Skeletal Radiol (2017) 46:909–918
DOI 10.1007/s00256-017-2631-8

SCIENTIFIC ARTICLE

Cuff tear arthropathy shoulder hemiarthroplasty: a radiographic outcome study

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Received: 27 December 2016 / Revised: 28 February 2017 / Accepted: 13 March 2017 / Published online: 4 April 2017

Abstract
Objective Cuff tear arthropathy (CTA) head prosthesis has recently become an alternative to standard shoulder hemiarthroplasty in patients with severe cuff disease by offering an increased surface area and decreased impingement. The purpose of this study is to evaluate the radiographic outcomes of CTA prosthesis and to correlate them with clinical outcomes.
Materials and Methods In this retrospective study of CTA hemiarthroplasties over an 11-year period, two radiologists reviewed pre-/postoperative radiographs and clinical data. Radiographic complications were correlated with subsequent surgery using Cox regression models. Rates of surgical revision and radiographic complications over time were estimated using Kaplan-Meier curves.
Results Ninety-seven CTA hemiarthroplasties were identified in 92 patients (5 bilateral) with a mean patient age of 68.7 years. Mean radiographic follow-up was 12 months with a mean of 3.3 radiographs per prosthesis. Twenty-six arthroplasties (26.8%) experienced at least one radiographic complication, including acromion remodeling (19.5%), anterior-posterior subluxation (5.2%), periprosthetic fracture (4.1%), glenoid remodeling (3.1%), hardware loosening (2.1%), superior subluxation (2.1%), and subsidence (1.0%). Eight cases underwent revision surgery (8.2%). The occurrence of a postoperative radiographic complication was associated with increased risk of surgical revision (hazard ratio 11.5, 95% CI: 2.4–55.7, p = 0.002); 73.5% of radiographic complications occurred by 3 months after the initial surgery (complication rate of 23.3%) based on Kaplan-Meier curve analysis.
Conclusion Radiographic complications after CTA head hemiarthroplasty are common with most occurring by 3 months after surgery and are highly associated with surgical revision.

Keywords Shoulder · Arthroplasty · Joint replacement · Rotator cuff

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Introduction

Cuff tear arthropathy (CTA) is a disease consisting of three components: (1) rotator cuff insufficiency, (2) humeral head instability, and (3) acromial-glenoid-humeral arthrosis [1, 2]. The disease process begins with a large rotator cuff tear leading to superior migration of the humeral head when the deltoid is flexed, which can be recognized on radiographs as a narrowed acromial humeral interval. Over time, the humeral head forms a fulcrum with the acromion, which manifests radiographically as concave remodeling of the acromion with reciprocal greater tuberosity remodeling, also known as acromion "acetabularization" and humeral head "femoralization." Additional axial motion from cuff

weakness leads to medialization of the humerus and glenohumeral arthritis [3, 4].

Since the definition of cuff tear arthropathy by Neer in 1983, surgical management of CTA has remained a challenge [5, 6]. Recent surgical options for patients with CTA include reverse shoulder arthroplasty and standard shoulder hemiarthroplasty. Reverse shoulder arthroplasty is performed when the coracoacromial arch is not intact. When the coracoacromial arch is intact, either reverse shoulder arthroplasty or hemiarthroplasty is performed depending on the age and functional goals. Reverse shoulder arthroplasty remains largely an option for more elderly and inactive individuals because of concern for prosthesis longevity, lack of salvage options, and constrained forward elevation in young patients who may have higher functional goals [7–11] as well as a lack of clarity regarding whether the same functional improvements seen in elderly patients apply to younger populations [12, 13]. Standard hemiarthroplasty has been suggested for those with higher functional goals [2]; however, functional and surgical outcomes have been variable [14–16]. Variable outcomes with standard shoulder hemiarthroplasties and concern for humeral-glenoid-acromial articulation erosion have led to the more recent popularization of CTA hemiarthroplasty [6, 16].

The CTA hemiarthroplasty design was introduced in 2004 by Visotsky and others, which consists of an extended humeral head component designed to take advantage of the altered hip-like fulcrum dynamics of the acromial-glenoid-humeral articulation [17, 18]. The extended head humeral articular surface theoretically provides less impingement between the humeral-acromion articulation during abduction [6, 18]. Recent studies reveal promising clinical results in patient populations with rotator cuff tear arthropathy [19–21]. Prior CTA head arthroplasty studies were largely focused on surgical and functional outcomes without a detailed analysis of radiographic complications. Therefore, the purpose of this study is to evaluate the radiographic outcome of CTA shoulder prosthesis and to correlate this with clinical outcome.

Materials and Methods

This retrospective study was approved by our Institutional Review Board and received a waiver for consent. A database search was performed and identified all patients who received a CTA arthroplasty over an approximately 11-year period spanning June 2004 to October 2015. All patients were included unless there was inadequate follow-up, defined as no pre- or postoperative radiographic follow-up. Clinical data were extracted from preoperative clinical notes, postoperative clinical notes and operative reports from the electronic medical record that included: age, sex, history of prior shoulder surgery, indication for CTA arthroplasty, surgeon, presence of pseudoparalysis, pain, date of CTA prosthesis revision, and reason for revision.

Pre- and postoperative radiographs were reviewed together by two radiologists, one of whom is a fellowship-trained musculoskeletal radiologist. Preoperative radiographs were reviewed for the following: Seebauer classification, superior subluxation, anterior-posterior subluxation, acromion remodeling, glenoid remodeling, and osteoarthritis of the glenohumeral and acromioclavicular joint. Seebauer classification of cuff tear arthropathy is a four-tiered classification system based on the degree of superior humeral migration and presence of medial glenoid erosion [17]. Postoperative radiographs were reviewed for radiographic complications including new periprosthetic fracture, hardware loosening, subsidence, superior humeral head subluxation, anterior-posterior humeral head subluxation, acromion remodeling, glenoid remodeling, glenoid fracture, periosteal reaction, loose bodies, and severe heterotopic ossification. In general, radiographic complication was described when appearing as a new finding or a worsening change using the immediate postoperative radiograph as baseline. Hardware loosening was defined as perihardware lucency greater than 2 mm in thickness. Two specific complications warrant additional explanation. Anterior-posterior humeral head subluxation from the glenoid was graded with acknowledgement of an expected range of normal as follows [22]: normal (0), mild anterior (1), moderate anterior (2), severe anterior (3), and dislocated anterior (4). Subluxation in the posterior direction was given a negative numerical value following the same guidelines as above. Anterior-posterior subluxation was counted as a postoperative complication if there was an interval absolute change of two or more grades relative to the immediate postoperative radiograph such as seen in Fig. 1 where there is an interval change from normal (0) to moderate anterior subluxation (2). Superior subluxation was graded based on the position of the superior border of the humeral head as follows: normal (0), mild (1; below the coracoid), moderate (2; at the coracoid), severe (3; above the coracoid but not dislocated), and dislocated (4). Superior subluxation was counted as a postoperative complication if there was an absolute change of two or more from the immediate postoperative radiograph.

Postoperative rates of surgical revision and radiographic complications over time were estimated using Kaplan-Meier curve analysis. Surgical revision was right censored at the time of the last available follow-up. Radiographic complications were treated as interval censored, with the complication occurring between the time of the radiograph on which it was originally seen and the time of the previous radiograph. The Kaplan-Meier curve for the interval-censored radiographic complications was estimated using the Turnbull expectation-maximization algorithm [23]. These Kaplan-Meier methods account for different lengths of follow-up among subjects and the heterogeneity in follow-up intervals, which are features present in our study.

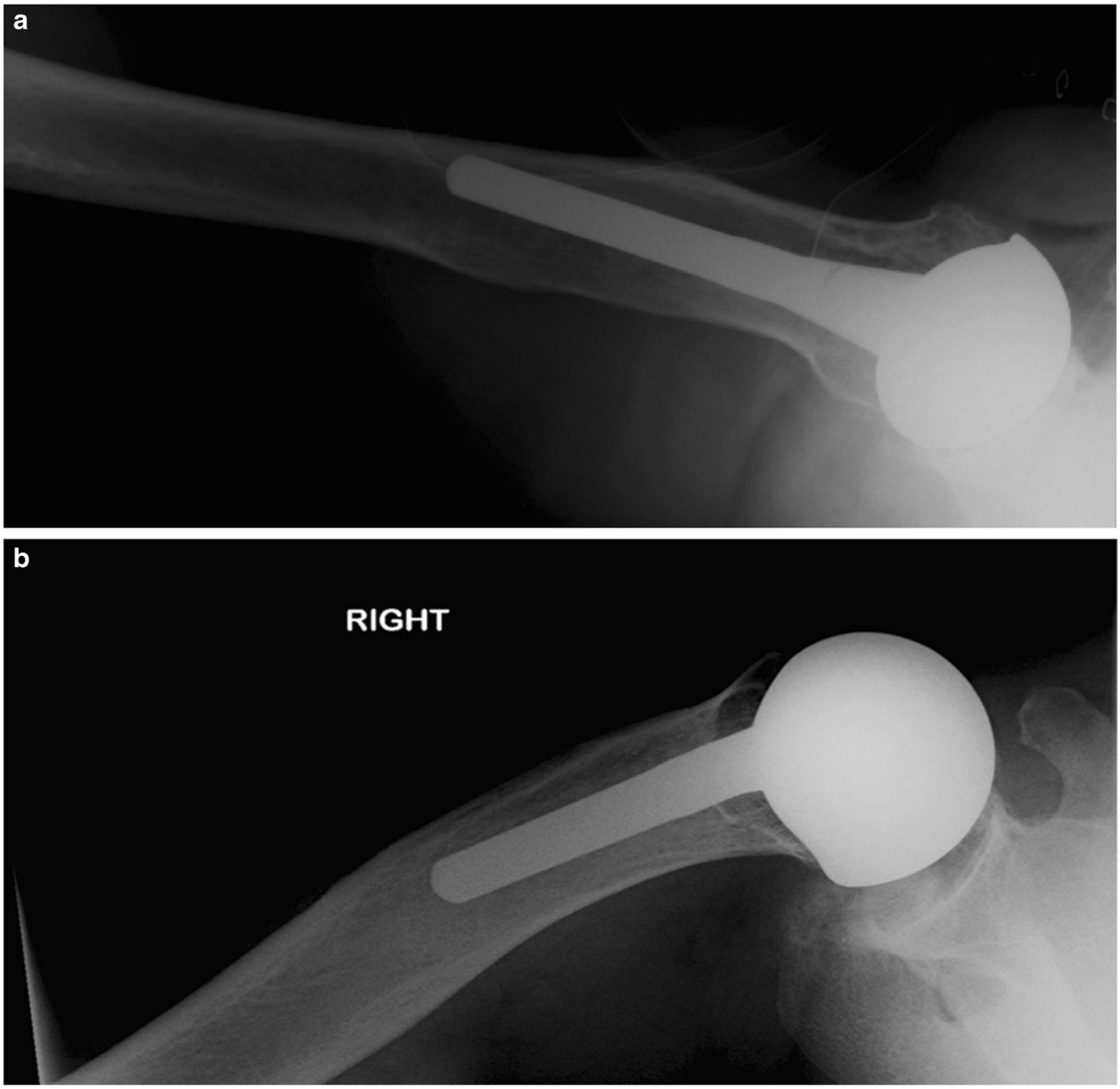

Fig. 1 CTA prosthesis complication. (**a**) Axillary shoulder radiograph in a 79-year-old male immediately after surgery shows the CTA prosthesis head well located within the glenoid. (**b**) Five weeks later, there is moderate anterior subluxation of the CTA prosthesis head from the glenoid

The occurrence of radiographic complications was correlated with subsequent surgery (outcome variable) using Cox regression models, which can account for variable loss to follow-up among subjects over the study period. The presence of a radiographic complication was treated as a time-varying binary covariate, which was 0 until the radiograph where it was first identified and then 1 until the end of follow-up. The corresponding hazard ratio (HR) was used to summarize the association between radiographic complications and subsequent surgery. Preoperative clinical and radiographic characteristics of CTA shoulder arthroplasties were correlated with postoperative radiographic complications (outcome variable) using Weibull proportional hazard models. HRs were used to summarize associations with radiographic complications. Cox models were not used to analyze radiographic outcomes because the standard software routines did not support interval censoring. Preoperative clinical and radiographic complications were not correlated with surgical outcomes because of limited power. All statistical calculations were conducted with the statistical computing language R (version

3.1.1; R Foundation for Statistical Computing, Vienna, Austria). Throughout, two-sided tests were used with statistical significance defined as $p < 0.05$.

Results

During the 11-year period, 97 CTA hemiarthroplasties in 92 patients (5 bilateral) were included. There were 48 males and 49 females with a mean age at time of surgery of 68.7 years (standard deviation, ±11.1; range, 33–90 years). All cases were performed by one of two surgeons with 83 arthroplasties performed by one and the rest performed by the other. Of these cases, 65 were performed on the right shoulder and 32 on the left shoulder. Prior surgical history included 25 rotator cuff repairs, 5 distal clavicular resections, 5 hemiarthroplasties, 4 open reduction and internal fixations, 3 subacromial decompressions, and 1 incomplete arthrodesis. A total of 59 patients had no prior shoulder surgery. Preoperative diagnosis included cuff tear arthropathy (83/97, 85.6%), prior arthroplasty failure (5/97, 5.1%), and other (9/97, 9.2%), which included rheumatoid arthritis, post-traumatic pain after open reduction internal fixation, incomplete arthrodesis, conventional osteoarthritis, or erosive osteoarthritis. Pseudoparalysis was noted in 6 of 67 cases (8.9%); in 30 cases, it was not noted. Pain levels were not consistently reported and therefore were not included in the final data analysis. Preoperative clinical characteristics are summarized in Table 1.

Preoperative radiographic characteristics are summarized in Table 2. Assessment of the Seebauer classification included 37 Seebauer 1A (38.9%), 28 Seebauer 1B (29.5%), and 30 Seebauer 2A (31.6%) shoulders. There were no Seebauer 2B shoulders. A total of 10 shoulders (10.5%) had no superior subluxation, 59 (62.1%) had mild superior subluxation, 22 (23.2%) had moderate superior subluxation, and 4 (4.2%) had severe superior subluxation. Assessment of anterior-superior subluxation included 63 (65.6%) with no subluxation, 24 (25%) with mild subluxation, 6 (6.2%) with moderate subluxation, and 3 (3.1%) with severe subluxation. Acromion remodeling was assigned as none for 34 (35.8%) shoulders, mild for 43 (45.3%) shoulders, moderate for 12 (12.6%) shoulders, and severe for 6 (6.3%) shoulders. Glenoid remodeling was absent for 53 (54.6%) shoulders, mild for 31 (32%) shoulders, moderate for 8 (8.2%) shoulders, and severe for 5 (5.2%) shoulders. Osteoarthritis of the glenohumeral joint was absent for 16 (16.7%), mild for 35 (36.5%), moderate for 27 (28.1%), and severe for 18 (18.8%). Osteoarthritis of the acromioclavicular joint was absent in 30 (31.6%), mild in 41 (43.2%), moderate for 21 (22.1%), and severe in 3 (3.2%). Three shoulders had missing radiographic views, which prevented optimal assessment of certain radiographic characteristics as detailed in Table 2.

Table 1 Preoperative clinical characteristics of CTA shoulder arthroplasties (N = 97)

Variable		No. (%) or Mean ± SD
Male sex		48 (49.5)
Age (years)		68.7 ± 11.1
Prior surgery	Rotator cuff repair	25 (25.8)
	Distal clavicular resection	5 (5.2)
	Hemiarthroplasty	5 (5.2)
	ORIF	4 (4.1)
	Other	4 (4.1)
	None	59 (60.8)
Indication	CTA only	83 (85.6)
	Prior arthroplasty failure	5 (5.1)
	Other	9 (9.2)
Surgeon	Surgeon 1	83 (85.6)
	Surgeon 2	14 (14.4)
Laterality	Right	65 (67.0)
	Left	32 (33.0)

CTA = Cuff tear arthropathy, *ORIF* = Open reduction internal fixation

Mean postoperative radiographic follow-up was 12 months with a mean of 3.3 radiographs per prosthesis. Overall, 26 arthroplasties (26.8%) experienced at least one radiographic complication (Table 3). Radiographic complications included: acromion remodeling (19.5%), anterior-posterior humeral head subluxation (5.2%), periprosthetic fracture (4.1%), glenoid remodeling (3.1%), hardware loosening (2.1%), superior humeral subluxation (2.1%), and subsidence (1.0%). There were no complications of glenoid fracture, periosteal reaction, loose joint bodies, or severe heterotopic ossification. Examples of anterior humeral subluxation and acromion remodeling are demonstrated in Figs. 1 and 2, respectively.

Eight patients underwent revision surgery (8.2%). Preoperative clinical characteristics of this revision cohort include seven patients who were >50 years old (with average age of 8 patients being 63 years), seven patients with CTA as a preoperative diagnosis and one with failed glenohumeral arthrodesis, five cases with mild glenoid remodeling and three without glenoid remodeling, five male patients and six cases with a prior surgical history. Clinical reasoning for revision surgery included five cases for anterior-superior escape on physical examination, two for pseudoparalysis, and one for infection. Of the revised cases, six patients underwent reverse total shoulder arthroplasties, and two underwent a CTA hemiarthroplasty exchange. Four out of five patients with anterior-superior escape had acromion remodeling. The fifth patient with anterior-superior escape experienced an acromion fracture. The first person who underwent CTA hemiarthroplasty for pseudoparalysis experienced glenoid remodeling and did not have pseudoparalysis preoperatively. The second person

Table 2 Radiographic preoperative characteristics of CTA shoulder arthroplasties (N = 97)

Variable		No. (%)
Seebauer class*	1A	37 (38.9)
	1B	28 (29.5)
	2A	30 (31.6)
Superior subluxation*	None	10 (10.5)
	Mild	59 (62.1)
	Moderate	22 (23.2)
	Severe	4 (4.2)
Anterior-posterior subluxation†	None	63 (65.6)
	Mild	24 (25.0)
	Moderate	6 (6.2)
	Severe	3 (3.1)
Acromion remodeling*	None	34 (35.8)
	Mild	43 (45.3)
	Moderate	12 (12.6)
	Severe	6 (6.3)
Glenoid remodeling	None	53 (54.6)
	Mild	31 (32.0)
	Moderate	8 (8.2)
	Severe	5 (5.2)
Osteoarthritis of glenohumeral joint†	None	16 (16.7)
	Mild	35 (36.5)
	Moderate	27 (28.1)
	Severe	18 (18.8)
Osteoarthritis of acromioclavicular joint*	None	30 (31.6)
	Mild	41 (43.2)
	Moderate	21 (22.1)
	Severe	3 (3.2)

*Two subjects were excluded because of missing views that prevented the assessment of this finding

†One subject was excluded because of missing views that prevented the assessment of this finding

with pseudoparalysis had no radiographic complications and had pseudoparalysis at baseline.

Statistical correlation of the eight surgical revisions with preoperative radiographic and clinical characteristics was not performed because of the limited number of revision cases. We did, however, correlate preoperative clinical and radiographic characteristics with postoperative radiographic complications, which is summarized in Table 4. However, none of the studied preoperative clinical characteristics of CTA hemiarthroplasty patients or the preoperative radiographic characteristics were significantly associated with the risk of any postoperative radiographic complications.

Kaplan-Meier survival curve analysis was performed to compare the cumulative incidence of surgical revision and radiographic complications over time, accounting for variable follow-up and variable imaging intervals (Fig. 3).

Table 3 Radiographic and surgical outcome of CTA shoulder arthroplasties (N = 97)

	No. (%) with Outcome
Primary outcomes	
Surgical revision	8 (8.2)
Any radiographic complication	26 (26.8)
Individual radiographic outcomes	
Acromion remodeling	19 (19.5)
Anterior-posterior humeral subluxation	5 (5.2)
Periprosthetic fracture	4 (4.1)
Glenoid remodeling	3 (3.1)
Hardware loosening	2 (2.1)
Superior humeral subluxation	2 (2.1)
Subsidence	1 (1.0)
Other*	0 (0.0)

*Glenoid fracture, periosteal reaction, loose bodies, and heterotopic ossification

Radiographic complications occurred earlier than surgical revision. Of all the radiographic complications that occurred during the study period, 73.5% had already occurred by 3 months after the initial surgery, with a cumulative complication rate of 23.3% at that time across all shoulders. Radiographic complications plateaued at around 9 months with a cumulative rate of 31.7% through at least 36 months.

Table 5 summarizes the rate of surgical revision by whether or not radiographic complications developed. The occurrence of any radiographic complication was associated with an increased risk of surgical revision, with 23.1% (6/26) of those with radiographic complication present undergoing revision surgery versus 2.8% (2/71) when radiographic complication was absent (HR = 11.5; 95% CI: 2.4–55.7; p = 0.002). The presence of any radiographic complication besides acromion remodeling (HR 3.5; 95% CI: 1.1–11.0; p = 0.034) and the presence of acromion remodeling specifically (HR = 29.2; 95% CI: 5.7–151.3; p < 0.001) were each significantly associated with increased risk of surgical revision.

Discussion

We present a retrospective evaluation of CTA head shoulder prosthesis with a specific focus on radiographic findings and correlation to clinical outcomes, especially surgical revision rates. Our results demonstrate that radiographic complications are common with 26 arthroplasties (26.8%) experiencing at least one radiographic complication. The top two radiographic complications include acromion remodeling (19.5%) and anterior-posterior subluxation (5.2%); 23.1% of those with radiographic complications (6 of 26 patients) went on to

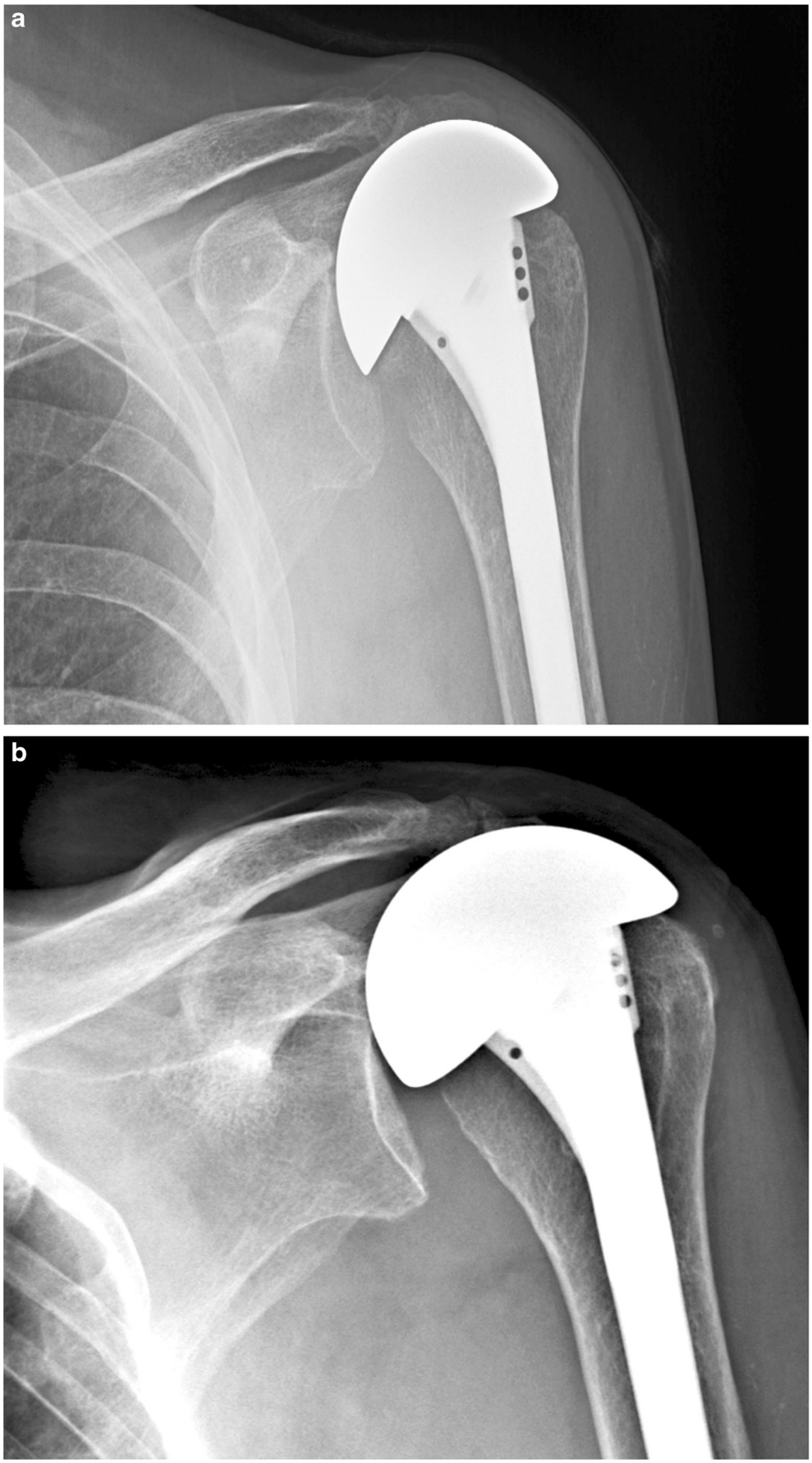

Fig. 2 CTA prosthesis complication. (**a**) Frontal shoulder radiograph in a 70-year-old male 1 month after surgery. (**b**) Four months later, there is increased thinning and remodeling of the acromion

receive revision surgery. Presence of any radiographic complication as well as acromion remodeling was associated with an increased rate of revision surgery. Kaplan-Meier curve estimates corroborated that radiographic complications are occurring earlier than surgical complications and that most radiographic complications will occur early by 3 months. Radiographic complications of acromion remodeling and anterior-posterior subluxation suggest persistence of CTA biomechanics after CTA arthroplasty. Understanding the radiographic surrogates for persistent clinically significant pathologic CTA biomechanics will allow for more accurate postoperative CTA radiographic surveillance.

The most common complication was acromion remodeling demonstrated in 19.5% of cases. Surgical literature on CTA prosthesis outcomes in patients with CTA have not found acromion remodeling to be an associated radiographic complication, with most studies reporting no radiographic complications [7, 17, 19, 20, 24]. Part of this discrepancy is because our study was specifically designed to assess for radiographic outcomes. There is a single study of 33 patients that reports a similar acromion remodeling rate of 15% with a CTA prosthesis; however, these patients all had a primary diagnosis of rheumatoid arthritis, which limits direct comparison [21]. Comparison to conventional hemiarthroplasty for CTA yields variable reported rates of acromion erosion ranging from 42.4% in a study of 33 cases with 5 years of follow-up [16] to none in a study of 22 cases with 6.8 years of follow-up [7].

The second most common radiographic complication was anterior-posterior subluxation at 5.2%, which has not been previously reported in the orthopedics literature on CTA head prosthesis. All prior studies focused on three or fewer radiographic complications such as Visotsky and others, where they specifically state that there were no glenoid changes, prosthetic dislocation or acromial fracture in their population of 60 CTA head prostheses [17]. Similar to other studies, there is no mention whether anything else was evaluated [18–21]. Again, these discrepant findings may be explained by the fact that this study was specifically designed to assess radiographic outcomes. Comparison to conventional hemiarthroplasty for cuff tear arthropathy results is again variable with one study reporting 25% anterior-superior subluxation on radiographs in a population of 20 patients with 2 years of follow-up [8]. Other studies with a combined patient population of 92 did not report any anterior subluxation [7, 15, 16].

Table 4 Associations between postoperative radiographic complications and preoperative characteristics of CTA shoulder arthroplasties (N = 97)

Variable*		HR	(95% CI)	P-value
Male sex		1.09	(0.51, 2.37)	0.82
Age, per 10 year increase		0.85	(0.55, 1.32)	0.48
Any prior surgery		1.99	(0.67, 5.90)	0.21
Surgeon	Surgeon 1	(ref)		0.83
	Surgeon 2	0.87	(0.23, 3.31)	
Laterality	Left	(ref)		0.63
	Right	0.82	(0.36, 1.85)	
Seebauer class	1A-1B	(ref)		0.15
	2A-2B	2.04	(0.77, 5.42)	
Superior subluxation	None	(ref)		0.17
	Mild	1.38	(0.33, 5.74)	
	Moderate/severe/dislocated	3.47	(0.68, 17.80)	
Any anterior-posterior subluxation		1.04	(0.46, 2.33)	0.93
Acromion remodeling	None	(ref)		0.75
	Mild	1.12	(0.45, 2.74)	
	Moderate/severe	1.52	(0.51, 4.54)	
Any glenoid remodeling		0.90	(0.39, 2.04)	0.79
Osteoarthritis of glenohumeral joint	None	(ref)		0.98
	Mild	1.20	(0.35, 4.12)	
	Moderate	0.98	(0.27, 3.58)	
	Severe	1.13	(0.29, 4.36)	
Osteoarthritis of acromioclavicular joint	None	(ref)		0.16
	Mild	0.41	(0.12, 1.43)	
	Moderate/severe	1.46	(0.59, 3.63)	

HR = hazard ratio where HR >1 indicates the variable is positively associated with a higher rate of complications

*Some variable categories were combined because of small sample sizes (see Tables 1 and 2)

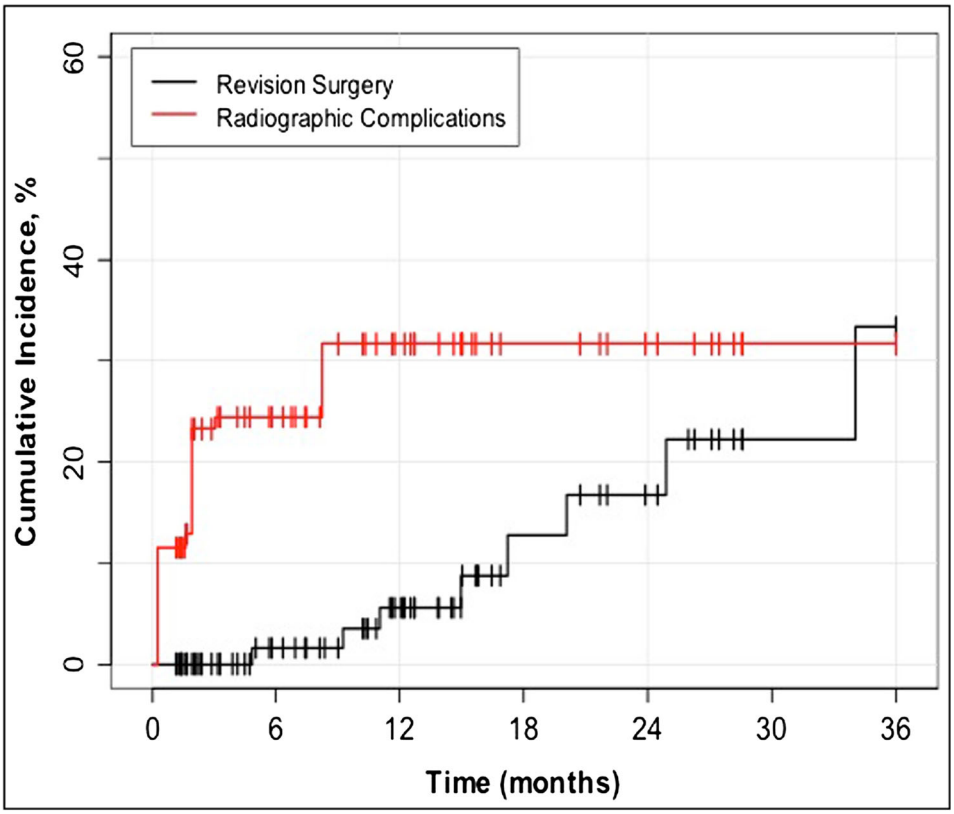

Fig. 3 Kaplan-Meier curves showing the cumulative incidence of surgical revision and radiographic complications. Radiographic complications occurred at a higher rate than surgical revision. The radiographic complication rate by 3 months was 23.3%. Follow-up was censored at 36 months because of the low number at risk by that time

The three largest studies in the literature with a combined patient population of 300 that look at CTA head hemiarthroplasty in the setting of cuff tear arthropathy had zero cases of glenoid remodeling, prosthetic subluxation, or perihardware loosening [7, 17, 20, 24]. There was one dislocation reported by Young and others; however, it was not clear whether this patient received a standard hemiarthroplasty or a CTA prosthesis [7]. Our discrepant rates of periprosthetic fracture (4.1%), glenoid remodeling (3.1%), superior subluxation (2.1%), hardware loosening (2.1%), and subsidence (1.0%) are likely secondary to our large sample size of 97 and methodical focus on radiographic complications. A glenoid remodeling rate of 42% was reported by Crawford and others; however, the patient population studied had rheumatoid arthritis as a primary diagnosis [21].

Our revision rate of 8.2% was comparable to reported revision rates ranging from 0–13.3% in the literature [17–21, 24]. Young and others report a revision rate of 8.8%; however, no distinction was made between standard hemiarthroplasty and cuff tear arthropathy hemiarthroplasty revision [7].

The two most common radiographic complications in CTA hemiarthroplasty are acromion remodeling and anterior subluxation. Similarly, reported complications of

Table 5 Correlation of radiographic outcomes with surgical revision (N = 97)

Complication	Percent with		HR	(95% CI)	P-value
	Revision surgery				
	Complication Present	Complication Absent			
Any radiographic complication	23.1% (6/26)	2.8% (2/71)	11.5	(2.4–55.7)	0.002
Any radiographic complication besides acromion remodeling	27.3% (3/11)	5.8% (5/86)	3.5	(1.1–11.0)	0.034
New acromion remodeling	26.3% (5/19)	3.8% (3/78)	29.2	(5.7–151.3)	<0.001

standard hemiarthroplasty for CTA include anterior-superior subluxation, acromion erosion, and glenoid erosion [8, 16]. The most common reason for surgical revision in our study cohort was anterior-superior instability on clinical examination, a direct sign of cuff failure, and pseudoparalysis, an indirect sign of cuff failure. The observed spectrum of radiographic complications in our study suggests that the pathologic biomechanics of CTA continue to persist even after arthroplasty. From an observational standpoint, postoperative CTA shoulder radiographs often demonstrated a high-riding hemiarthroplasty, often times corresponding with the degree of superior subluxation on preoperative radiographs. This is likely not a complication of the hemiarthroplasty but rather a marker of the sequelae of cuff tear arthropathy as the deltoid continues to exert an unbalanced superior vector arm on the humeral head because of unopposed balance from rotator cuff tear. Comparison to baseline immediate postoperative imaging is crucial to avoid overcalling superior subluxation. Complications such as heterotopic ossification and hardware loosening were uncommon in CTA hemiarthroplasty as well as shoulder replacement in general compared to weight-bearing joints such as in total ankle arthroplasty where hardware loosening, hardware fracture, and subsidence comprise of the most common complications [25].

Clinically, severe rotator cuff failure can be diagnosed with a physical examination finding called "anterior-superior escape" where there is anterior and superior subluxation of the humeral head when the patient raises his/her arm. Not surprisingly, this humeral head subluxation is often occult on static radiographic evaluation, which corresponds well with our finding that only two out of the five patients who underwent revision for a clinical diagnosis of anterior-superior escape had evidence of anterior or superior subluxation on radiographs. Our study raises the possibility that acromion remodeling, instead of glenohumeral alignment, may be a more reliable marker for ongoing pathologic altered cuff tear dynamics and ultimately cuff failure. It is a finding that is not dependent on a provoked physical examination maneuver or arm positioning and a finding that is likely less dependent on projection than glenohumeral subluxation.

Preoperative clinical characteristics associated with increased surgical revision or poor functional outcomes in general shoulder hemiarthroplasty include diagnosis of CTA or fracture sequela and prior history of surgical revision [26, 27]. Our analysis did not demonstrate that prior history of shoulder surgery was associated with radiographic complications. Our study cohort did not have enough power to appropriately evaluate the relationship of fracture sequela or history of shoulder surgery with revision in patients with CTA. Preoperative eccentric glenoid remodeling has also been associated with improved shoulder function and patient satisfaction in those who received hemiarthroplasty for osteoarthritis but not necessarily improved prosthesis survival [28]. Eccentric glenoid remodeling radiographic data were collected but are not reported as it was felt to be less reliable without a specific statement made in the operative report and given the lack of preoperative computed tomography. In general, younger patients tend to experience higher rates of revision, possibly due to higher functional demands as reported in a study that looked at approximately 15,000 cases of shoulder arthroplasty [29]. Our study lacked the power to appropriately study this given that the majority of our patients were over 50 years old.

There are some potential limitations that warrant discussion. First, our mean follow-up time of at least 1 year is relatively short compared to other studies, and follow-up was variable with three postoperative radiographs on average. However, our statistical approach was able to accommodate variable follow-up, and while the relatively short follow-up may tend to lead to an underestimation of complications, this was not apparent given our radiographic complication rate was comparable to or greater than those reported in the literature. Recent studies have suggested that the status of the rotator cuff as well as the degree of atrophy of cuff muscles may play a role in clinical outcome [30–32]. We were unable to study the relationship between muscle atrophy and cuff status with radiographic complications or surgical revision as no MRI was available at baseline or post-operation as this is not commonly ordered at our institution. Third, we did not have postoperative cross-sectional imaging, such as CT, as a gold standard for the evaluation of acromion remodeling and were subjected to the inherent projectional difficulties associated with radiograph plain film interpretation. Nonetheless, we feel that this was adequately mitigated with our consensus reader approach. Lastly, the number of surgical revision cases in our cohort was small, which limited our ability to adequately evaluate preoperative radiographic and clinical predictors of surgical outcome and compare this to other studies that have examined this in a more general population.

In conclusion, CTA head hemiarthroplasty is a popular option for a subset of those with cuff tear arthropathy. Radiographic complications after CTA hemiarthroplasty are common and important to recognize as they may increase the likelihood of surgical revision.

Compliance with ethical standards

Disclosures None.

Conflict of Interest The authors declare that they have no conflict of interest.

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