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Cement-within-cement technique in revision reverse total shoulder arthroplasty: complications, reoperations, and revision rates at 5-year mean follow-up

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A R T I C L E I N F O

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Reverse total shoulder arthroplasty
Implant survivorship
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Level of evidence: Level IV; Retrospective Case Series

Background: Revision reverse total shoulder arthroplasty (rTSA) of a previously cemented humeral component is challenging. In hip arthroplasty, the cement-within-cement (CwC) technique has been well described as an effective option. However, for shoulder arthroplasty there remains a paucity of data investigating this technique. The purpose of this study was to determine the mid-term outcomes of patients who underwent a revision rTSA utilizing the CwC for management of the humeral component.
Methods: Between 2005 and 2021, 68 revision rTSA using the CwC technique with a minimum of 2 years clinical follow-up were identified from a single institution joint registry database. Revised implants consisted of 38 (55.9%) hemiarthroplasties, 22 (32.4%) anatomic total shoulder arthroplasties, and 8 (11.8%) rTSA. A total of 12 (17.6%) shoulders required an osteotomy (corticotomy or window) to assist with extraction of the cemented stem. The mean follow-up after revision was 5.4 years (range, 2-16 years). Surgical complications, reoperations, revisions, and implant survivorship were assessed.
Results: Of the 12 shoulders that required an osteotomy for component removal, 11 (91.7%) were healed. At final follow-up, the overall complication rate was 26.9%. The most common complication was fracture or fragmentation of the greater tuberosity (20.6%, n = 13) with 10 (76.9%) cases showing signs of healing at final follow-up. The overall survivorship free of revision surgery was 88.2% at 2 and 80.9% at 5 years, respectively. The most frequent causes of re-revision surgery were aseptic glenoid component loosening (n = 4) and instability (n = 4), with only 2 (2.9%) patients developing humeral component loosening (at 2 and 5 years, respectively). Male sex was associated with an increased risk of revision surgery (hazard ratio [HR], 3.52 [95% confidence interval [CI] 1.22-10.18]; $P = .02$) and complications (HR, 3.56 [95% CI, 1.40-9.07]; $P = .008$). The grade of postoperative lucent lines at the humerus (HR, 1.35 [95% CI, 1.04-1.74]; $P = .02$) and glenoid (HR, 1.59 [95% CI, 1.22-2.10]; $P = .001$) also correlated with an increased risk of re-revision surgery.
Conclusion: The CwC technique is a reliable option for revising previously cemented humeral components in revision rTSA. Although a low rate of humeral component loosening was observed, higher rates of complications and re-revision surgery were observed over time secondary to aseptic glenoid component loosening and instability, which are not directly related to CwC technique but to revision surgery in general.

The number of primary shoulder arthroplasty (SA) performed every year has grown substantially over the last 2 decades, with increases of more than 300% expected between 2011 and 2030.[4,15,18] Correspondingly, the annual rate of revision SA has also increased, given both the volume of primary SA and younger

This study was approved by the Mayo Clinic Institutional Review Board; Mayo IRB # 12-007498.

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patient populations undergoing arthroplasty surgery.[11,21,26] Currently, reverse total shoulder arthroplasty (rTSA) is the most commonly performed SA procedure in the United States.[10] This rapid rise is related to the ability for rTSA to address many presenting shoulder pathologies, but also accommodate for failure of prior shoulder surgeries.[2,6,23,27,29]

Revision rTSA is a technically demanding but useful surgical technique for patients presenting with failure of prior arthroplasty procedures.[2,13,22] Common causes for revision to a rTSA include rotator cuff failure, glenoid component loosening, and infection after anatomic total SA, and instability, infection, and periprosthetic fractures after rTSA.[2,19,27] Not uncommonly, at the time of revision surgery surgeons are faced with humeral component malposition or loosening, joint medialization, or periprosthetic fractures that would all require exchange of the humeral component.[7,12,29,30] When faced with the revision of a stemmed humeral component, surgeons must balance the need to avoid further compromise of humeral bone stock and at the same time obtain adequate primary stability of the revision humeral component. This becomes especially challenging in the setting of a well-fixed cemented humeral component, as stem extraction and removal of cement can lead to cortical perforation, fracture, substantial bone loss, and even risk of thermal injury to the radial nerve when ultrasound-based cement removal techniques are utilized.[1,2,6,11,25-27,30]

As a result, the cement-within-cement (CwC) technique remains very attractive to help mitigate these risks, preserve bone stock, and provide a solid fixation.[12,28] Literature supportive of CwC was introduced in 1978 for the revision of total hip arthroplasty, with subsequent evidence demonstrating low perioperative complication rates and favorable rates of long-term revision-free survival.[25,31] However with regard to the humerus, outcomes on CwC is limited to two small case series and one biomechanical study.[12,25,28] Therefore, the purpose of this study was to add to the known literature by describing the mid-term complication rate and survivorship of patients who underwent revision to a rTSA using the CwC technique.

Methods

Cohort selection

Following institutional review board approval, this retrospective case series utilized our institutional Total Joint Registry Database to identify all patients who underwent revision of a failed cemented humeral component to a cemented reverse component using the CwC technique. Patients with signs of infection (preoperatively or intraoperatively) and those with less than 2 years of follow-up were excluded. Other exclusions consisted of patients requiring an allograft prosthetic composite, a modular segmental proximal humerus replacement (tumor prosthesis), need for a strut allograft, or those presenting with a periprosthetic fracture. The initial data collection was obtained through our institutional Total Joint Registry Database, which prospectively captures patient demographics, operative details, complications, reoperations, and implant revisions.[3]

For confirmation of details and additional information, a manual electronic medical record review was performed for all patients.

Between January 1, 2005, and December 31, 2021, 68 consecutive patients underwent revision of a failed cemented humeral component to a cemented reverse component using the CwC technique. The mean follow-up was 5.4 years (range, 2-16 years). Failed arthroplasties to be revised consisted of 38 (55.9%) hemiarthroplasties, 22 (32.4%) anatomic total shoulder arthroplasties, and 8 (11.8%) rTSA. The most common cause of revision surgery was rotator cuff failure (57 shoulders, 83.8%), with a variable degree of associated glenoid wear in this group of patients. Additional reasons for revision included glenoid loosening (n = 6, 8.8%), humeral loosening (n = 3, 4.4%), and instability (n = 2, 2.9%). Table I summarizes all demographic data.

Table I
Demographic characteristics of patients undergoing the cement-within-cement technique.

Variable	No. (%) or mean ± SD or median (range)
Number	68
Age at surgery (y)	70.5 (26-89)
Female Sex	50 (73.5%)
BMI at surgery (kg/m^2)	31.4 ± 5.6
Tobacco use	
Current	6 (8.8%)
Former	30 (44.1%)
Never	32 (47.1%)
Presenting implants	
Hemi	38 (55.9%)
aTSA	22 (32.4%)
rTSA	8 (11.8%)
Follow-up (y)	5.1 (2-15.6)

BMI, body mass index; *Hemi*, Hemiarthroplasty; *aTSA*, anatomic total shoulder arthroplasty; *rTSA*, reverse total shoulder arthroplasty; *SD*, standard deviation.

Surgical details

All revision surgeries were performed through a standard deltopectoral approach. Humeral component extraction was attempted from the upper end of the humerus utilizing a combination of pencil tip burrs, flexible osteotomes, and an oscillating saw as necessary. In 12 (17.6%) shoulders an osteotomy was required to extract the stem with 8 (11.8%) shoulders requiring a window osteotomy and 4 (5.9%) shoulders requiring a vertical osteotomy/corticotomy. In all these cases stem removal was first attempted using a single vertical osteotomy at the anterior cortex of the humerus at the bicipital groove. If extraction was unsuccessful, we would proceed with a second vertical osteotomy (around 2 cm lateral to the previous one) and then connecting both vertical osteotomies distally with a horizontal cut to create a window for implant extraction. All osteotomies were repaired either with sutures (n = 6; 8.8%) or wires (n = 6; 8.8%).

After the humeral component was explanted, the remaining cement mantle was roughened with a high-speed burr, cleaned, and dried prior to placing the new cement. Cultures were taken in 34 cases; 8 of these 34 cases (24%) grew unexpected positive cultures. These 34 patients correspond to surgeons that routinely obtain cultures in all their revision cases. Antibiotics (gentamicin and vancomycin) were added to the cement in 52 out of 68 shoulders (75.3%) also based on surgeońs preferences. The revision components used in conjunction with the CwC technique were 49 (72.1%) Zimmer-Biomet (Warsaw, IN, USA), 11 (16.2%) DJO (Austin, TX, USA), 5 (7.4%) DePuy (Raynham, MA, USA), 2 (2.9%) Stryker (Kalamazoo, MI, USA), and 1 (1.5%) Exactech (Gainesville, FL, USA). Of note, revision stems were smaller than the extracted stems to allow for a cement mantle of at least 2-3 mm between the old and new cement. There were 14 (20.6%) intraoperative complications noted, including 1 (1.5%) glenoid fracture that was treated at the time of surgery with screw fixation, and 13 (19.1%) greater tuberosity fractures that were treated with suture fixation. Fig. 1 shows an example of a CwC revision rTSA surgery.

Radiographic assessment

For each patient, preoperative, immediate postoperative, and most recent radiographs were evaluated for humeral loosening,

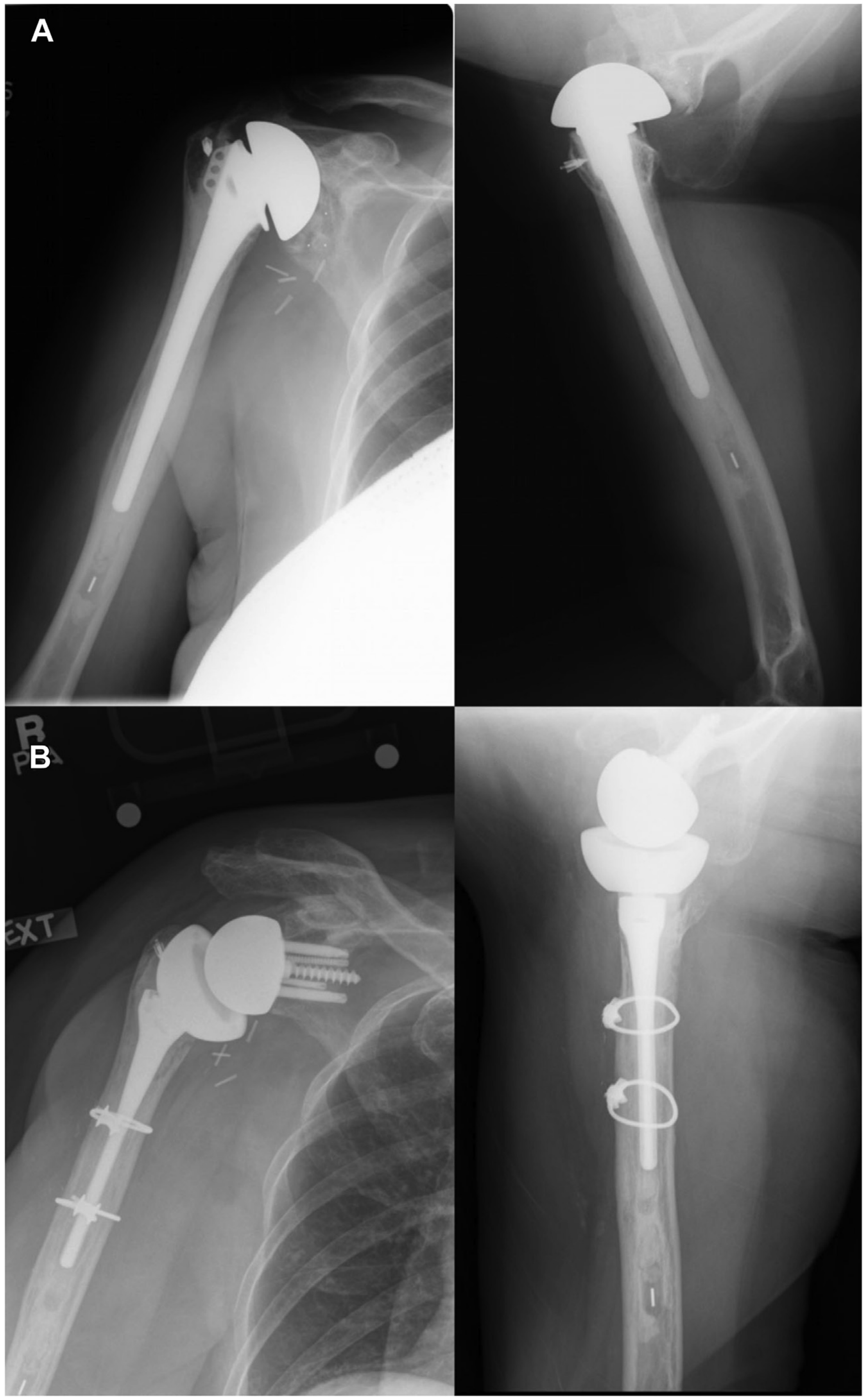

Figure 1 (**A**) Preoperative radiographs of a patient who underwent revision to reverse for glenoid component loosening and rotator cuff tearing. (**B**) Radiographs taken 6 years after revision to reverse arthroplasty with a cement within cement technique. The patient underwent a humeral split to remove the humeral component with wiring of the humerus.

glenoid loosening, and subluxation (both severity and direction). Humeral periprosthetic lucency was classified as 0 (none), 1 (<1 mm wide, incomplete), 2 (1 mm wide, complete), 3 (1.5 mm wide, incomplete), 4 (1.5 mm wide, complete), or 5 (2 mm wide, complete).[5] The humeral lucency scale, as defined above, evaluated any lucent lines in the periprosthetic space between the implant and cement mantle or the space between the outer cement mantle and the bone. Notching was assessed according to the classification described by Sirveaux et al.[24]

Statistical analysis

The statistical analysis was performed utilizing Stata 15.1 (StataCorp LLC, College Station, TX, USA). For descriptive analytics the results are reported using mean ± standard deviation for parametric continuous variables and median (range) for nonparametric or categorical ordinal variables. The Shapiro-wilk test was used to assess normality. Association between categorical variables was established using the chi-square test (or Fisheŕs exact for lower

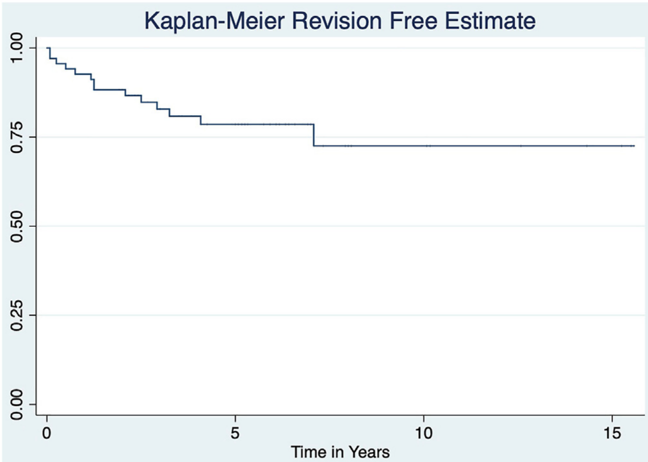

Figure 2 Kaplan-Meier estimate for revisions. Note that most of the events occur in two clusters, the first within the first two years and the second around three years postoperative.

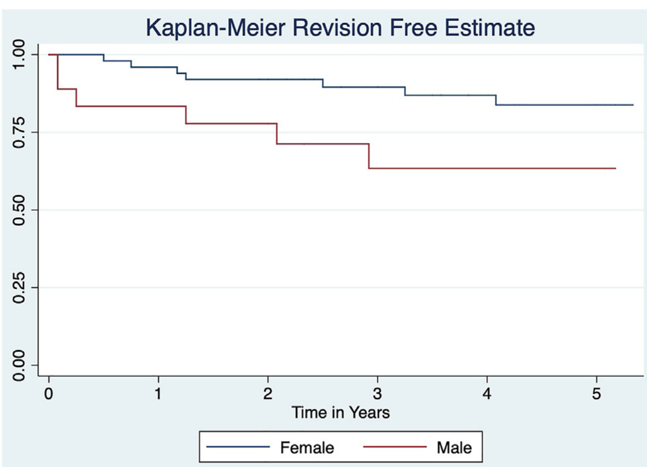

Figure 3 Kaplan Meier estimates at five years for males and females. Males have a higher chance to be revised in the observation period ($P = .019$).

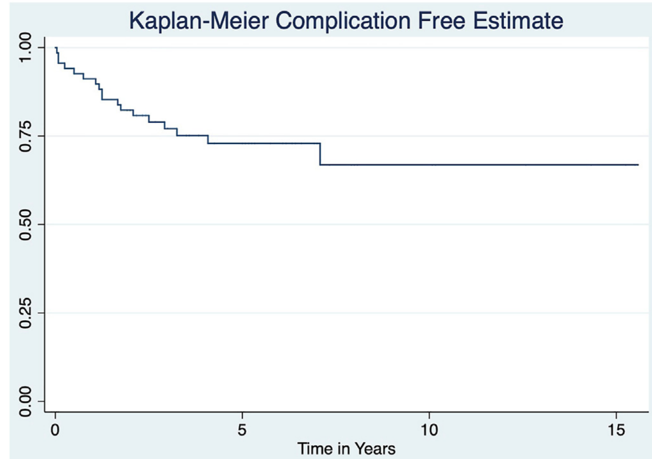

Figure 4 Kaplan-Meier estimate for complications.

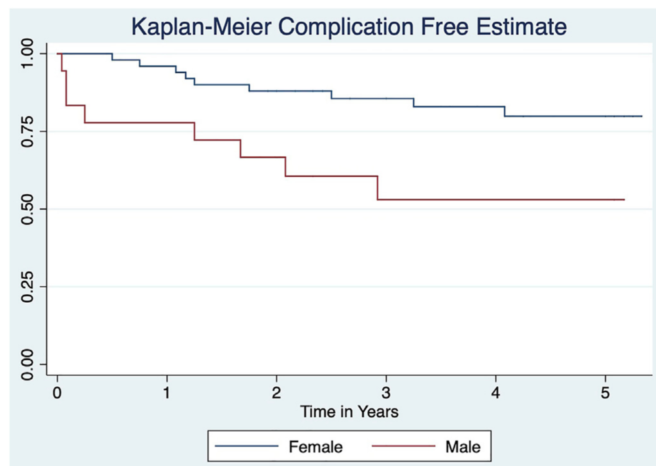

Figure 5 Kaplan-Meier estimates at five years for males and females. Males have a higher chance of having a complication in the observation period ($P = .006$).

counts). Kaplan Meier survival analysis was performed for complications and revisions. To establish differences in survivorship between subgroups, the log-rank test for equality of survival functions was used. Cox proportional hazard ratios (HRs) were calculated for variables that impacted survivorship adjusting for sex and age and reported with a 95% confidence Interval (CI). For all analyses, statistical significance was set at $P < .05$.

Results

Implant survival, reoperations, and post operative complications

Of the 68 shoulders revised to a rTSA with the CwC technique, 14 shoulders (20.6%) had. required additional revision surgery at final follow-up. In 8 shoulders (11.8%), revision surgery was performed prior to 2 years and in 6 (8.8%) shoulders after 2 years of follow-up. The median time to additional surgery after the index CwC revision surgery was 1.25 years (0.5-2.9). A Kaplan Meier survival analysis curve is provided in Fig. 2. The overall revision free survival was 88.2% (60/68) at 2 years and 80.9% (55/68) at 5 years. Male sex was associated with an increased risk of revision surgery (HR, 3.52 [95% CI 1.22-10.18]; $P = .02$), while, with the numbers available, age, number of prior surgeries, tobacco use, body mass index, the use of osteotomies, positive cultures, intraoperative complications, or adding antibiotics to the cement were not found to affect the risk of requiring additional surgery or developing a complication (Fig. 3). Indications for additional revision surgery include glenoid component loosening (n = 4), instability (n = 4), periprosthetic fracture (n = 3), humeral component loosening (n = 2), and infection (n = 1). The two cases of revision due to humeral loosening were performed at 2 and 7 years of follow-up, respectively.

The overall rate of complications was 26.9% (n=18). Additional complications which did not lead to revision surgery included glenoid loosening (n = 2), instability (n = 1), and infection (n = 1). All incidents of infection after CwC technique revision occurred in shoulders in which cement had added antibiotics. As with revisions, male sex was associated to a higher chance of sustaining a complication (HR, 3.56 [95% CI, 1.40-9.07]; $P = .008$). Kaplan-Meier estimate curves for complications of the complete cohort and by sex are provided in Figs. 4 and 5, respectively.

Radiographic outcomes

Of the 68 patients included, 65 had adequate radiographs at final follow-up. For the 12 shoulders that required an osteotomy

Table II
Radiographic outcomes of patients undergoing the cement-within-cement technique.

Outcome measure	No. (%)	Number of further revisions after CwC	HR for further revision after CwC
Preoperative humeral lucency			0.85 (*P* = .52, [95% CI 0.52-1.39])
Grade 3	6 (8.8%)	2	
Grade 4	2 (2.9%)	0	
Grade 5	1 (1.5%)	0	
Preoperative glenoid lucency			0.92 (*P* = .61, [95% CI 0.67-1.27])
Grade 3	7 (10.3%)	0	
Grade 4	6 (8.8%)	2	
Grade 5	7 (10.3%)	1	
Postoperative humeral lucency			**1.35 (*P* = .02, [95% CI 1.04-1.74]**
Grade 3	4 (6.2%)	1	
Grade 4	0	-	
Grade 5	4 (6.2%)	3	
Postoperative glenoid lucency			**1.59 (*P* = .001, [95% CI 1.22-2.1]**
Grade 3	0	-	
Grade 4	2 (3.1%)	1	
Grade 5	4 (6.2%)	3	
Postoperative notching grade			1.59 (*P* = .08, [95% CI 0.95-2.67]
Grade 2 and 3*	7 (10.3%)	4	

HR, Hazard Ratio; *rTSA*, reverse total shoulder arthroplasty; *CwC*, Cement-within-cement.
Bold values represent statistical significance ($P < .05$).
*There were no patients with grade 4 notching.

(window or vertical), healing was observed in 11 of 12 cases (91.7%). For shoulders in which a fracture of the greater tuberosity occurred at the time of revision surgery, 10/13 (76.9%) healed radiographically at final follow-up. The grade of preoperative lucent lines in the humerus or glenoid as well as the grade of superior humeral subluxation did not influence the risk of further revision surgery. Conversely, the grade of postoperative lucent lines at the humerus (HR, 1.35 [95% CI, 1.04-1.74]; $P = .02$) and glenoid (HR, 1.59 [95% CI, 1.22-2.10]; $P = .001$) correlated with an increased risk of further revision surgery after CwC rTSA. Scapular notching was infrequent, with 61 patients (89.7%) having notching grade 0 to 1 at final follow-up. Table II summarizes the radiographic outcomes.

Discussion

Revision of a cemented humeral component presents a number of challenges, including stem and cement removal, humeral bone stock preservation, and creation of a stable foundation for implantation of revision humeral stem.[5,8,16,17,27] The CwC technique has been well described in the revision hip arthroplasty literature as a predictable technique to minimize bone loss and provide secure fixation.[9,14,20,31] There have been few papers published in the SA literature on this technique. The results of our study seem to indicate that this technique is reliable in the field of SA, with only two of 68 shoulders requiring an additional revision procedure specifically for humeral component loosening.

Wagner et al[26] published on the short-term outcome of 38 shoulders that underwent CwC revision SA at a mean of 3.7 years of follow-up. Patients experienced significant improvements in pain relief and range of motion, with high satisfaction rates. There were 7 (18%) intraoperative greater tuberosity fractures, but all of these had healed at time of final follow-up. Notably, the authors reported no patients who required revision for humeral component loosening, suggesting success of the CwC technique.

Gorman et al[12] recently reported on 98 patients who underwent a CwC technique and were followed for a mean of 4.5 years. These authors also noted significant improvement in functional outcome scores and range of motion. However, they also observed that 8 of their 98 (8.2%) shoulders developed humeral component loosening. Sub analysis of their cementation technique highlighted the importance of considering using a smaller humeral stem than previously implanted in order to help maximize the cement volume used during implantation of the revision humeral component.

The present study builds on the existing literature observing similar findings. In our cohort, we observed a 14.7% rate of tuberosity fragmentation that occurred mostly during humeral component removal. Fortunately, 10 of 13 (76.9%) shoulders had healed their tuberosity fracture at final follow-up. There were 12 patients who required a humeral window or split to remove the stem, but 91.7% of these cases were healed at final follow-up. Finally, in this complex cohort, the overall implant survivorship rates at 2 and 5 years were 85.5% and 79.2%, respectively. As noted, when looking specifically at the durability of the CwC technique, there were only two patients who underwent revision surgery for humeral component loosening (2.9%).

This study highlights several technical aspects that may be helpful for the surgeon performing this technique. It is important to carefully evaluate the preoperative radiographs to ensure that the distal cement mantle is stably interdigitated with the cortical bone. Humeral component removal must be performed with the goal of preserving as much proximal humerus as possible. In cases where the stem cannot be effectively removed from above, the surgeon should be prepared for the use of a humeral window or cortical split if necessary. The data from this study highlights a high rate of osteotomy and window union; therefore, these techniques should be encouraged in cases where humeral extraction from above proves difficult.

After successful humeral component removal, an intraoperative evaluation of the stability of the remaining cement mantle should be carefully performed. Subsequently, use of a high-speed burr to roughen the surface of the cement to promote interdigitation is routinely performed in our practice and encouraged to others. It is helpful to have short and narrow stems available that can fit within the preexisting mantle. This allows the stem to be placed without removing significant amounts of cement and allows for a higher volume of new cement to be added at the time of reimplantation. In select cases, it may be useful to preoperatively template the case to ensure that the system to be used has a stem short enough and thin enough to be placed in the retained cement space. Finally, while not directly supported by our current study, the surgeon may consider the addition of antibiotics in the cement in cases that could be at higher risk of having positive intraoperative cultures.

There are several limitations associated with this study. First, this is a retrospective investigation of an established database spanning multiple decades, yet we still have a relatively small number of patients undergoing the CwC revision rTSA technique. This limits the ability to fully examine cofounding variables that may be associated with our results. Second, there is an inherent diverse nature of pathologies that led these patients to present for revision surgery, all of which may individually influence the outcome of revision surgery and we were unable to control for this. Third, we were unable to perform a volumetric analysis of the cement placed after CwC; therefore, we cannot fully assess the impact of cementation volume.

Conclusion

The CwC technique is a reliable option for revising previously cemented humeral components in revision rTSA. Although a low rate of humeral component loosening was observed, over time higher rates of complications and revision surgery were observed related mainly to aseptic glenoid component loosening and instability, which are not directly related to CwC technique but to revision surgery in general.

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