The rate of infection after primary total shoulder arthroplasty (TSA) has been reported as 0.7% to 6%, and it is even higher for revision procedures. The optimal management of infected TSA remains uncertain. There is little high-quality evidence, with few reports in the literature, and studies are often based on expert opinion and single-institution case series. Debridement, 1- or 2-stage revision, definitive treatment with articulating antibiotic spacers, and excision arthroplasty have all been reported. However, the optimal circumstances for each treatment are unknown, and the expected clinical outcomes are unclear.

The utility of articulating, antibiotic-impregnated cement spacers to treat periprosthetic hip and knee infections is well established, and that knowledge has been translated to the management of infected shoulder prostheses. However, the role of these implants as part of staged revision procedures (eg, 2-stage revision procedures) or as a definitive treatment modal...

The authors are from the Department of Orthopaedic Surgery, NYU Hospital for Joint Diseases, New York University Langone Medical Center, New York, New York.

Drs Mahure, Mollon, and Yu have no relevant financial relationships to disclose. Dr Kwon is a paid consultant for DJO Surgical. Dr Zuckerman receives royalties from Exactech.

Correspondence should be addressed to: Siddharth A. Mahure, MD, MBA, Department of Orthopaedic Surgery, NYU Hospital for Joint Diseases, New York University Langone Medical Center, 301 E 17th St, New York, NY 10003 (Siddharth.mahure@nyumc.org).

Received: January 19, 2016; Accepted: April 20, 2016.

doi: 10.3928/01477447-20160623-07

Infection in the setting of shoulder arthroplasty can result in significant pain, loss of function, and the need for additional surgery. As the use of shoulder arthroplasty increases, the medical and economic burdens of periprosthetic joint infection increase as well. The ideal management of infected shoulder prostheses has not been established. This report describes 9 patients from a single institution who had an infected shoulder arthroplasty that was definitively managed with a cement spacer. All patients had a minimum of 2 years of follow-up. Of the 9 patients in this study, 6 were men. Mean age was 73±9 years. Of the study patients, 1 had diabetes, 2 presented with Parkinson’s disease, and 5 had a history of tobacco use. Average body mass index was 27.9±7 kg/m². After mean follow-up of 4 years, none of the patients had clinical or radiographic evidence of infection. Functional outcomes, as measured by American Shoulder and Elbow Surgeons scores, were good or fair in 89% of patients, and the average American Shoulder and Elbow Surgeons score was 57. A review of recent literature suggested that the current findings were similar to those in studies reporting 1- or 2-stage revision procedures. Although cement spacers are typically used as part of a 2-stage revision procedure, the current findings suggest that cement spacers can be used effectively to eradicate infection and allow for acceptable functional recovery and range of motion in patients who have severe medical comorbidities and cannot tolerate additional surgery. [Orthopedics. 2016; 39(5):e924-e930.]

The rate of infection after primary total shoulder arthroplasty (TSA) has been reported as 0.7% to 6%, and it is even higher for revision procedures. The optimal management of the infected TSA remains uncertain. There is little high-quality evidence, with few reports in the literature, and studies are often based on expert opinion and single-institution case series. Debridement, 1- or 2-stage revision, definitive treatment with articulating antibiotic spacers, and excision arthroplasty have all been reported. However, the optimal circumstances for each treatment are unknown, and the expected clinical outcomes are unclear.

The utility of articulating, antibiotic-impregnated cement spacers to treat periprosthetic hip and knee infections is well established, and that knowledge has been translated to the management of infected shoulder prostheses. However, the role of these implants as part of staged revision procedures (eg, 2-stage revision procedures) or as a definitive treatment modal...
ity is uncertain.\(^1,10\) Additionally, although surgeon-made cement spacers have been described, many prefabricated spacers are now available.\(^3\)

Because of differences in surgical technique and varying functional and weight-bearing demands of the hip and knee compared with the shoulder, it is difficult to directly translate knowledge from the lower extremity to the upper extremity. Compared with lower-extremity replacements, cement spacers used around the shoulder are inserted with a greater emphasis placed on maintaining the integrity of the soft tissue envelope and maintaining joint stability without bony constraint. Further, the weight-bearing demands of the shoulder are much less compared with the lower extremity, and limitations in range of motion can often be better tolerated when aligned with realistic functional expectations. Although less virulent organisms are generally responsible for shoulder infections compared with hip and knee arthroplasty, reinfection of the previously infected shoulder arthroplasty often results in detrimental outcomes and only modest improvements in function.\(^3,4,14,15\)

An ideal surgical treatment for infected shoulder arthroplasty would eradicate the infection while providing adequate pain relief and maximizing function. Insertion of a glenoid component after eradication of infection is believed to optimize patient outcomes and mitigate long-term complications (eg, glenoid erosion). However, few data are available on the use of articulating cement spacers for definitive treatment of the infected shoulder arthroplasty. The authors conducted a retrospective case series to identify patients who were treated definitively with a cement spacer after periprosthetic shoulder infection. The authors hypothesized that a cement spacer would eradicate infection and provide adequate pain relief with acceptable functional outcomes and that definitive management with a cement spacer can be a viable treatment modality in carefully selected patient populations.

**Materials and Methods**

After institutional review board approval was obtained, the authors retrospectively reviewed their institution’s database to identify patients who underwent removal of an infected shoulder arthroplasty and insertion of an articulating cement spacer between 1990 and 2013. Patients were followed for a minimum of 2 years. Exclusion criteria included documentation that the patient was scheduled for removal of the cement spacer and a subsequent second-stage revision procedure either at the study institution or at another facility. Data obtained from the chart review included patient age, sex, medical comorbidities, initial diagnosis, previous surgery, diagnostic imaging, results of infectious workup (eg, culture results, inflammatory serology), and range of motion. Pre- and postoperative American Shoulder and Elbow Surgeons (ASES) scores have been validated in patients with infected shoulder arthroplasty and were reported when available.

**Patient Sample**

With the described protocol, this study identified 9 patients who underwent insertion of an articulating cement spacer to treat an infected shoulder arthroplasty as definitive treatment at the study institution by 1 of the 2 senior authors (Y.W.K., J.D.Z.). Mean patient age at presentation with an infected prosthesis was 73±9 years (range, 60-87 years), and 67% of the patients were male. The right side was treated surgically in 78% (7 of 9) of cases, and in all but 1 patient the right hand was dominant. Degenerative joint disease was the most common indication for initial arthroplasty (5 of 9), followed by fracture (2 of 9), cuff tear arthropathy (1 of 9), and proximal humeral nonunion (1 of 9). In 5 cases, the infected prosthesis was a total shoulder arthroplasty (TSA), in 2 cases it was a hemiarthroplasty, and in 2 cases it was a reverse TSA. A total of 7 patients presented after having only 1 previous procedure on the shoulder. The other 2 patients had undergone 2 previous procedures each. In 1 case, the patient had undergone hemiarthroplasty for treatment of a proximal humerus fracture and was subsequently converted to reverse TSA because of pain and functional limitations, and the other patient required conversion from TSA to reverse TSA 20 years after the initial procedure because of glenoid loosening and rotator cuff failure. In addition, 1 patient had type II diabetes mellitus, 1 patient was a current smoker, and 4 patients had quit smoking before presentation. Average body mass index was 27.9±7.0 kg/m\(^2\).

Preoperative workup for infection was varied and included a combination of clinical, radiographic, and laboratory tests (Table 1). Eradication of infection was defined as the absence of clinical signs of infection, normalization of inflammatory markers (if performed), and radiographic findings that showed no progressive osteolysis.

**Cement Spacer Insertion**

All patients underwent removal of the shoulder arthroplasty and cement, collection of intraoperative cultures, and thorough irrigation and debridement, followed by insertion of a cement spacer. All patients were treated as if this were the first stage of a 2-stage revision. Mean time between the previous arthroplasty insertion and conversion to the cement spacer was 19 months (range, 3 weeks to 83 months). Prefabricated cement spacers were used in all but 1 patient. This patient’s surgery was performed before premade spacers were available. All prefabricated spacers were the same model made by the same manufacturer (InterSpace Shoulder; Exactech, Inc, Gainesville, Florida) and consisted of gentamicin-impregnated polymethyl methacrylate around an AISI 316L stainless steel core.\(^13\) For the 1 patient who was treated with a surgeon-made spacer, unspecified doses of tobramycin and vancomycin were mixed into commercially available cement that was then molded over a bent Rush rod.
For all patients, intraoperative and preoperative cultures were used to determine the causative organism, and 2 or more types of bacteria were identified in 2 patients (Table 1). Consultation with an infectious disease specialist was obtained for all patients for appropriate management of postoperative antibiotics.

### Literature Search

A review of the literature was performed to identify other case series of infected shoulder arthroplasty treated definitively with cement spacers. The authors searched MEDLINE, Embase, and Google Scholar to identify studies containing the word “shoulder” and “infection” in any field, from inception of the database to December 2014. The relevant studies were then forward searched by reviewing the bibliographies of all retrieved studies and other relevant publications, including review articles, to identify additional investigations. Data were analyzed descriptively and reported as means±SD unless otherwise specified.

### Results

After a mean follow-up of 48 months (SD, 35.1; range, 24-132 months), none of the 9 patients had clinical or radiographic signs of infection. Functional outcomes varied widely (Table 2). Overall, self-reported outcomes were good in 6 patients, fair in 2, and poor in 1. Mean postoperative ASES score was 57 (SD, 24-45; range, 30-97), and mean active forward flexion in the scapular plane was 67° (SD, 45°-150°). The overall complication rate was 11%, with 2 patients undergoing additional revision or surgical procedures since implantation of the cement spacer. At the most recent follow-up, 2 of 9 patients were considering a revision (although they had not undergone definitive surgery).

### Table 1

<table>
<thead>
<tr>
<th>Patient No.</th>
<th>Initial Procedure</th>
<th>Radiographic Evidence of Infection</th>
<th>Erythrocyte Sedimentation Rate, mm/h</th>
<th>C-reactive Protein Level, mg/L</th>
<th>White Blood Cell Count, /µL</th>
<th>Aspiration</th>
<th>Final Cultures</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Hemiarthroplasty</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
<td>Positive</td>
<td>Enterococcus</td>
</tr>
<tr>
<td>2</td>
<td>Reverse TSA</td>
<td>Yes</td>
<td>131</td>
<td>Elevated</td>
<td></td>
<td>Negative</td>
<td>Serratia</td>
</tr>
<tr>
<td>3</td>
<td>TSA</td>
<td>No</td>
<td>61</td>
<td>24</td>
<td>8.9</td>
<td>Positive</td>
<td>Propionibacterium acnes, Proteus mirabilis</td>
</tr>
<tr>
<td>4</td>
<td>Reverse TSA</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
<td>Negative</td>
<td>Propionibacterium granulosum</td>
</tr>
<tr>
<td>5</td>
<td>Hemiarthroplasty</td>
<td>Yes</td>
<td>78</td>
<td>23</td>
<td>5.2</td>
<td>Negative</td>
<td>S epidermidis</td>
</tr>
<tr>
<td>6</td>
<td>TSA</td>
<td>Yes</td>
<td>55</td>
<td>33</td>
<td>5.8</td>
<td>Negative</td>
<td>Coagulase-negative Staphylococcus; P acnes</td>
</tr>
<tr>
<td>7</td>
<td>TSA</td>
<td>Yes</td>
<td>90</td>
<td>66</td>
<td>Small increase</td>
<td>Negative</td>
<td>P acnes</td>
</tr>
<tr>
<td>8</td>
<td>TSA</td>
<td>No</td>
<td>28</td>
<td>1.3</td>
<td>5.7</td>
<td>Positive</td>
<td>P acnes</td>
</tr>
</tbody>
</table>

Abbreviation: TSA, total shoulder arthroplasty.

*Six weeks before insertion of the antibiotic spacer, the patient required irrigation and debridement of an ipsilateral total elbow arthroplasty for osteomyelitis. Surgical pathologic findings from this elbow procedure and clinical and radiographic evidence of shoulder infection were used as indications for insertion of a shoulder antibiotic spacer.*
The first patient presented with radiographic evidence of glenoid erosion 132 months after insertion of the cement spacer (Figure 1). The other patient reported poor clinical outcomes without any radiographic abnormalities 32 months after cement spacer insertion. When medical comorbidities were considered in combination with realistic expectations of functional status, both patients were advised against proceeding with revision.

At the most recent follow-up, radiographic findings were unremarkable in 6 patients (67%), with the prosthesis in an acceptable position and no evidence of progressive glenoid or humeral osteolysis. In 2 patients (22%), there was evidence of mild glenoid erosion at 40 and 132 months, respectively (Figures 1-2), and 1 patient (11%) had a fracture that healed with valgus deformity.

The literature search identified 10 studies that included 58 patients who were treated definitively with cement spacers (Table 3). Although it was difficult to extract complete data on all patients as a result of limited reporting, the reinfection rate with an in situ cement spacer was 5% (3 of 58). Functional results were generally poorly captured by previous studies. Average postoperative active range of motion after definitive treatment with a cement spacer was 74° to 110° forward flexion, 11° to 25° external rotation, and 51° to 78° abduction. Functional outcome scores were reported in 6 studies. Constant scores ranged from 26 to 57, and the only DASH score reported was 37.5. Of 58 patients, 4 (7%) had a complication: 3 cement spacers fractured and 1 patient had a periprosthetic fracture that was treated with a brace alone.

**Discussion**

Infection after shoulder arthroplasty is an uncommon but potentially devastating complication. The current findings suggest that removal of the infected prosthesis, followed by thorough irrigation and debridement and subsequent insertion of
a cement spacer, can be a relatively successful mode of definitive treatment in appropriate patients. After a mean follow-up of 48 months, this study reported 0% recurrence of infection in the 9 study patients. Overall functional results did not appear drastically different from the published results for 1- or 2-stage revision. Mean follow-up ASES score in the current series was 57 (SD, 24; range, 30-97), which is comparable to the findings of Klatte et al24 and Beekman et al,7 who reported Constant-Murley scores of 51.1 and 55, respectively, in patients with 1-stage revision. Additionally, Coffey et al13 reported a mean ASES score of 74 and a mean Constant score of 57 in patients with 2-stage revision. Functionally, this cohort of patients had average forward flexion of 67°±45°, which is comparable to the average forward flexion (66.4°±20.8°) reported by Sabesan et al9 in planned 2-stage revisions. Although a literature search found few clinical data on the use of cement spacers as definitive treatment in patients with infection, functional outcomes in the current study are in line with previous series that reported an overall reinfection rate of 5%.

Most of the patients in the current series had significant medical comorbidities or substantial bony deformity or destruction that made the risks of subsequent shoulder reconstructive efforts outweigh the potential benefits. Based on the authors’ clinical experience, patients who had no significant medical comorbidities tended to be less satisfied with the outcomes with an in situ cement spacer. In the current series, when patients with significant medical comorbidities were compared with those without significant comorbidities, patients with fair or poor results tended to be sicker, whereas healthier patients had greater average active range of motion (eg, forward flexion 95° vs 33°, respectively) and higher ASES scores (68 vs 40, respectively). Parkinson’s disease precluded 2-stage revision in 2 of the 4 patients with significant medical comorbidities. The risks associated with surgery and the potential for postoperative complications were not believed to justify the likely ultimate functional recovery. Because of limitations in reporting, the authors could not perform a similar comparison with data obtained during the literature review.
The decision to retain a cement spacer is associated with potential complications. In the current series, 1 patient had a periprosthetic humeral shaft fracture just distal to the stem of the cement spacer, and this complication was also reported in 1 study identified during the literature search. This complication is likely related to the common technique of placing cement only proximally around the cement spacer to facilitate removal during the second stage of revision. Additionally, the humeral stem, which is available in limited sizes and is often intentionally undersized to avoid fracture and facilitate ease of subsequent removal, can be expected to move easily within the humeral canal, causing endosteal resorption and increasing the risk of fracture. Although the patient in the current series who had a periprosthetic fracture ultimately healed with nonoperative treatment, the residual valgus deformity would complicate future attempts at conversion to an implant. Another potential consequence of a retained cement spacer is glenoid erosion. This finding occurred in 2 patients after 40 and 132 months of follow-up, respectively. Because prefabricated cement spacers were not commercially available at the time of surgery, 1 patient received a surgeon-made cement spacer. It has since been reported that the smooth surface of prefabricated spacers allows for better articulation and causes less glenoid erosion than surgeon-made spacers. Thus, the current patient’s glenoid erosion probably can be attributed to the limitations of cement spacer options at the time of surgery. Although glenoid erosion in both cases was mild, the implications of a cement spacer articulating directly on glenoid bone stock over a sustained period are unclear and warrant longitudinal investigation.

### Table 3

Results of Literature Review on Definitive Treatment With Cement Spacers for Deep Shoulder Infection

<table>
<thead>
<tr>
<th>Study (Year)</th>
<th>No. of Patients/Shoulders</th>
<th>Spacer Type</th>
<th>Average Follow-up, mo</th>
<th>Mean Postoperative ROM</th>
<th>Mean Functional Score</th>
<th>Recurrent Infection Rate</th>
<th>Complications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ghijselings et al (2013)</td>
<td>5/5</td>
<td>IO/1 PF</td>
<td>64.8</td>
<td>NR</td>
<td>Constant, 20.6</td>
<td>0</td>
<td>1/5: Periprosthetic humeral fracture treated conservatively with a brace</td>
</tr>
<tr>
<td>Romano et al (2012)</td>
<td>15/15</td>
<td>IO/4 PF</td>
<td>36</td>
<td>15°</td>
<td>Abduction, 51°; ER, 13°</td>
<td>Constant, 34</td>
<td>7% (1/15)</td>
</tr>
<tr>
<td>Verhelst et al (2011)</td>
<td>6/6</td>
<td>IO</td>
<td>27.6</td>
<td>AEE, 83°</td>
<td>NR</td>
<td>NR</td>
<td></td>
</tr>
<tr>
<td>Beekman et al (2010)</td>
<td>1/1</td>
<td>NR</td>
<td>24</td>
<td>NR</td>
<td>24°</td>
<td>NR</td>
<td></td>
</tr>
<tr>
<td>Coste et al (2004)</td>
<td>3/3</td>
<td>IO</td>
<td>33</td>
<td>AEE, 74°; AER, 14°</td>
<td>NR</td>
<td>NR</td>
<td></td>
</tr>
<tr>
<td>Themistocleous et al (2007)</td>
<td>9/9</td>
<td>PF</td>
<td>22</td>
<td>Abd, 75°; ER, 25°</td>
<td>DASH, 37.5</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Proubasta et al (2005)</td>
<td>1/1</td>
<td>IO</td>
<td>60</td>
<td>NR</td>
<td>NR</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Jerosch and Schneppenheim (2003)</td>
<td>2/2</td>
<td>IO</td>
<td>30</td>
<td>2 Jo</td>
<td>Constant, 48°</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Probst and Stumpfmann (2002)</td>
<td>2/2</td>
<td>IO</td>
<td>30</td>
<td>2 Jo</td>
<td>Constant, 48°</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Schell and Etter (2000)</td>
<td>2/2</td>
<td>IO</td>
<td>30</td>
<td>2 Jo</td>
<td>Constant, 48°</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Cafferty et al (1998)</td>
<td>2/2</td>
<td>IO</td>
<td>30</td>
<td>2 Jo</td>
<td>Constant, 48°</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Themistocleous et al (2007)</td>
<td>9/9</td>
<td>PF</td>
<td>22</td>
<td>Abd, 75°; ER, 25°</td>
<td>DASH, 37.5</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Proubasta et al (2005)</td>
<td>1/1</td>
<td>IO</td>
<td>60</td>
<td>NR</td>
<td>NR</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: IO, intraoperatively made spacer; PF, prefabricated spacer; NR, not reported; ROM, range of motion. The decision to retain a cement spacer is associated with potential complications. In the current series, 1 patient had a periprosthetic humeral shaft fracture just distal to the stem of the cement spacer, and this complication was also reported in 1 study identified during the literature search. This complication is likely related to the common technique of placing cement only proximally around the cement spacer to facilitate removal during the second stage of revision. Additionally, the humeral stem, which is available in limited sizes and is often intentionally undersized to avoid fracture and facilitate ease of subsequent removal, can be expected to move easily within the humeral canal, causing endosteal resorption and increasing the risk of fracture. Although the patient in the current series who had a periprosthetic fracture ultimately healed with nonoperative treatment, the residual valgus deformity would complicate future attempts at conversion to an implant. Another potential consequence of a retained cement spacer is glenoid erosion. This finding occurred in 2 patients after 40 and 132 months of follow-up, respectively. Because prefabricated cement spacers were not commercially available at the time of surgery, 1 patient received a surgeon-made cement spacer. It has since been reported that the smooth surface of prefabricated spacers allows for better articulation and causes less glenoid erosion than surgeon-made spacers. Thus, the current patient’s glenoid erosion probably can be attributed to the limitations of cement spacer options at the time of surgery. Although glenoid erosion in both cases was mild, the implications of a cement spacer articulating directly on glenoid bone stock over a sustained period are unclear and warrant longitudinal investigation.
on diagnostic workup was available. However, a strength of the current study was the ability to achieve minimum 2-year follow-up on all patients. Because cement spacers are retained only in very specific circumstances, the current case series does not reflect the general population presenting with an infected shoulder arthroplasty. Based on a review of data from recent years within the institution’s shoulder database, it is estimated that this series represents approximately 2% of patients treated for infected shoulder arthroplasty over the study time frame. The authors’ technique when using a cement spacer assumes that it will be removed later. Finally, because of the limited sample size, it is not clear which patient-specific factors may result in retention of the cement spacer.

CONCLUSION

In some patients with infected shoulder arthroplasty, definitive management with a cement spacer is a viable treatment option that results in low rates of reinfection. Although definitive treatment with cement spacers may not be appropriate for the general population, these spacers can provide reasonable range of motion and acceptable functional outcomes in patients with severe medical comorbidities, particularly when patient expectations are realistic. Cement spacers also can be used to delay 2-stage revisions for patients who may require lengthy medical optimization before surgery. Concerns about reduced function, the risk of humeral periprosthetic fracture, and erosion of the medial glenoid may limit the utility of cement spacers, particularly in healthier patients who can tolerate additional surgery. The long-term outcomes of definitive treatment with cement spacers compared with 1- and 2-stage revisions for infection warrant further investigation.

REFERENCES