

# Creation of a Custom-Length, Humeral Antibiotic Cement Spacer for Use in Treatment of Shoulder Periprosthetic Joint Infection



Emma L. Klosterman, M.D., Eric J. Cotter, M.D., Matthew W. Squire, M.D., M.S., and Brian F. Grogan, M.D.

**Abstract:** Periprosthetic joint infection of the shoulder is a challenging clinical situation to manage owing to the fastidious organisms often present and delayed clinical presentation. While several treatment options have been described, the mainstay of treatment remains a staged revision with the use of a humeral antibiotic cement spacer. Such spacers are commercially available or can be made by hand. When an extended humeral osteotomy is required to remove a well-fixed long stem humeral component, it may be advantageous to place an antibiotic spacer with a stem length approximately as long as the hardware being removed. This technique demonstrates creation of a custom length, humeral antibiotic cement spacer for use in treatment of shoulder periprosthetic joint infection.

Periprosthetic joint infection (PJI) is a rare but highly morbid complication of shoulder arthroplasty. The incidence of PJI ranges from 1.1% to 3.8% following primary shoulder arthroplasty and is reported to be as high as 15.4% after revision shoulder arthroplasty.<sup>1</sup> Shoulder PJI frequently presents nonspecifically with shoulder pain but should be suspected in cases of postoperative stiffness and osteolysis.<sup>2</sup> Evaluation of potential shoulder PJI is difficult, owing to the indolent nature of many such infections. Normal inflammatory markers, negative cultures after shoulder aspiration, and normal radiographic findings despite existence of infection are commonly encountered.<sup>3</sup>

Intraoperative culture remains the gold standard of diagnosis, whereas arthroscopic tissue biopsy is a more recently described diagnostic method, with sensitivity and specificity of 100% in a recent study.<sup>4</sup> The most frequently isolated organisms have been *Cutibacterium acnes*, *Staphylococcus epidermidis*, and *Staphylococcus aureus*.<sup>2</sup> Treatment goals for shoulder PJI include eradication of the infection, decreased pain, and increased function.

Two-stage revision is a common treatment strategy for patients with shoulder PJI due to the relatively low infection recurrence rates (0%-36%), pain relief, and improvement in shoulder function.<sup>2</sup> This technique typically involves initial shoulder irrigation and debridement, hardware removal, and placement of a humeral antibiotic cement spacer in conjunction with oral or intravenous antibiotics. Once the PJI has been eradicated, the humeral antibiotic cement spacer can be revised and an arthroplasty prosthesis (hemi-arthroplasty, anatomic total shoulder arthroplasty, or reverse total shoulder arthroplasty) can be placed. Some patients do not proceed with prosthesis reimplantation. Antibiotic spacers as definitive treatment have been found to have similar infection recurrence, pain scores, and patient satisfaction as 2-stage revision with decreased but still improved functional outcomes.<sup>5-8</sup> This technique describes creation of a custom-length, humeral antibiotic cement spacer for use in 2-stage revision or as definitive treatment when managing shoulder PJI.

From the Department of Orthopedics and Rehabilitation, University of Wisconsin School of Medicine and Public Health, Madison, Wisconsin, U.S.A.

The authors report the following potential conflicts of interest or sources of funding: M.W.S. reports other from Biomet, other from American Journal of Roentgenology, and other from Journal of Arthroplasty, outside the submitted work. In addition, M.W.S. has a patent Biomet with royalties paid. Full ICMJE author disclosure forms are available for this article online, as supplementary material.

Received September 19, 2020; accepted October 21, 2020.

Address correspondence to Emma L. Klosterman, M.D., Orthopedic Surgery Resident, Department of Orthopedics and Rehabilitation, University of Wisconsin School of Medicine and Public Health, 1685 Highland Ave., 6th Floor, Madison, WI 53705. E-mail: [eklosterman@uwhealth.org](mailto:eklosterman@uwhealth.org)

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2212-6287/201601

<https://doi.org/10.1016/j.eats.2020.10.027>



**Fig 1.** Commercially available proximal humerus antibiotic spacer molds and associated humeral head trials provide a variety of sizes for creation of a custom mold.

**Surgical Technique (With Video Illustration)**

**Preoperative Planning**

In addition to standard revision equipment, the construction of the custom length, antibiotic-loaded, articular humeral cement spacer will require commercially available proximal humerus antibiotic spacer molds (Aequalis Ascend Flex Convertible Shoulder System Molds; Wright Medical Technology, Escondido, CA) (Fig 1), a metal guide rod (2.5-mm Reaming Rod with ball tip; DePuy Synthes, Raynham, MA), chest tubes in a variety of sizes (Thoracic Catheter; Straight; Argyle), mineral oil (Muri-Lube; Fresenius Kabi, Bad Homburg, Germany), bone cement (Palacos; Zimmer Biomet, Warsaw, IN), and antibiotic powder (Table 1, Video 1).

**Preoperative Analgesia and Patient Positioning**

Treatment of periprosthetic shoulder infection using a custom-length, antibiotic-loaded, articular humeral

cement spacer is performed with the patient in the beach chair position under general anesthesia. An interscalene nerve block is recommended. The surgical site is prepared and draped in the usual, sterile fashion.







**Intraoperative Sizing**

In most cases, the previous incision can be used with a deltopectoral approach to the shoulder. After removal of the existing total shoulder arthroplasty humeral component, the length and diameter of the revision humeral cement stem is determined by using the straight reamers typically employed for humeral canal preparation (Aequalis Flex Revive Shoulder System; Wright Medical Technology). Crosscheck intraoperative measurements against preoperative humerus radiographs and/or computed tomography scan to finalize the humeral canal diameter measurement and the desired length. The distal canal size is converted from the straight reamer diameter in millimeters to the

**Table 1.** Pearls and Pitfalls

Step	Pearls	Pitfalls
Preoperative planning	<ul style="list-style-type: none"> <li>• Discuss with operative team before case to have equipment available</li> </ul>	
Intraoperative sizing	<ul style="list-style-type: none"> <li>• Have chest tubes size 24- 34 F available</li> </ul>	
Assembly of the articular humeral mold Creating the distal chest tube augment		<ul style="list-style-type: none"> <li>• Better to overestimate length; excess stem can be trimmed later as needed</li> <li>• Mineral oil is key to be able to remove the chest tube</li> </ul>
Mixing antibiotic cement		<ul style="list-style-type: none"> <li>• Mix cement in 2 batches or mix 3 packets of cement</li> </ul>
Fill and construction of the spacer		<ul style="list-style-type: none"> <li>• Mineral oil is key to be able to remove the spacer</li> </ul>
Extraction of the spacer	<ul style="list-style-type: none"> <li>• Have a humeral head impactor available</li> </ul>	

**Fig 2.** Use a conversion chart or the equation 3 millimeters = 1 French Gauge to determine the chest tube size needed from the diameter of the distal humeral canal determined intraoperatively with the straight reamers and preoperative imaging.

Conversion Chart						
Fr	24	26	28	30	32	34
mm	8.0	8.7	9.3	10.0	10.7	11.3
in	0.315	0.341	0.367	0.393	0.419	0.445
						

corresponding chest tube size using a conversion chart or the equation 3 millimeters = 1 French Gauge (Fig 2). The circulating nurse can open the correct chest tube to the back table and record the desired length.

Next, the size of the commercially available proximal humerus antibiotic spacer mold is determined by broaching the humerus using the standard implant system (Aequalis Ascend Flex Convertible Shoulder System, long humeral component; Wright Medical Technology). A trial head is placed. The shoulder is reduced and taken through a range of motion to ensure proper component size. Once the appropriate size is determined, the corresponding size antibiotic spacer mold jigs can be pulled from the pan to the back table. The antibiotic spacers molds are available in 4 stem sizes (2, 4, 6, 8 Ascend Flex; Wright Medical Technology) with 3 head options (43 × 16 mm, 48 × 18 mm, and 52 × 23 mm Ascend Flex; Wright Medical Technology).

**Assembly of the Articular Humeral Mold**

At the back table with sterile technique, an assistant can begin to assemble the articular humeral mold (Fig 3, Video 1). Secure the chosen humeral stem size and



**Fig 3.** Assemble the articular humeral mold by connecting the chosen stem size and head size jigs with a 3.5-mm hexagonal head screwdriver (DePuy Synthes).

head size jigs together using a 3.5-mm hexagonal screwdriver (DePuy Synthes).

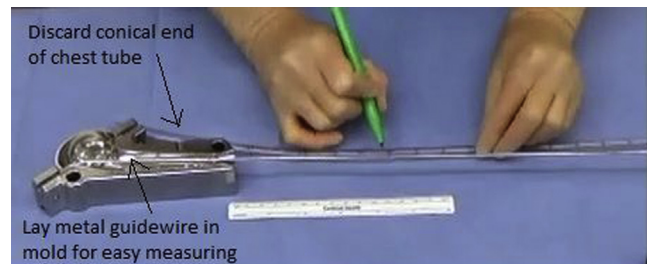
**Creating the Distal Chest Tube Augment**

The desired total component length was determined intraoperatively as reviewed earlier. The distal stem augment length is determined by subtracting the length of the articular humeral mold stem from the total component length. Cut the chest tube to the distal stem augment length. It is better to overestimate length at this step; excess stem can be trimmed later as needed. The metal guidewire (2.5-mm Reaming Rod with ball tip; DePuy Synthes) will serve to connect the articular humeral mold to the chest tube augment. The ball tip will eventually lay within the humeral head. Cut the flat end of the metal guidewire to the total component length using either an end biting pin cutter (DePuy Synthes) or a double-action pin cutter (DePuy Synthes) (Fig 4, Video 1).

Both halves of the articular humeral mold are coated in mineral oil. The chest tube is coated in mineral oil using a small syringe and then inverting and spinning the tube. This facilitates the spacer extraction and is crucial.

**Mixing Antibiotic Cement**

The liquid monomer can be refrigerated before use to slow cement hardening and allow more time for manipulation. Combine the liquid monomer and antibiotic powder in the mixing bowl. Use a freer to ensure that there are no clumps of antibiotic powder remaining. Add the cement polymer and mix to the



**Fig 4.** Cut to measurement the chest tube and metal guidewire for use as the distal stem augment.



**Table 2.** Antibiotic Cement Recipe to Use for Filling of the Articular Humeral Spacer and the Chest Tube Augment in Creation of a Custom-Length, Antibiotic-Loaded, Articular Humeral Cement Spacer

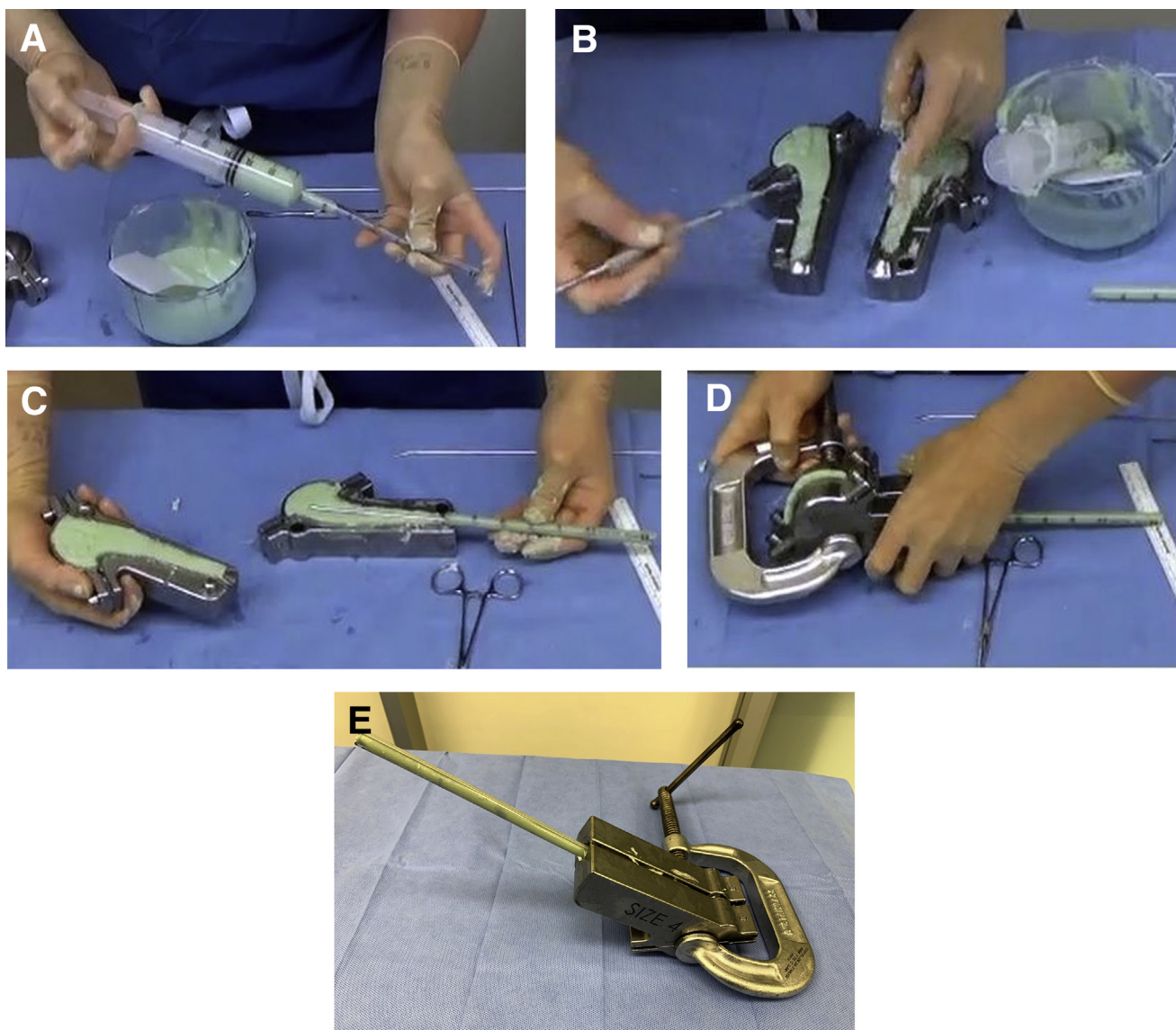
Antibiotic Cement Recipe
3.6 g tobramycin and 2.0 g vancomycin per pack of Palacos
2 packs of Palacos to 2.5 doses of liquid monomer
3 packs of Palacos to 3.5 doses of liquid monomer
Mix antibiotics and monomer first and then add Palacos

consistency of runny peanut butter (Video 1). To conserve medical supplies, antibiotics were not used in this video. At this institution, 2 packets of Palacos polymer is typically mixed with 4.0 g of vancomycin, 7.2 g of tobramycin, and 2.5 doses of liquid monomer

(Table 2). Plan to mix 3 packs of Palacos for first-time custom spacer creation.

#### Fill and Construction of the Spacer

Cut the tip off of a sterile 60-cc syringe. While runny, load about 15 cc of the cement into the syringe. Use the syringe to fill the prepared chest tube augment (Fig 5A, Video 1) and clamp one end with a hemostat to prevent cement from leaking. Next, fill each half of the articular humeral mold with cement (Fig 5B, Video 1). Do not fill the distal most cone. At this point, the cement is more viscous but not yet hard. Insert the cut end of the metal guidewire into the cement filled chest tube augment making sure it is centered. Lay the ball tip end of the metal guidewire along the stemmed portion of



**Fig 5.** Construction of the custom-length, antibiotic-loaded, articular humeral cement spacer with sterile technique at the back table. (A) A 60-cc syringe is used to fill the prepared chest tube augment. (B) The articular molds are filled with cement. (C) Lay the ball tip end of the metal guidewire along the stemmed portion of one of the articular molds. (D) Close the articular molds and apply the clamp. (E) Set the construct aside and allow to harden.



**Fig 6.** The final custom length, antibiotic-loaded, articular humeral cement spacer can be fine-tuned by smoothing the edges with a Darrach retractor and trimming excess length with bolt cutters.

one of the articular molds (Fig 5C, Video 1). Lay the other half of the articular mold on top of the first articular mold and secure with a clamp (Fig 5D, Video 1). Remove any excess cement. Ensure that the chest tube augment is centered on the articular mold. Keep some cement on the back table to monitor cement hardening as this is variable, but usually takes about 16 minutes (Fig 5E, Video 1).

Surgeons may find it easier, although more time consuming, to mix 2 batches of antibiotic cement. The humeral mold is filled first, with the metal guidewire protruding distally. After the cement has hardened and the mold has been removed, the second batch of antibiotic cement is mixed and used to fill the chest tube. The chest tube is then placed over the exposed guide rod.

### Extraction of the Spacer

Once the cement is hardened, use a #10 blade scalpel and freer to remove the chest tube and reveal the stem augment. Then remove the clamp from the articular mold and open the mold. A humeral head impactor might be needed to remove the spacer from the mold (Video 1). Any excess length of the spacer can be trimmed using bolt cutters. The serrated end of a Darrach retractor or a file is used to smooth any rough edges. Particular attention is paid to the articulating surface of the humeral component.

The final custom-length, humeral antibiotic cement spacer is implanted in the standard fashion, and the

case completed per routine (Fig 6). If a humeral osteotomy was required to remove the humeral component and related cement, the implant can be placed in the humeral canal and the osteotomy can be closed over top of the implant. The osteotomy is typically secured with multiple cerclage tapes (FiberTape Cerclage System; Arthrex, Naples, FL).

## Discussion

Shoulder periprosthetic joint infections are a difficult problem to manage, resulting in a spectrum of accepted treatment options: debridement, antibiotics, and implant retention (i.e., DAIR), resection arthroplasty, 1-stage revision, 2-stage revision, arthrodesis, amputation, functional antibiotic spacer, and definitive treatment with a permanent antibiotic spacer.<sup>2,9</sup> This technique describes creation of a custom-length, humeral antibiotic cement spacer for use in 2-stage revision or as definitive treatment.

Compared with other treatment strategies, the use of antibiotic spacers has been shown to have high eradication rates with persistent infection rates at 6.1% compared with 1-stage revision at 3.9%, resection arthroplasty at 11.5%, 2-stage revision at 14.3%, and debridement at 29.6%.<sup>10</sup> Functional scores of patients undergoing revision procedures tend to be better than those with nonrevision procedures. Constant and Murley scores for antibiotic spacer retention have been reported at 31 to 38, compared with resection arthroplasty at 29, debridement at 41, 2-stage revision at 42, and 1-stage revision at 49.<sup>6,10</sup> In a subset of patients with low functional demands or multiple medical comorbidities precluding surgery, this is a viable definitive treatment option in whom 94% of patients reported good to satisfying results at 8 years.<sup>6</sup>

This technique offers several advantages to pre-fabricated antibiotic impregnated cement spacers or manually molded stemmed spacers (Table 3). It allows custom stem length and humeral head size to maintain soft-tissue tension, the length of the arm, and proper fill of the metaphyseal and diaphyseal bone. The extended stem length may be advantageous after the removal of an infected long humeral component, especially when an extended humeral osteotomy is required for hardware removal. The molded humeral head provides a smooth

**Table 3.** Advantages and Disadvantages

Advantages	Disadvantages
<ul style="list-style-type: none"> <li>• Custom stem length and humeral head size to maintain soft-tissue tension and length of the arm</li> <li>• Smooth articular surface</li> <li>• Confer stability to humeral osteotomy repair construct</li> <li>• Serve as local depot for antibiotic elution</li> <li>• Allow tailored antibiotic/cement mixture based on the pathogen concerned</li> </ul>	<ul style="list-style-type: none"> <li>• Time for implant construction and cement hardening</li> <li>• Need for numerous intraoperative supplies</li> </ul>

surface for articulation with the remaining native glenoid similar to a prefabricated spacers and the metal articular surface of a functional antibiotic spacer.<sup>11</sup> The longer wire-reinforced antibiotic stem may confer stability and aid in repair of a humeral osteotomy. The length of the spacer is made of antibiotic-loaded cement, which can serve as a local depot for antibiotic elution.<sup>12</sup> Antibiotic cement is placed in direct contact with bone through the entire length of the previous implant, unlike short prefabricated or handmade antibiotic cement spacers, which may not extend much farther than the metaphysis. The custom nature of the spacer also allows manual mixing, antibiotic selection and high dosage choice.<sup>12-15</sup>

The risks of this technique have not been directly studied to our knowledge. Complications can be inferred from studies evaluating commercially available antibiotic spacer implants. McFarland et al.<sup>11</sup> reported on complications of implantation and noted humeral shaft fracture. Throughout the lifetime of the antibiotic spacer, it can be associated with bone erosion, fractures of the spacer, and spacer rotation and dislocation. Finally, explantation can be complicated by fracture and retained distal cement.

The limitations of this technique are that its clinical utility has not been directly studied. There is one known analysis of ideal antibiotic spacer design in shoulder PJI investigating stemmed versus stemless constructs. Padegimas et al.<sup>16</sup> show that there was no difference in eradication rates, reimplantation rates, complication rates, operative time, or final active forward elevation after reimplantation between the stemmed (hand-made, short stem) versus stemless (hand-made, spherical) constructs.

This technique demonstrates creation of a custom-length, humeral antibiotic cement spacer for use in treatment of shoulder periprosthetic joint infection.

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