software, version 11.0 (SPSS, Chicago, IL).

Results

The mean age of the patient population was 52 years (range, 33 to 68 years) and there were 23 men and 6 women. Of the 29 patients (30 shoulders), 2 refused to undergo follow-up and 6 (6 shoulders) progressed to arthroplasty. Because not every patient who progressed to arthroplasty completed a questionnaire before arthroplasty, these patients' postoperative data were not used in the final outcomes analysis and they were defined as failures in the survivorship analysis. The mean subjective follow-up on 18 of 22 shoulders (82%) that did not fail was 2.6 years (range, 2.1 to 4.7 years). All patients had significant improvements in range of motion after the procedure ($P < .05$) (Table 2). Subjectively, the ASES score significantly improved from 58 (range, 42 to 78) preoperatively to 83 (range, 60 to 100) postoperatively ($P < .001$). Patients had less pain postoperatively with activities of daily living ($P < .001$), work ($P = .002$), recreation ($P < .001$), and sleep ($P < .001$) compared with preoperative levels (Table 3). The mean postoperative DASH and Single Assessment Numeric Evaluation scores were 17 (range, 0 to 41) and 87 (range, 70 to 100), respectively. No patients had complications, and the median patient satisfaction rating at final follow-up was 9 (range, 3 to 10).

Univariate Analysis

There was excellent interobserver and intraobserver agreement for humeral osteophyte size, with κ values of 0.976 and 0.978, respectively. There was almost perfect agreement for joint space measurements (Table 4).

Fourteen patients had an osteophyte removed from the humeral head, with a mean size of 14.7 mm (range, 8.6 to 28.7 mm). There was a significant positive correlation between the size of humeral head osteophytes and improvement in forward elevation obtained

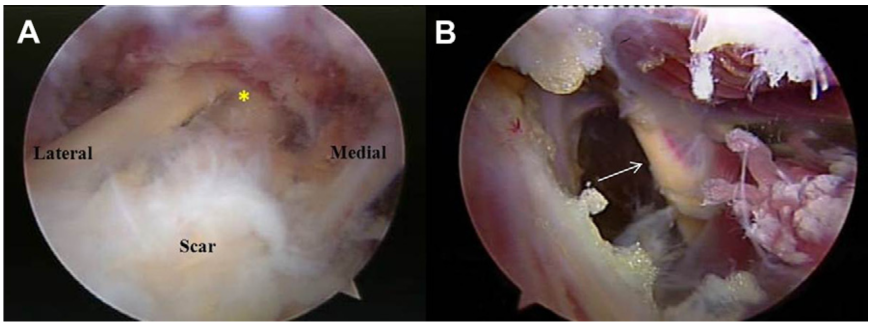

Fig 6. (A) Arthroscopic view of a scarred axillary nerve that is arborized with a number of branches (asterisk). (B) Tethered axillary nerve before release (arrow).

Table 2. Intraoperative and Postoperative ROM

	EUA Mean (SE)			Mean Active ROM 2-3 mo Postoperatively (SE)	*P* Value Compared With Preoperative EUA
	Preoperative	Postoperative	*P* Value		
Forward elevation	98.2° (9.4°) (range, 20°-180°)	152.9° (4.4°) (range, 20°-180°)	< .001*	152° (7.3°) (range, 90°-180°)	.001*
External rotation	13.4° (4.7°) (range, −15°-80°)	62.2° (3.2°) (range, 20°-90°)	< .001*	46° (5.3°) (range, 15°-75°)	.014*
External rotation at 90° abduction	27.3° (5.6°) (range, −30°-180°)	75.4° (2.8°) (range, 45°-100°)	< .001*	96° (5.4°) (range, 70°-130°)	< .001*
Internal rotation	23.8° (4.3°) (range, 0°-80°)	60.8° (3.5°) (range, 20°-90°)	< .001*	NA	

EUA, examination under anesthesia; NA, not available; ROM, range of motion; SE, standard error of mean.
*Statistical significance.

at surgery ($r = 0.479$, $P = .038$). However, patients who had osteophytes removed were less satisfied at final follow-up ($P = .004$). Patients who participated in recreational activities that involved overhead activities had larger osteophytes (12.3 mm *v* 5.7 mm) than those who did not ($P = .028$). Patients who had an axillary nerve release showed greater improvements in motion, particularly internal rotation (56° *v* 36°, $P = .024$), and had a higher postoperative physical component score on the SF-12 (57.5 *v* 48.2, $P = .002$) than those who did not have a nerve release.

Preoperative external rotation at 90° of abduction was correlated with satisfaction at follow-up ($r = 0.572$, $P = .033$) suggesting that patients with more restricted external rotation motion before surgery were more satisfied with their surgical outcomes. Lower postoperative ASES scores were correlated with less intraoperative improvement in internal rotation ($r = 0.573$, $P = .040$).

Patients with Kellgren-Lawrence grade IV chondral damage as graded on radiographs were less satisfied than patients with grade III lesions, with median satisfaction of 7 versus 9 ($P = .02$). Patients who progressed to arthroplasty had significantly less joint space (0.69 mm *v* 2.9 mm, $P = .030$) and lower preoperative ASES scores (49 *v* 60, $P = .034$) than patients who did not progress. Of 13 patients with less than 2.0 mm of joint space, 5 (38%) progressed to arthroplasty. Patients with less than 2.0 mm of joint space were 7.8 times more likely to progress to an arthroplasty ($P = .037$).

Survivorship Analysis

Six patients (6 shoulders) progressed to total shoulder arthroplasty at a mean of 1.9 years (range, 0.9 to 3.4 years). Survivorship was calculated to be 92% at 1 year and 85% at 2 years (Fig 7). Patients who ultimately progressed to arthroplasty had a significantly lower mean preoperative ASES score of 39 versus 58 ($P = .001$).

Discussion

The results of this study indicate that an aggressive arthroscopic approach may be used in younger patients with advanced glenohumeral OA to improve shoulder function, diminish pain, and potentially delay arthroplasty. Patients undergoing the CAM procedure had significant improvements in pain relief, range of motion, and subjective functional scores, with no perioperative complications and high patient satisfaction. However, 6 patients (6 shoulders) in this series progressed to total shoulder replacement at a mean of 1.9 years (range, 1 to 3.4 years) after the CAM procedure. Survivorship was calculated to be 92% at 1 year and 85% at 2 years. Patients with less than 2.0 mm of glenohumeral joint space were 7.8 times more likely to

Table 3. Outcome Measures

	Preoperative	Postoperative	*P* Value
Mean pain today (SE)	3.5 (0.477) (range, 0-6)	1.7 (0.547) (range, 0-7)	.006*
Mean pain at worst (SE)	8.3 (0.7) (range, 5-10)	4.6 (0.86) (range, 0-10)	.002*
Mean ASES score (SE)	58 (2.6) (range, 33-78)	83 (3.7) (range, 60-100)	< .001*
Mean SF-12 PCS score (SE)	42.8 (1.4) (range, 35.8-50.4)	49.4 (2.7) (range, 37.1-60.5)	.042*
Mean SF-12 MCS score (SE)	53.3 (3.6) (range, 33.5-66.0)	55.9 (2.5) (range, 36.4-63.4)	.509
Do you have pain with your arm at your side?	Mild	None	< .001*
Does pain affect your sports endurance?	Moderate	Mild	.015*
Does pain affect your sports speed?	Moderate	Mild	.015*
Does pain affect your sports accuracy or agility?	Severe	Mild	.003*
Does pain affect your ability to compete?†	Moderate	Mild	.011*

MCS, mental component summary; PCS, physical component summary; SE, standard error of mean; SF-12, Short Form 12.
*Statistical significance.
†The answer was rated on scale from 1 to 6.

Table 4. κ Agreement for Joint Space Measurements

	Observer 1 Mean in mm (Range)	Observer 2 Mean in mm (Range)	κ
Humeral osteophyte size	8.67 (0-28.70)	8.01 (0-26.50)	0.976 (95% CI, 0.934-0.990) Almost perfect agreement
AP radiograph			
Superior joint space	4.23 (0-8.10)	4.97 (1.33-8.72)	0.572 (95% CI, 0.057-0.809) Moderate agreement
Central joint space	3.22 (0-6.90)	3.09 (0.32-7.78)	0.870 (95% CI, 0.704-0.943) Almost perfect agreement
Inferior joint space	3.28 (0-7.20)	3.45 (0-7.49)	0.837 (95% CI, 0.630-0.928) Almost perfect agreement
Smallest joint space	2.94 (0-6.0)	2.50 (0-6.16)	0.925 (95% CI, 0.832-0.967) Almost perfect agreement

CI, confidence interval.

progress to an arthroplasty ($P = .037$). These outcomes show that arthroscopy can play an important role in the management of advanced shoulder OA, especially in those patients attempting to avoid an arthroplasty procedure, but they also highlight that, perhaps with improved patient selection, we may be able to improve survivorship in the future. Perhaps patients with less than 2.0 mm of joint space would be better off undergoing total shoulder arthroplasty as the index procedure. Although the outcomes from this study show some promise, longer-term follow-up is undoubtedly necessary to assess the durability of the CAM procedure and to better define the ideal candidates for this procedure.

The first reports of arthroscopic management of OA of the glenohumeral joint were published in the 1980s.[3,8] These procedures primarily consisted of glenohumeral lavage, debridement of torn labral tissue and cartilage flaps, and removal of loose bodies. Since that time, more aggressive arthroscopic approaches have been described in an attempt to expand the indications to patients with more advanced OA. In these studies additional procedures including osteophyte excision, capsular release, and biceps tenodesis have been proposed to improve surgical outcomes. Overall, the results of these studies have yielded reasonable results, however, patients with more extensive degenerative disease including larger osteophytes and bipolar lesions had poorer outcomes.[1,8-10,21] Weinstein et al.[10] published good or excellent results after arthroscopic debridement alone in 80% of patients with mild arthritic changes, but their results were less encouraging in patients with advanced glenohumeral OA and they found inferior results when inferior spurs were present. Most recently, Van Thiel et al.[21] published a series of 71 patients treated arthroscopically for glenohumeral OA 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 arthroplasty included the presence of grade IV bipolar arthritis, joint space of less than 2 mm, and large osteophytes. Our study confirmed that patients with less than 2 mm of joint space were 7.8 times more likely to progress to arthroplasty. However, the presence of osteophytes or grade IV OA was not associated with progressing to shoulder arthroplasty in our series. Compared with these other studies, our patients actually had more advanced OA, which we treated more aggressively, addressing not only the glenohumeral joint and capsular tightness but also the biceps tendon, inferior osteophytes, axillary nerve, and subacromial space. By addressing all of these potential pain generators, we were able to obtain good to excellent results even in a patient population with end-stage OA that included large osteophytes, joint space narrowing, and involvement of both humeral and glenoid surfaces.

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 OA have posterior shoulder pain in the quadrangular space that may be due to compression of the axillary nerve. In addition, the senior author has noted that patients with advanced shoulder OA and projecting inferior osteophytes have MRI evidence of atrophy of the teres minor.[22] Consideration of the decreased interval between the axillary nerve and the

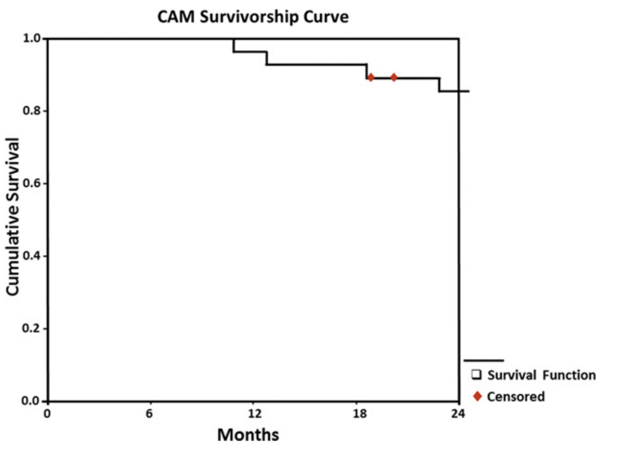

Fig 7. Overall survivorship was 92% at 1 year after CAM surgery and 85% at 2 years.

glenohumeral bony structures (that may also be appreciated on MRI) may suggest that impingement of the nerve is occurring. Although it is difficult to attribute the results of our study to this decompression alone, we think that this step may play an important role in helping explain why patients who underwent neurolysis had better motion, better subjective outcomes, and less pain.

Recent attention has been given to the biceps tendon as a potential pain generator in the shoulder.[23,24] Several studies have shown that releasing the biceps tendon provides significant pain relief in patients with irreparable massive rotator cuff tears.[25,26] Although the underlying shoulder pathology is different in our population compared with other studies in which patients predominantly had rotator cuff tears, our study suggests that the biceps tendon is still an important structure to be considered. Given the low morbidity of performing a biceps tenodesis, we have a low threshold to address the long head of the biceps tendon when performing the CAM procedure.

Kircher et al.[27] found that features of OA, such as loss of joint space and osteophyte size, were predictive factors for function but not pain. However, in our study, factors such as age and preoperative recreational activity were not associated with inferior subjective outcomes.

We did find that patients with Kellgren-Lawrence grade IV lesions were less satisfied than patients with grade III lesions. Preoperative range of motion may be associated with postoperative outcomes such that patients who present with more restricted motion will benefit more from the surgery and have larger gains in their subjective outcomes. As in the study by Kircher et al.,[27] we found that patients with less than 2 mm of joint space were more likely to fail.

Limitations

This study has several limitations. First, the CAM procedure should only be attempted by experienced shoulder arthroscopists because of the technical difficulties involved with excision of osteophytes in an otherwise tight and scarred arthritic shoulder joint and the potential for nerve damage. Second, the total number of patients limited our ability to run multivariate analysis to determine which procedure—osteoplasty, capsular release, or axillary nerve neurolysis—had the most robust association with improvements in pain and function. Finally, there is no control or comparison group in this study. We considered comparing the CAM procedure group with a group of young patients who underwent primary total shoulder arthroplasty, however, we did not have adequate numbers in our patient registry to perform such an analysis. There are a number of other potential limitations to this study. For example, the Kellgren-Lawrence grading scheme for OA was developed in the knee, so it might not be appropriate for use in the shoulder. Joint space and spur measurements were difficult in some cases when arm position was slightly rotated from a direct AP view. In some cases, when there was significant deformity from OA, the humeral head convexity was malformed and not centered over the glenoid which made measurements more challenging although we attempted to standardize measurements by using the smallest joint space measurement for analysis. Loose bodies within the joint and fracturing of some of the spurs introduced potential error in the osteophyte measurements. In addition, our choice of arthroplasty as an endpoint for failure in our survivorship analysis may underestimate the number of dissatisfied patients because some patients may be coping with their OA and may have elected to postpone an arthroplasty even though, clinically, they were not doing well.

Conclusions

The CAM procedure reduced pain, improved function, and provided reasonable short-term durability for our cohort of young, active patients with advanced shoulder OA and may serve as a joint-preserving alternative to arthroplasty. Patients with less than 2 mm of joint space had a significantly higher failure rate. The CAM procedure is a viable surgical option in young, active patients with advanced OA, showing survivorship of 85% at 2 years.

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