Total Shoulder Arthroplasty After Previous Arthroscopic Surgery for Glenohumeral Osteoarthritis

A Case-Control Matched Cohort Study

Philip-C. Nolte,[*†] MD, MA, Bryant P. Elrick,[*] MSc, Justin W. Arner,[*‡] MD, T.J. Ridley,[*‡] MD, Thomas E. Woolson,[*] BS, Anna-K. Tross,[*§] MD, Kaare S. Midtgaard,[*||¶] MD, and Peter J. Millett,[*‡#] MD, MSc
Investigation performed at the Steadman Philippon Research Institute, Vail, Colorado, USA

Background: When comprehensive arthroscopic management (CAM) for glenohumeral osteoarthritis fails, total shoulder arthroplasty (TSA) may be needed, and it remains unknown whether previous CAM adversely affects outcomes after subsequent TSA.

Purpose: To compare the outcomes of patients with glenohumeral osteoarthritis who underwent TSA as a primary procedure with those who underwent TSA after CAM (CAM-TSA).

Study Design: Cohort study; Level of evidence, 3.

Methods: Patients younger than 70 years who underwent primary TSA or CAM-TSA and were at least 2 years postoperative were included. A total of 21 patients who underwent CAM-TSA were matched to 42 patients who underwent primary TSA by age, sex, and grade of osteoarthritis. Intraoperative blood loss and surgical time were assessed. Patient-reported outcome (PRO) scores were collected preoperatively and at final follow-up including the American Shoulder and Elbow Surgeons (ASES) score, Single Assessment Numeric Evaluation (SANE), shortened version of Disabilities of the Arm, Shoulder and Hand (QuickDASH), 12-Item Short Form Health Survey Physical Component Summary (SF-12 PCS), visual analog scale, and patient satisfaction. Revision arthroplasty was defined as failure.

Results: Of 63 patients, 56 of them (19 CAM-TSA and 37 primary TSA; 88.9%) were available for follow-up. There were 16 female (28.6%) and 40 male (71.4%) patients with a mean age of 57.8 years (range, 38.8-66.7 years). There were no significant differences in intraoperative blood loss ($P > .999$) or surgical time ($P = .127$) between the groups. There were 4 patients (7.1%) who had failure, and failure rates did not differ significantly between the CAM-TSA (5.3%; n = 1) and primary TSA (8.1%; n = 3) groups ($P > .999$). Additionally, 2 patients underwent revision arthroplasty because of trauma. A total of 50 patients who did not experience failure (17 CAM-TSA and 33 primary TSA) completed PRO measures at a mean follow-up of 4.8 years (range, 2.0-11.5 years), with no significant difference between the CAM-TSA (4.4 years [range, 2.1-10.5 years]) and primary TSA (5.0 years [range, 2.0-11.5 years]) groups ($P = .164$). Both groups improved significantly from preoperatively to postoperatively in all PRO scores ($P < .05$). No significant differences in any median PRO scores between the CAM-TSA and primary TSA groups, respectively, were seen at final follow-up: ASES: 89.9 (interquartile range [IQR], 74.9-96.6) versus 94.1 (IQR, 74.9-98.3) ($P = .545$); SANE: 84.0 (IQR, 74.0-94.0) versus 91.5 (IQR, 75.3-99.0) ($P = .246$); QuickDASH: 9.0 (IQR, 3.4-27.3) versus 9.0 (IQR, 5.1-18.1) ($P = .921$); SF-12 PCS: 53.8 (IQR, 50.1-57.1) versus 49.3 (IQR, 41.2-56.5) ($P = .065$); and patient satisfaction: 9.5 (IQR, 7.3-10.0) versus 9.0 (IQR, 5.3-10.0) ($P = .308$).

Conclusion: Patients with severe glenohumeral osteoarthritis who failed previous CAM benefited similarly from TSA compared with patients who opted directly for TSA.

Keywords: shoulder; glenohumeral osteoarthritis; intraoperative blood loss; surgery time; patient-reported outcome scores; axillary nerve release

Glenohumeral osteoarthritis in the young and active patient is a challenging abnormality to treat. Total shoulder arthroplasty (TSA) is often referred to as the gold standard,[3,15] as it has been shown to result in reproducible and satisfactory outcomes.[1,6,20,22] However, younger patients often have higher activity levels, greater function, and

The American Journal of Sports Medicine
2021;49(7):1839–1846
DOI: 10.1177/03635465211006479

higher expectations, which may raise concerns regarding implant longevity.[2,3,20] Comprehensive arthroscopic management (CAM) represents an option that preserves the joint and delays TSA in young, high-demand patients.[9-14]

In addition to previously described arthroscopic management techniques such as debridement, synovectomy, removal of loose bodies, subacromial decompression, chondroplasty, and tenotomy of the long head of the biceps tendon,[4,21] CAM adds inferior humeral osteoplasty, axillary nerve release, microfracture, and tenodesis of the long head of the biceps tendon.[9-14] Although CAM may delay TSA, approximately 13.1% of patients progress to TSA at 5 years.[12] If CAM fails, TSA may be necessary, and it remains unknown whether previous CAM adversely affects the outcomes after subsequent TSA. This raises concerns, as it has been shown that previous nonarthroplasty surgery is associated with inferior clinical outcomes, infections, and higher rates of revision surgery after TSA.[5,19,23] Similarly, higher revision rates have been shown for patients who underwent total knee arthroplasty after previous knee arthroscopic surgery.[7]

Therefore, the purpose of this study was to compare the outcomes of patients with glenohumeral osteoarthritis who underwent TSA as a primary procedure to those who underwent TSA after CAM (CAM-TSA). It was hypothesized that patients who failed CAM and progressed to TSA (CAM-TSA) would have similar outcomes after a minimum 2-year follow-up compared with patients who underwent primary TSA for glenohumeral osteoarthritis.

METHODS

In this retrospective, single-center, single-surgeon (P.J.M.) study, patients who had failure after CAM for severe, symptomatic osteoarthritis and then went on to TSA (CAM-TSA) between the years 2007 and 2018 and were at least 2 years out from surgery were included. Exclusion criteria were acute fractures around the shoulder, revision shoulder arthroplasty, and a postoperative period of less than 2 years.

A total of 21 patients who underwent CAM-TSA met the final inclusion criteria. Every patient who underwent CAM-TSA was matched to 2 patients who underwent primary TSA without previous CAM by age, sex, and grade of osteoarthritis according to the Kellgren-Lawrence classification, resulting in 42 patients in the primary TSA group.

Surgical Technique and Rehabilitation

All surgical procedures were performed by a single shoulder surgeon (P.J.M.) with the patient in the beach-chair position.

Comprehensive Arthroscopic Management. CAM has been previously described by Millett et al[9,10] and Mook et al.[14] In summary, glenohumeral debridement of unstable chondral injuries and degenerative labral tears as well as synovectomy were performed. Loose bodies were removed. Microfracture was utilized if there were high-grade focal chondral defects. If present, inferior humeral osteophytes were resected utilizing an arthroscopic bur and curved curette. The anterior, inferior, and posterior portions of the glenohumeral joint capsule were released. If preoperative symptoms and/or imaging or intraoperative visualization of a large inferior humeral osteophyte were consistent with axillary nerve compression, axillary neurolysis was performed. Finally, coracoplasty and/or acromioplasty was performed if needed. If instability of the biceps anchor, luxation/subluxation, tearing, or tendinopathy of the long head of the biceps tendon was present, the tendon was released at the biceps anchor, and subpectoral tenodesis was performed after completion of the arthroscopic portion of the surgical procedure.[16]

Total Shoulder Arthroplasty. All TSA procedures were performed using a standard deltopectoral approach. The subscapularis tendon was removed by lesser tuberosity osteotomy and tagged with sutures for later reconstruction.[17] The long head of the biceps tendon was tenotomized at the biceps anchor, and tenodesis was performed at the superior aspect of the pectoralis major. The humeral head was then resected, and the glenoid was prepared. A cemented, pegged glenoid was used in all cases. A short- (Univers Apex; Arthrex) or regular-stemmed (Univers II; Arthrex) humeral component was implanted in a press-fit technique after the placement of bone tunnels for later restoration of the subscapularis tendon and lesser tuberosity. If there was concern about bone quality, the humeral component was cemented. The lesser tuberosity was then

#Address correspondence to Peter J. Millett, MD, MSc, The Steadman Clinic, 181 West Meadow Drive, Suite 400, Vail, CO 81657, USA (email: drmillett@thesteadmanclinic.com).

*Steadman Philippon Research Institute, Vail, Colorado, USA.

†Clinic for Trauma and Orthopaedic Surgery, BG Trauma Center Ludwigshafen, University of Heidelberg, Ludwigshafen, Germany.

‡The Steadman Clinic, Vail, Colorado, USA.

§Clinic for Orthopedics and Trauma Surgery, Heidelberg University Hospital, Heidelberg, Germany.

||Division of Orthopaedic Surgery, Oslo University Hospital, Oslo, Norway.

¶Norwegian Armed Forces Joint Medical Services, Sessvollmoen, Norway.

Submitted July 9, 2020; accepted December 22, 2020.

One or more of the authors has declared the following potential conflict of interest or source of funding: P.-C.N., B.P.E., and T.E.W. are supported by the Steadman Philippon Research Institute, which is a 501(c)(3) nonprofit institution supported financially by private donations and corporate support. The Steadman Philippon Research Institute exercises special care to identify any financial interests or relationships related to research conducted here. During the past calendar year, the Steadman Philippon Research Institute has received grant funding or in-kind donations from Arthrex, Ossur, Siemens, Smith & Nephew, the Department of Defense, DJO, Major League Baseball, and XTRE. P.J.M. has received royalties from Arthrex and MedBridge; has received research support from Arthrex, Ossur, Siemens, and Smith & Nephew; has received hospitality payments from Merz Pharmaceuticals, Arthrosurface, Gemini Mountain Medical, Stryker, and Sanofi-Aventis; and holds stock in VuMedi. AOSSM checks author disclosures against the Open Payments Database (OPD). AOSSM has not conducted an independent investigation on the OPD and disclaims any liability or responsibility relating thereto.

repaired to its insertion using high-strength sutures (No. 5 FiberWire; Arthrex) wrapped around the stem using bone tunnels.[17] Then, 1 g of vancomycin was placed in the wound, both deep and superficially, after copious irrigation.

Postoperative Rehabilitation. Patients wore a sling for 4 weeks, and active range of motion of the elbow, hand, and fingers was begun on postoperative day 1. In the first 4 weeks, passive full range of motion for flexion and abduction was recommended with an internal rotation limit to the body and external rotation limit to 30°. Active-assisted range of motion was begun after 4 weeks, and active range of motion was begun when full passive range of motion was achieved. Strengthening exercises were started after 6 weeks postoperatively.

Demographic and Intraoperative Variables

Demographic variables, such as age, sex, and injured side, as well as intraoperative variables, including blood loss (<50, <100, <150, ≥150 mL) and surgical time (minutes), were collected and compared between the 2 groups.

Clinical Evaluation

Preoperatively and at final follow-up, patient-reported outcome (PRO) scores that were collected included the American Shoulder and Elbow Surgeons (ASES) score, Single Assessment Numeric Evaluation (SANE) score, shortened version of Disabilities of the Arm, Shoulder and Hand (QuickDASH) score, 12-Item Short Form Health Survey (SF-12) Physical Component Summary (PCS) score, and visual analog scale (VAS) for pain score (0-10; 10 = worst pain). Additionally, patient satisfaction with surgery (1-10; 10 = very satisfied) was evaluated. Before 2010, SANE and QuickDASH scores were not routinely collected preoperatively; therefore, analysis of these patients was limited to postoperative scores in regard to the SANE and QuickDASH only. Also, questions about return to the patients' preoperative fitness program were asked. Complications and further surgical interventions after TSA were recorded. Failure was defined as revision arthroplasty.

Preoperatively and at a minimum follow-up of 2 years, questionnaires were sent to the patients by email to evaluate the aforementioned scores. If patients did not return their questionnaires by email, they were contacted via telephone and were encouraged to return their questionnaire.

Statistical Analysis

The control group consisting of patients who underwent primary TSA was drawn from a pool of 261 qualifying TSA cases performed by the senior author (P.J.M.). Nearest neighbor matching using a "greedy" algorithm (the closest control [TSA] was matched to each experimental participant [CAM-TSA] 1 at a time without regard to minimizing a global distance measure that pertained to the total cohort) was performed on the investigation group of patients who underwent CAM-TSA. The matching procedure was completed using the statistical package R Version 3.6.2 (with additional package MatchIt; R Core Team).[8,18] The normality of data was assessed using the Shapiro-Wilk test. Normally distributed continuous data were reported as mean (range), and skewed continuous data were reported as median (interquartile range [IQR]). Normally distributed continuous data were analyzed using the unpaired t test and nonparametric data using the Mann-Whitney U test. The Wilcoxon matched-pair test or the paired t test was used for analysis of dependent continuous data. The Fisher exact test and the chi-square test were used to analyze bivariate or categorical data.

The study sample size was fixed; therefore, a priori power analysis was not performed. Assuming a study design with a minimum number of available samples per group of 17 and 34, 2-tailed testing, and an alpha level of .05, an effect size of $d = 0.87$ was detectable with 80% statistical power. Thus, we interpret that this study may be underpowered to detect group differences that are more subtle than $d = 0.87$. To assess for statistical significance, 2-tailed P values were calculated, and significance was set at $P < .05$. Statistical analysis was performed using Prism software Version 8.2.1 (GraphPad).

RESULTS

Of the 63 patients who were eligible, 7 were lost to follow-up (2 CAM-TSA and 5 primary TSA; these patients could not be reached via telephone or email or did not return their questionnaires despite multiple reminders), leaving a total of 56 (88.9%) patients for inclusion in this study. The mean age of the total cohort was 57.8 years (range, 38.8-66.7 years) in 40 men (71.4%) and 16 women (28.6%). Excluding the CAM procedures in the CAM-TSA group, 31 patients (55.4%) of the total cohort underwent previous surgery on the affected shoulder. No significant differences were observed when comparing previous procedures between the CAM-TSA (57.9%) and primary TSA (54.1%) groups ($P > .999$). The most common previous procedure performed was arthroscopic debridement in both groups (CAM-TSA: 23.5%; primary TSA: 29.0%). At the time of TSA, patients in the CAM-TSA group were a mean of 3.4 years (range, 0.9-8.0 years) out from their previous CAM procedure. All patients had either an osteoarthritis grade 3 (n = 19; 33.9%) or 4 (n = 37; 66.1%) according to the Kellgren-Lawrence classification. All patients had intraoperative blood loss of <150 mL. The median blood loss in the CAM-TSA group was <50 mL (IQR, <50-<100 mL), and the median blood loss in the primary TSA group was <50 mL (IQR, <50-<150 mL), with no significant differences between the groups ($P > .999$). The median surgical time was 106.0 minutes (IQR, 91.0-127.0 minutes) for the CAM-TSA group and 99.0 minutes (IQR, 78.5-116.0 minutes) for the primary TSA group ($P = .127$). Demographic and surgery-related variables of the total cohort and a comparison between the CAM-TSA and primary TSA groups are shown in Table 1.

TABLE 1
Characteristics and Intraoperative Variables[a]

	Total Cohort (N = 56)	CAM-TSA (n = 19)	Primary TSA (n = 37)	*P* Value
Age, mean (range), y	57.8 (38.8-66.7)	57.8 (38.8-66.7)	57.8 (48.0-66.7)	.604[b]
Previous shoulder surgery	31 (55.4)	11 (57.9)	20 (54.1)	>.999[c]
Time from CAM to TSA, mean (range), y	N/A	3.4 (0.9-8.0)	N/A	N/A
Follow-up time, mean (range), y	4.8 (2.0-11.5)	4.4 (2.1-10.5)	5.0 (2.0-11.5)	.164[b]
Sex				
Female	16 (28.6)	6 (31.6)	10 (27.0)	.527[c]
Male	40 (71.4)	13 (68.4)	27 (73.0)	
Dominant side affected	36 (64.3)	10 (52.6)	26 (70.3)	.244[c]
Kellgren-Lawrence classification				
Grade 3	19 (33.9)	6 (31.6)	13 (35.1)	>.999[c]
Grade 4	37 (66.1)	13 (68.4)	24 (64.9)	
Blood loss, median (IQR), mL	<50 (<50-<150)	<50 (<50-<100)	<50 (<50-<150)	>.999[b]
Surgical time, median (IQR), min	101.0 (80.0-123.0)	106.0 (91.0-127.0)	99.0 (78.5-116.0)	.127[b]

[a]Data are reported as n (%) unless otherwise indicated. CAM, comprehensive arthroscopic management; IQR, interquartile range; N/A, not applicable; TSA, total shoulder arthroplasty.
[b]Mann-Whitney test.
[c]Fisher exact test.

TABLE 2
Demographics, Causes of Failure, Time to Revision, and Revision Procedures Performed for Patients Who Failed TSA[a]

Patient	Group	Age, y	Sex	Injured Side	Cause of Failure	Time After TSA, mo	Revision Procedure
1	CAM-TSA	52	Male	Left	Aseptic humeral stem loosening from mountain biking	52	Revision TSA
2	CAM-TSA	63	Female	Right	A fall postoperatively and irreparable subscapularis tear at presentation	9	Revision RSA
3	Primary TSA	57	Male	Right	Capsular release for stiffness, repair of small supraspinatus tear, and rotator cuff failure	22	Revision RSA
4	Primary TSA	58	Male	Right	Aseptic glenoid component loosening	63	Revision TSA
5	Primary TSA	60	Female	Left	Pain and reduced range of motion	36	Revision RSA
6	Primary TSA	61	Female	Right	Periprosthetic fracture from a fall	30	Revision RSA

[a]CAM, comprehensive arthroscopic management; RSA, reverse shoulder arthroplasty; TSA, total shoulder arthroplasty.

There were 2 patients, 1 in each group, who fell on their respective shoulder and therefore underwent revision TSA (1 periprosthetic fracture [primary TSA] and 1 irreparable subscapularis tear [CAM-TSA]). When these were excluded, there were a total of 4 true failures (7.1%), with 1 failure in the CAM-TSA group (5.3%) and 3 failures in the primary TSA group (8.1%), with no significant differences between the groups ($P > .999$). Of note, another 4 revision surgical procedures (7.1%) were performed that did not necessitate revision arthroplasty, with 1 in the CAM-TSA group (5.3%; repair of small subscapularis tear) and 3 in the primary TSA group (8.1%; 2 patients with lysis of adhesions and mobilization under anesthesia for adhesive capsulitis and 1 patient with distal clavicle resection for symptomatic acromioclavicular joint arthritis) ($P > .999$). There were no infections among the complications and revisions. Patient characteristics and modes of failure are presented in Table 2.

After the exclusion of 6 patients with failures, a total of 50 patients (17 CAM-TSA and 33 primary TSA) were available for further analysis, all of whom completed PRO measures at a mean follow-up of 4.8 years (range, 2.0-11.5 years). The CAM-TSA group had a median postoperative ASES score of 89.9 (IQR, 74.9-96.6), a median SANE score of 84.0 (IQR, 74.0-94.0), a median QuickDASH score of 9.0 (IQR, 3.4-27.3), and a median SF-12 PCS score of 53.8 (IQR, 50.1-57.1), all of which improved significantly over preoperative scores ($P < .05$). Median patient satisfaction in the CAM-TSA group was 9.5 (IQR, 7.3-10.0). Moreover, 16 of 17 patients (94.1%) had participated in a preoperative fitness program. At final follow-up, 11 of 16 patients (68.8%) in the CAM-TSA group stated that they resumed their preoperative fitness program, 4 patients (25.0%) stated that they somewhat resumed their fitness program, and only 1 patient (6.3%) was not able to resume her preoperative fitness program. Detailed preoperative and postoperative PRO scores for the CAM-TSA group are shown in Table 3.

At final follow-up, the primary TSA group had a median ASES score of 94.1 (IQR, 74.9-98.3), a median SANE score

TABLE 3
Preoperative and Postoperative Patient-Reported Outcome Scores for the CAM-TSA Group[a]

	Preoperative	Postoperative	*P* Value
ASES	48.3 (42.9-61.2)	89.9 (74.9-96.6)	.002
SANE	59.0 (49.0-69.0)	84.0 (74.0-94.0)	.021
QuickDASH	35.2 (25.0-39.7)	9.0 (3.4-27.3)	<.001
SF-12 PCS	41.1 (35.2-45.3)	53.8 (50.1-57.1)	<.001
VAS			
Pain today	4.0 (3.0-5.5)	0.0 (0.0-2.0)	<.001
Worst pain	8.0 (6.5-9.0)	3.0 (2.0-6.5)	<.001
Patient satisfaction	N/A	9.5 (7.3-10.0)	N/A

[a]Data are reported as median (interquartile range). Significance was assessed using the Wilcoxon test. ASES, American Shoulder and Elbow Surgeons; CAM, comprehensive arthroscopic management; N/A, not applicable; QuickDASH, shortened version of Disabilities of the Arm, Shoulder and Hand; SANE, Single Assessment Numeric Evaluation; SF-12 PCS, 12-Item Short Form Health Survey Physical Component Summary; TSA, total shoulder arthroplasty; VAS, visual analog scale.

of 91.5 (IQR, 75.3-99.0), a median QuickDASH score of 9.0 (IQR, 5.1-18.1), and a median SF-12 PCS score of 49.3 (IQR, 41.2-56.5), all of which improved significantly over preoperative scores ($P < .05$). Median patient satisfaction in the primary TSA group was 9.0 (IQR, 5.3-10.0). Furthermore, 29 of 33 patients (87.9%) had participated in a preoperative fitness program. At final follow-up, 12 of 29 patients (41.4%) in the primary TSA group stated that they were able to resume their preoperative fitness program, 15 patients (51.7%) stated that they somewhat resumed their fitness program, and 2 patients (6.9%) were not able to resume their preoperative fitness program. Detailed preoperative and postoperative PRO scores for the primary TSA group are shown in Table 4. Figure 1 illustrates the postoperative PRO scores for both groups.

With the numbers available, no significant differences were seen for any preoperative PRO scores when comparing the CAM-TSA group with the primary TSA group ($P > .05$), and more importantly, no significant differences were seen when comparing postoperative PRO scores between the 2 groups ($P > .05$) (Table 5). No significant differences were seen for returning to preoperative fitness programs between the groups ($P = .196$).

DISCUSSION

The most important finding of this study was that at a minimum follow-up of 2 years, there were no significant differences in intraoperative variables, such as blood loss and surgical time, or failure rates between the CAM-TSA and primary TSA groups. Furthermore, no significant differences were seen in postoperative PRO scores when comparing the 2 groups.

TSA is considered the gold standard in patients with severe glenohumeral osteoarthritis who have failed nonoperative treatment, as it results in good reproducible outcomes.[1,3,6,15,20,22] However, shoulder joint replacement

TABLE 4
Preoperative and Postoperative Patient-Reported Outcome Scores for the Primary TSA Group[a]

	Preoperative	Postoperative	*P* Value
ASES	49.9 (35.0-59.9)	94.1 (74.9-98.3)	<.001
SANE	49.0 (27.8-61.5)	91.5 (75.3-99.0)	<.001
QuickDASH	40.9 (32.9-51.1)	9.0 (5.1-18.1)	<.001
SF-12 PCS	38.2 (32.8-46.9)	49.3 (41.2-56.5)	.001
VAS			
Pain today	4.0 (3.0-7.0)	0.0 (0.0-2.0)	<.001
Worst pain	8.5 (8.0-9.3)	3.0 (0.0-5.5)	<.001
Patient satisfaction	N/A	9.0 (5.3-10.0)	N/A

[a]Data are reported as median (interquartile range). Significance was assessed using the Wilcoxon test. ASES, American Shoulder and Elbow Surgeons; N/A, not applicable; QuickDASH, shortened version of Disabilities of the Arm, Shoulder and Hand; SANE, Single Assessment Numeric Evaluation; SF-12 PCS, 12-Item Short Form Health Survey Physical Component Summary; TSA, total shoulder arthroplasty; VAS, visual analog scale.

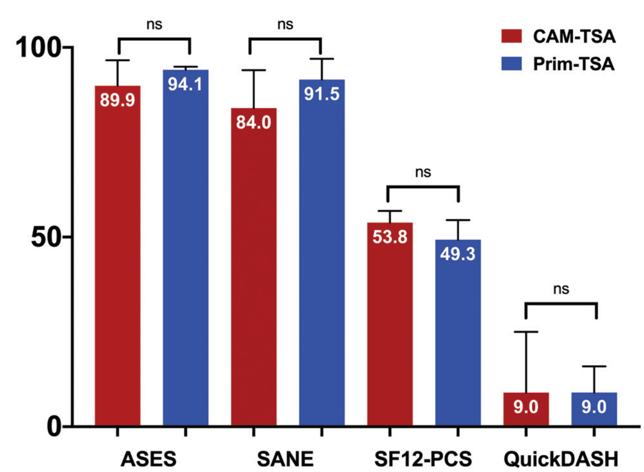

Figure 1. Postoperative patient-reported outcome scores for the CAM-TSA and primary TSA groups. Error bars represent 95% CIs. Values represent medians. ASES, American Shoulder and Elbow Surgeons; CAM, comprehensive arthroscopic management; ns, no significance; QuickDASH, shortened version of Disabilities of the Arm, Shoulder and Hand; SANE, Single Assessment Numeric Evaluation; SF-12 PCS, 12-Item Short Form Health Survey Physical Component Summary; TSA, total shoulder arthroplasty.

may not be the optimal management strategy for younger patients with higher demands and longer life expectancy, and younger patient age has been reported as a risk factor for revision surgery after TSA.[2,3,20] Brewley et al[2] demonstrated that patients younger than 65 years had a 3.4-fold increased risk for revision surgery after TSA.

To delay the necessity for TSA in young and active patients with glenohumeral osteoarthritis, surgeons have applied arthroscopic treatment strategies,[4,9-14,21] which have been shown to improve range of motion and PRO

TABLE 5
Comparison of Preoperative and Postoperative Patient-Reported Outcome Scores Between the Groups[a]

	Preoperative			Postoperative		
	CAM-TSA	Primary TSA	*P* Value	CAM-TSA	Primary TSA	*P* Value
ASES	48.3 (42.9-61.2)	49.9 (35.0-59.9)	.684[b]	89.9 (74.9-96.6)	94.1 (74.9-98.3)	.545[c]
SANE	59.0 (49.0-69.0)	49.0 (27.8-61.5)	.062[b]	84.0 (74.0-94.0)	91.5 (75.3-99.0)	.246[c]
QuickDASH	35.2 (25.0-39.7)	40.9 (32.9-51.1)	.093[b]	9.0 (3.4-27.3)	9.0 (5.1-18.1)	.921[c]
SF-12 PCS	41.1 (35.2-45.3)	38.2 (32.8-46.9)	.424[b]	53.8 (50.1-57.1)	49.3 (41.2-56.5)	.065[c]
VAS						
Pain today	4.0 (3.0-5.5)	4.0 (3.0-7.0)	.590[b]	0.0 (0.0-2.0)	0.0 (0.0-2.0)	.481[c]
Worst pain	8.0 (6.5-9.0)	8.5 (8.0-9.3)	.213[c]	3.0 (2.0-6.5)	3.0 (0.0-5.5)	.238[c]
Patient satisfaction	N/A	N/A	N/A	9.5 (7.3-10.0)	9.0 (5.3-10.0)	.308[c]

[a]Data are reported as median (interquartile range). ASES, American Shoulder and Elbow Surgeons; CAM, comprehensive arthroscopic management; N/A, not applicable; QuickDASH, shortened version of Disabilities of the Arm, Shoulder and Hand; SANE, Single Assessment Numeric Evaluation; SF-12 PCS, 12-Item Short Form Health Survey Physical Component Summary; TSA, total shoulder arthroplasty; VAS, visual analog scale.
[b]Unpaired *t* test.
[c]Mann-Whitney test.

scores.[24] The most notable difference between standard arthroscopic management techniques for glenohumeral osteoarthritis is the addition of inferior humeral osteoplasty, axillary nerve release, and microfracture.[14] Mitchell et al[12] demonstrated that CAM results in significant improvements in ASES, SANE, QuickDASH, and SF-12 scores compared with preoperative values at a mean follow-up of 5.7 years, with a survivorship rate of 76.9% at a minimum of 5 years' follow-up. Although these are excellent results when considering that the included patients met the criteria for TSA preoperatively but opted for a joint-preserving option, there still is a significant number of patients who experience failure and progress to shoulder arthroplasty. Inferior clinical outcomes and higher revision rates after TSA have been demonstrated in patients who have undergone previous nonarthroplasty surgery.[19] This has raised concerns of whether patients may benefit from CAM when they will ultimately need TSA.[19] In this study, we did not find significant differences in failure or complication rates between the 2 groups ($P >$ .999). In contrast, Schiffman et al[19] compared the revision rate of patients undergoing TSA with patients undergoing TSA with a history of nonarthroplasty surgery. The authors found a significantly higher revision rate for those undergoing TSA after a previous nonarthroplasty procedure (8%) compared with those without previous surgery (1%). Werthel et al[23] demonstrated a significantly increased risk for deep postoperative infections after primary shoulder arthroplasty in patients who had undergone previous nonarthroplasty surgery (2.46% vs 1.49%, respectively). In the present study, however, no infections occurred. In general, our reported failure rate is within the previously documented margins for primary TSA. The lack of increased infections, although not proven in the literature, may be because of our use of vancomycin powder. Brewley et al[2] demonstrated a revision rate of 6.9% in patients younger than 65 years. In a retrospective study of 202 patients aged ≤60 years with a mean follow-up of 9 years, Neyton et al[15] demonstrated a revision arthroplasty rate of 16.1%.

Both groups showed significant improvements in PRO scores from preoperatively to postoperatively (all $P <$ .05), and at a mean follow-up of 4.8 years, no significant differences in postoperative PRO scores were found between the groups. At final follow-up, we observed a median ASES score of 89.9 (IQR, 74.9-96.6) for the CAM-TSA group and 94.1 (IQR, 74.9-98.3) for the primary TSA group (P = .545). Frank et al[5] compared the PRO scores of patients who underwent shoulder arthroplasty with previous nonarthroplasty surgery with those who did not undergo previous nonarthroplasty surgery. They found that both groups showed significant improvements in PRO scores (ASES, Simple Shoulder Test, and VAS) compared with preoperatively; however, at a minimum follow-up of 2 years, the group of patients with previous surgery had significantly inferior PRO scores (mean ASES, 73.2 ± 21.7) compared with those without previous surgery (mean ASES, 84.9 ± 16.9). Schiffman et al[19] found significantly inferior SANE scores for patients undergoing TSA who had undergone previous nonarthroplasty surgery (mean, 74 [range, 20-100]) compared with those undergoing TSA without previous surgery (mean, 86 [range, 25-100]). This is in contrast to our findings, as we did not find significant differences in postoperative median SANE scores between the CAM-TSA and primary TSA groups: 84.0 (IQR, 74.0-94.0) versus 91.5 (IQR, 75.3-99.0), respectively (P = .246). Although it is unknown why our results did not show inferior outcomes after arthroscopic treatment, as seen in some of the previously discussed studies, we postulate that one reason may be the improvement in arthroplasty technology and knowledge of the importance and treatment of glenoid deformities. Further, extensive capsular release, humeral head osteoplasty, and axillary neurolysis are unique to CAM and may provide greater range of motion and function before a later TSA procedure compared with other arthroscopic procedures, possibly resulting in better outcomes after TSA. However, our PRO scores are in line with previously published scores for primary TSA in younger patients. Brewley et al[2] demonstrated a mean postoperative ASES score of 77 (range, 73-81) for patients younger than 65 years at a mean follow-up of 50 months. Also, Garcia et al[6] showed an ASES score of 88.4 at a mean follow-up of 60 months, which is similar to our reported ASES scores for both the CAM-TSA group (median, 89.9) and the primary TSA group (median, 94.1).

Finally, we investigated intraoperative variables. The 2 groups did not show a significant difference in intraoperative blood loss or surgical time ($P > .05$). This suggests that TSA was not complicated by a previous CAM procedure, which could be the case if excessive postoperative scarring is encountered. At our institution, patients who undergo CAM meet the clinical and radiographic criteria for TSA but opt for a joint-preserving treatment option. The mean time from CAM to TSA in the CAM-TSA group was 3.4 years (range, 1.9-8.0 years). Considering a delay to TSA of over 3 years, similar complication and revision rates, similar PRO scores at final follow-up, and no differences in intraoperative blood loss or surgical time, our results suggest that CAM is a viable treatment strategy and does not negatively affect outcomes even in cases in which patients progress to TSA. To our knowledge, this is the first study that has investigated this question, and our results suggest that CAM may be a viable treatment option in younger patients with glenohumeral osteoarthritis that does not compromise outcomes or failure rates of subsequent TSA.

Limitations

This study was not without limitations. First, this was a single-surgeon, single-center study. Given the complexity of the CAM procedure, the results of this study may not be transferable to all surgeons. Second, this was a retrospective study, which rendered it prone to loss of data; however, we were able to obtain a follow-up rate of over 85%. Third, we did not perform radiographic or in-person clinical follow-up, and despite good PRO scores and no significant differences between the groups for the assessed parameters, we cannot make assumptions on potential implant loosening that may have occurred. However, patients were functioning well, and therefore, we believe that radiographic outcomes would not have an effect on these results. Fourth, the sample size is relatively small; thus, differences between the groups may have been missed. Additionally, because of a minimum follow-up of 2 years, we cannot make assumptions on long-term survivorship. Finally, although we matched the CAM-TSA group to the primary TSA group by age, sex, and grade of osteoarthritis, there may be other variables that we did not account for.

CONCLUSION

Patients with severe glenohumeral osteoarthritis who failed previous CAM benefited similarly from TSA compared with patients who opted directly for TSA.

ORCID iD

Peter J. Millett https://orcid.org/0000-0002-8298-3746

REFERENCES

1. Bartelt R, Sperling JW, Schleck CD, Cofield RH. Shoulder arthroplasty in patients aged fifty-five years or younger with osteoarthritis. *J Shoulder Elbow Surg*. 2011;20(1):123-130.
2. Brewley EE Jr, Christmas KN, Gorman RA 2nd, Downes KL, Mighell MA, Frankle MA. Defining the younger patient: age as a predictive factor for outcomes in shoulder arthroplasty. *J Shoulder Elbow Surg*. 2020;29(7)(suppl):S1-S8.
3. Brolin TJ, Thakar OV, Abboud JA. Outcomes after shoulder replacement surgery in the young patient: how do they do and how long can we expect them to last? *Clin Sports Med*. 2018;37(4):593-607.
4. Cole BJ, Yanke A, Provencher MT. Nonarthroplasty alternatives for the treatment of glenohumeral arthritis. *J Shoulder Elbow Surg*. 2007;16(5)(suppl):S231-S240.
5. Frank RM, Lee S, Sumner S, et al. Shoulder arthroplasty outcomes after prior non-arthroplasty shoulder surgery. *JB JS Open Access*. 2018;3(3):e0055.
6. Garcia GH, Liu JN, Sinatro A, et al. High satisfaction and return to sports after total shoulder arthroplasty in patients aged 55 years and younger. *Am J Sports Med*. 2017;45(7):1664-1669.
7. Gu A, Malahias MA, Cohen JS, et al. Prior knee arthroscopy is associated with increased risk of revision after total knee arthroplasty. *J Arthroplasty*. 2020;35(1):100-104.
8. Ho D, Imai K, King G, Stuart EA. MatchIt: nonparametric preprocessing for parametric causal inference. *J Stat Softw*. 2011;42(8):1-28.
9. Millett PJ, Gaskill TR. Arthroscopic management of glenohumeral arthrosis: humeral osteoplasty, capsular release, and arthroscopic axillary nerve release as a joint-preserving approach. *Arthroscopy*. 2011;27(9):1296-1303.
10. Millett PJ, Horan MP, Pennock AT, Rios D. Comprehensive arthroscopic management (CAM) procedure: clinical results of a joint-preserving arthroscopic treatment for young, active patients with advanced shoulder osteoarthritis. *Arthroscopy*. 2013;29(3):440-448.
11. Millett PJ, Schoenahl JY, Allen MJ, Motta T, Gaskill TR. An association between the inferior humeral head osteophyte and teres minor fatty infiltration: evidence for axillary nerve entrapment in glenohumeral osteoarthritis. *J Shoulder Elbow Surg*. 2013;22(2):215-221.
12. Mitchell JJ, Horan MP, Greenspoon JA, Menge TJ, Tahal DS, Millett PJ. Survivorship and patient-reported outcomes after comprehensive arthroscopic management of glenohumeral osteoarthritis: minimum 5-year follow-up. *Am J Sports Med*. 2016;44(12):3206-3213.
13. Mitchell JJ, Warner BT, Horan MP, et al. Comprehensive arthroscopic management of glenohumeral osteoarthritis: preoperative factors predictive of treatment failure. *Am J Sports Med*. 2017;45(4):794-802.
14. Mook WR, Petri M, Greenspoon JA, Millett PJ. The comprehensive arthroscopic management procedure for treatment of glenohumeral osteoarthritis. *Arthrosc Tech*. 2015;4(5):e435-e441.
15. Neyton L, Kirsch JM, Collotte P, et al. Mid- to long-term follow-up of shoulder arthroplasty for primary glenohumeral osteoarthritis in

patients aged 60 or under. *J Shoulder Elbow Surg*. 2019;28(9): 1666-1673.
16. Pogorzelski J, Horan MP, Hussain ZB, Vap A, Fritz EM, Millett PJ. Subpectoral biceps tenodesis for treatment of isolated type II SLAP lesions in a young and active population. *Arthroscopy*. 2018;34(2):371-376.
17. Ponce BA, Ahluwalia RS, Mazzocca AD, Gobezie RG, Warner JJ, Millett PJ. Biomechanical and clinical evaluation of a novel lesser tuberosity repair technique in total shoulder arthroplasty. *J Bone Joint Surg Am*. 2005;87(suppl 2):1-8.
18. R Core Team. *R: a Language and Environment for Statistical Computing*. R Foundation for Statistical Computing. Accessed January 1, 2021. https://www.R-project.org/
19. Schiffman CJ, Hannay WM, Whitson AJ, Neradilek MB, Matsen FA 3rd, Hsu JE. Impact of previous non-arthroplasty surgery on clinical outcomes after primary anatomic shoulder arthroplasty. *J Shoulder Elbow Surg*. 2020;29(10):2056-2064.
20. Schoch B, Schleck C, Cofield RH, Sperling JW. Shoulder arthroplasty in patients younger than 50 years: minimum 20-year follow-up. *J Shoulder Elbow Surg*. 2015;24(5):705-710.
21. Skelley NW, Namdari S, Chamberlain AM, Keener JD, Galatz LM, Yamaguchi K. Arthroscopic debridement and capsular release for the treatment of shoulder osteoarthritis. *Arthroscopy*. 2015;31(3):494-500.
22. Sowa B, Bochenek M, Bulhoff M, et al. The medium- and long-term outcome of total shoulder arthroplasty for primary glenohumeral osteoarthritis in middle-aged patients. *Bone Joint J*. 2017;99(7):939-943.
23. Werthel JD, Hatta T, Schoch B, Cofield R, Sperling JW, Elhassan BT. Is previous nonarthroplasty surgery a risk factor for periprosthetic infection in primary shoulder arthroplasty? *J Shoulder Elbow Surg*. 2017;26(4):635-640.
24. Williams BT, Beletsky A, Kunze KN, et al. Outcomes and survivorship after arthroscopic treatment of glenohumeral arthritis: a systematic review. *Arthroscopy*. 2020;36(7):2010-2021.