Primary shoulder sepsis and infection after shoulder arthroplasty are rare, with a reported incidence of 0% to 4% for infected shoulder arthroplasty.}^{9,13,23,24} {Staged revision arthroplasty remains a satisfactory treatment}^{22,23} {despite reports of high complication rates.}^{22,24} {Treatment of an infected shoulder arthroplasty with an intraoperatively crafted antibiotic-impregnated cement spacer has been reported to be effective in eradicating infection.}^{10} {This article reports our experience treating infected shoulder arthroplasty and primary shoulder sepsis using a commercially produced antibiotic-impregnated cement spacer.}
Materials and methods

This study was approved by the Institutional Review Board of Miami Valley Hospital, Dayton, Ohio (Protocol #09-0023).

Between 2006 and 2008, 17 shoulders in 16 patients were treated by 1 surgeon for infected arthroplasty or osteomyelitis of the proximal humerus, of which 16 shoulders were included in the present study. One patient was excluded because of reinfection of the revision total shoulder prosthesis. His prosthesis was presumed to have been seeded from a pelvic abscess that had cultures positive for the same organism as the shoulder reinfection, but different from the previous infection.

Infection was diagnosed by laboratory analysis of aspirated synovial fluid in 3 patients and by the presence of a draining sinus in 4. The infection in 4 patients was diagnosed by the presence of purulence intraoperatively during revision of a painful hemiarthroplasty. The infection in the remaining 5 patients was diagnosed by pain on clinical examination, erythema, and elevated laboratory indices.

All patients underwent extensive irrigation and débridement of the infected shoulder, with collection of intraoperative cultures and bone biopsy. Infection was confirmed in all patients by intraoperative frozen section and pathologic analysis of intraoperative biopsy specimens. Implants and cement were removed from shoulders, and patients with humeral head osteomyelitis underwent humeral head resection. An articulating hemiarthroplasty with the InterSpace Shoulder, a gentamicin-impregnated polymethylmethacrylate cement spacer (manufactured by Tecres S.p.a. Sommacampagna (Verona) Italy, and distributed by Exactech, Gainesville, FL; Fig. 1 and Fig. 2), was then placed. The spacer has a concentration of gentamicin by weight of 2.8%, with a total of 0.8 grams of gentamicin per spacer. The spacer is available in 1 size, with a 46-mm diameter head, 11-mm diameter stem, 125-mm stem length, and 130° stem-neck angle. All spacers were fixed with a vancomycin-impregnated cement collar for stability and broader coverage against methicillin-resistant Staphylococcus aureus (MRSA).

All patients received culture-specific intravenous antibiotics postoperatively and were monitored clinically, radiographically, and with white blood cell count (WBC), serum erythrocyte sedimentation rate (ESR), C-reactive protein (CRP), and interleukin-6 (IL-6) levels every 2 to 3 weeks after spacer placement.

Patients were allowed to use their operative arms as tolerated with the spacer in place. Most patients underwent a second procedure in which the spacer was removed and a total shoulder arthroplasty was placed. The revision was performed when the patient’s serum IL-6 value had returned to normal or was trending down. Intraoperative tissue biopsy was performed at the time of revision arthroplasty, and the surgeon proceeded with revision arthroplasty only if there were fewer than 5 WBCs per high-power field.

All patients were evaluated with the University of California, Los Angeles (UCLA) Shoulder Rating Scale, Simple Shoulder Test (SST), American Shoulder and Elbow Surgeons (ASES) Standardized Shoulder Assessment Form, and Constant shoulder score surveys before surgery and at each follow-up visit. At each visit patients were also assessed on shoulder range of motion and a visual analog pain scale.

Results

Of the 16 shoulders included in this study, 6 had an infected hemiarthroplasty, 5 had an infected total shoulder arthroplasty (3 of which were a reverse ball-and-socket prosthesis), 4 had primary osteomyelitis of the humeral head, and 1 had proximal humeral osteomyelitis with retained hardware from previous open reduction and internal fixation of a proximal humerus fracture. The group consisted of 11 right and 5 left shoulders in 12 men and 3 women, and their mean age was 58.9 years (range, 45-89 years) at the time of spacer placement.

Positive cultures were found in 12 of 16 shoulders at the initial débridement. Organisms cultured included 3 with MRSA, 3 with S. epidermidis, 2 with Corynebacterium spp., and 1 each with methicillin-sensitive S. aureus, Propionibacterium acnes, Escherichia coli, Enterococcus spp., Serratia spp., or Klebsiella spp. (Table I). Intraoperative cultures were sent during 9 of 12 revision procedures, and all 9 were negative.

Five patients had a tissue diagnosis of osteomyelitis at initial débridement. All patients were seen in consultation by an infectious diseases specialist and received culture-specific
intravenous antibiotic therapy after spacer placement. Mean duration of intravenous antibiotic therapy was 5.6 weeks (range, 2-6 weeks) after antibiotic spacer placement.

One shoulder was revised with a total shoulder arthroplasty (Fig. 3). Nine shoulders were revised with total shoulder arthroplasty with a reverse ball-and-socket prosthesis because of rotator cuff deficiency. One shoulder was revised to a total shoulder arthroplasty and was later converted to a total shoulder arthroplasty with a reverse ball-and-socket prosthesis due to development of rotator cuff deficiency. One shoulder underwent arthrodesis after spacer removal because of deltoid deficiency. Four patients refused revision and still have their original spacers. In patients who underwent a revision procedure, mean time from spacer placement to revision procedure was 11.2 weeks (range, 6-30 weeks).

Prior to initial débridement, the WBC count was within the normal reference range in 13 patients and was elevated in 2. ESR was within normal reference range in 4 patients and elevated in 10. CRP was within normal reference range in 2 patients and elevated in 12. IL-6 was within the normal reference range in 1 patient and elevated in 13. Laboratory values were not available for WBC in 1 patient, ESR in 2, CRP in 2, and IL-6 in 2 (Table II). The WBC count returned to within the normal reference range in the 12 patients who underwent revision. At the time of revision, ESR returned to normal in 6 patients and remained elevated in 6, CRP returned to normal in 8 patients and remained elevated in 4, and IL-6 returned to normal in 9 and remained elevated in 2; however, the IL-6 in these 2 patients had been trending down. The serum IL-6 value before revision was not available for 1 patient, however that patient’s IL-6 had also been trending down before revision (Table III). Laboratory indices were not monitored after the revision surgery.

Mean follow-up care of the 16 shoulders was 20.5 months (range, 12-30 months) after spacer placement. Mean follow-up for the 12 shoulders that had revision surgery was 18.33 months following revision surgery (range, 10-29 months). The 4 shoulders with retained spacers had a mean follow-up of 19.25 months after spacer placement (range, 16-25 months).

The mean visual analog pain scale score decreased from 8.4 before spacer placement to 0.5 at final follow-up. The mean active forward flexion increased from 65° before spacer placement to 110° at final follow-up. The mean active external rotation increased from −5° before spacer placement to 20° at final follow-up. There was no recurrence of infection in any of the 16 shoulders.

The mean UCLA score increased from 7 (35 possible) before spacer placement to 26 at final follow-up. The mean SST score increased from 1.2 (12 possible) before spacer placement to 6.6 at final follow-up. The mean ASES score increased from 16 (100 possible) before spacer placement to 74 at final follow-up. The mean Constant shoulder score increased from 16 (100 possible) before spacer placement to 57 at final follow-up (Table IV).

**Discussion**

Many modalities for treatment of deep infection of the shoulder have been reported. Although débridement and culture-specific intravenous antibiotics are almost ubiquitously advocated, various means of definitive treatment are currently used, including 1-stage and 2-stage revision arthroplasty with an articulating interval spacer.

Several authors have reported successful eradication of deep infection using 2-stage revision with an articulating interval antibiotic-impregnated cement spacer.
Successful treatment of infection using a commercially produced antibiotic-impregnated spacer has been reported extensively for total hip and total knee arthroplasty.5,12,14-16,20,21 To our knowledge, we are the first to report successful treatment of deep shoulder infection with the use of a commercially produced antibiotic-impregnated spacer. We note that successful treatment of infection cannot be completely attributed to the antibiotic spacer, but rather the spectrum of treatment, including thorough debridement, spacer placement, and culture-specific intravenous antibiotic treatment.

We believe that the commercially produced spacer is superior to spacers created intraoperatively on the back table for several reasons. It allows for a more predictable level of antibiotic elution, as was recently demonstrated by Mutimer et al.18 in a series of infected total knee arthroplasties. The spacer used in their study is made by the same company and has identical consistency as the one used in this study. They demonstrated therapeutic intra-articular gentamicin levels at a median 99 days after spacer placement.18 Although the spacer achieves therapeutic intra-articular antibiotic concentrations, serum levels have also been detected; however, these levels have been demonstrated to be low.18 There are several reports of acute renal failure after placement of cement spacers containing gentamicin and tobramycin, so caution should be exercised in patients with poor renal function.6,8,19,25

We added a collar of vancomycin-impregnated polymethylmethacrylate cement at the time of spacer placement. The addition of vancomycin-impregnated cement has demonstrated a synergistic effect against certain bacterial species and has also been shown not to affect the release kinetics of gentamicin or vancomycin.1,2

The prefabricated spacer eliminates the operating room time required for crafting the spacer on the back table and for sizing adjustments. It is an articulating spacer, and its smooth surface allows for less destruction of the articular surface of the glenoid before revision surgery. In patients who refuse surgical revision, as did 4 of our patients, it may allow better function than intraoperatively produced spacer implants.

The incidence of reinfection in our series of 16 infected shoulders was zero, whereas the incidence in other series of infected shoulders treated with staged revision arthroplasty with an antibiotic spacer ranges from 0% to 40%.5,7,9 In addition to absence of reinfection, patients in our series demonstrated clinical improvement with regard to visual analog pain scale, range of motion, and other subjective and objective shoulder evaluation scores.

Similar to other reports,3,10,22,24 MRSA and S. epidermidis were the organisms most frequently cultured in our case series. However, other studies have found a much higher incidence of cultures positive for P. acnes than the 1 patient encountered in our series.3,24 This phenomenon could have been due to varying rates of colonization between different geographic regions or patient populations, or both, or perhaps the laboratory may not have held the cultures for a sufficiently long period of time. Because the 4 shoulders with negative cultures at the time of initial débridement all had clinical evidence of infection, as well as laboratory indices suggestive of infection, we presume they were infected with P. acnes and that the cultures were not held long enough by the laboratory. Our

### Table II

<table>
<thead>
<tr>
<th>Test</th>
<th>Within normal limits</th>
<th>Elevated</th>
<th>NA</th>
</tr>
</thead>
<tbody>
<tr>
<td>White blood cell count</td>
<td>13</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>ESR</td>
<td>4</td>
<td>10</td>
<td>2</td>
</tr>
<tr>
<td>C-reactive protein</td>
<td>2</td>
<td>12</td>
<td>2</td>
</tr>
<tr>
<td>Interleukin-6</td>
<td>1</td>
<td>13</td>
<td>2</td>
</tr>
</tbody>
</table>

ESR, Erythrocyte sedimentation rate; NA, not available.
laboratory has since begun the practice of holding these cultures for 21 days.

The clinical usefulness of serum ESR and CRP levels in the diagnosis of infection has been demonstrated in total knee and in total hip arthroplasty.\(^7\)\(^,\)\(^11\) A recent prospective study by Di Cesare et al\(^7\) demonstrated a sensitivity of 1.00 and specificity of 0.95 for serum IL-6 level in the diagnosis of periprosthetic infection of total hip and knee arthroplasty. Serum WBC count had returned to normal in all patients in our series before revision; however, Di Cesare et al\(^7\) reported a sensitivity of 0.47 and specificity of 1.00 for WBC count in their series. The shoulders in our study demonstrated similar results for ESR, CRP, and IL-6 in terms of values that had returned to normal before revision surgery. For this reason, IL-6 appears to be useful in determining the presence of shoulder infection and that an IL-6 level within normal reference range may be helpful in the timing of revision shoulder arthroplasty.

Our study has limitations, namely, the small patient number and lack of comparison with a control group of glenohumeral infections treated with an interval intraoperatively crafted antibiotic-impregnated cement spacer. Also, we did not monitor laboratory indices after revision surgery.

### Conclusions

We treated 16 infected shoulders in 15 patients with staged revision arthroplasty with an interval, commercially produced, antibiotic-impregnated articulating cement spacer and observed no recurrence of infection. Our patients demonstrated improved pain and range of motion, as well as subjective and objective shoulder evaluation scores. A commercially produced spacer may be as effective in controlling infection as an intraoperatively crafted spacer because it allows for a more predictable level of antibiotic elution, eliminates the operating room time required for crafting the spacer on the back table, has a smooth articular surface, and may allow better shoulder function than intraoperatively produced spacer implants. The serum IL-6 level appears to be a useful indicator for the timing of revision total shoulder arthroplasty after infection. Due to the small number of patients in our series, a larger multicenter trial is required to validate these early findings.

### Table IV  Shoulder survey results

<table>
<thead>
<tr>
<th>Survey</th>
<th>Total possible</th>
<th>Mean score At spacer placement</th>
<th>Mean score At final follow-up</th>
</tr>
</thead>
<tbody>
<tr>
<td>UCLA</td>
<td>35</td>
<td>7</td>
<td>26</td>
</tr>
<tr>
<td>SST</td>
<td>12</td>
<td>1.2</td>
<td>6.6</td>
</tr>
<tr>
<td>ASES</td>
<td>100</td>
<td>16</td>
<td>74</td>
</tr>
<tr>
<td>Constant</td>
<td>100</td>
<td>16</td>
<td>57</td>
</tr>
</tbody>
</table>

ASES, American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form; SST, Simple Shoulder Test; UCLA, University of California, Los Angeles Shoulder Rating Scale.

### Disclaimer

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### References


