

- [9] Codd T, Yamaguchi K, Pollock R, Flatow EL, Bigliani LU. Infected shoulder arthroplasties: treatment with staged reimplantation vs resection arthroplasty. *Orthop Trans.* 1996;20:59.
- [10] Charalambous CP, Saidapur S, Alvi F, Haines J, Trail I. Excision arthroplasty following shoulder replacement. *Acta Orthop Belg.* 2011;77:448–452.
- [11] Maynou C, Ménager S, Senneville E, Bocquet D, Mestdagh H. [Clinical results of resection arthroplasty for infected shoulder arthroplasty]. *Rev Chir Orthop Reparatrice Appar Mot.* 2006;92:567–574.
- [12] Sperling JW, Kozak TK, Hanssen AD, Cofield RH. Infection after shoulder arthroplasty. *Clin Orthop Relat Res.* 2001;206–216.
- [13] Verhelst L, Stuyck J, Bellemans J, Debeer P. Resection arthroplasty of the shoulder as a salvage procedure for deep shoulder infection: does the use of a cement spacer improve outcome? *J Shoulder Elbow Surg.* 2011;20:1224–1233. doi:10.1016/j.jse.2011.02.003.
- [14] Ghijselings S, Stuyck J, Debeer P. Surgical treatment algorithm for infected shoulder arthroplasty: a retrospective analysis of 17 cases. *Acta Orthop Belg.* 2013;79:626–635.
- [15] Ueda Y, Comer GC, Saleh JR, Costouros JG. Simultaneous bilateral resection total shoulder arthroplasty with anatomic antibiotic cement spacer retention. *JSES Open Access.* 2017;1:129–132. doi:10.1016/j.jses.2017.07.003.
- [16] Stevens NM, Kim HM, Armstrong AD. Functional outcomes after shoulder resection: the patient's perspective. *J Shoulder Elbow Surg.* 2015;24:e247–e254. doi:10.1016/j.jse.2015.03.027.
- [17] Bonneville N, Dauzères F, Toulemonde J, Elia F, Laffosse J-M, Mansat P. Periprosthetic shoulder infection: an overview. *EFORT Open Rev.* 2017;2:104–109. doi:10.1302/2058-5241.2.160023.



3.7. TREATMENT: REVISION

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QUESTION 1: Is there a role for an antibiotic spacer for the treatment of shoulder periprosthetic joint infection (PJI)?

RECOMMENDATION: An antibiotic loaded cement spacer may be used as part of a shoulder two-stage exchange arthroplasty for local delivery of high concentration of antibiotics. An antibiotic loaded cement spacer may be used as a definitive/permanent treatment option in select cases.

LEVEL OF EVIDENCE: Limited

DELEGATE VOTE: Agree: 100%, Disagree: 0%, Abstain: 0% (Unanimous, Strongest Consensus)

RATIONALE

Antibiotic loaded cement spacers can be used in the management of infected shoulder arthroplasty [1–4]. The antibiotic loaded cement spacer delivers antibiotics to the local tissues, eliminates dead space, maintains soft tissue tension and shoulder function and is used for these reasons as a temporary spacer in two-stage reimplantation for infected shoulder arthroplasty [2,3]. Less commonly, it can be considered as a permanent/definitive spacer if the patient declines further surgery or if the patient is not a good surgical candidate for the second stage of two-stage reimplantation (e.g., sick patient, significant bone loss) [5–8].

The role of antibiotic loaded cement spacer in shoulder PJI has been studied previously in retrospective cohort studies (Table 1). An antibiotic loaded cement spacer is indicated as a temporary spacer in the two-stage treatment of shoulder PJI in conjunction with intravenous antibiotics [2,3]. However, use as a definite/permanent spacer has also been described as a treatment for patients who are a high surgical risk or refuse second stage of two-stage treatment [5–7]. Jawa et al. reported a retrospective review of 28 patients with infected shoulder arthroplasty who were managed with antibiotic loaded cement spacer [2]. Sixteen patients underwent a two-stage operation, and twelve patients declined second stage procedure. Five patients had recurrence of infection (18%), and 5 patients had severe pain (18%) at final follow up. Complications with the use of cement spacer included dislocation (1 patient) and fracture (3 patients). Torrens et al. reported a culture positive rate of 13.6% (3 shoulders) from 22 antibiotic loaded cement spacers retrieved during second stage reimplantation [9]. In contrast to studies by Jawa et al. and Torrens et al., other investigators have reported lower rates of recurrence of infection with antibiotic loaded cement spacer use. Pellegrini et al. reported no recurrence of infection with a definitive antibiotic spacer in a cohort of 19 low demand, elderly subjects who had infected shoulder

arthroplasties [6]. At a mean follow up of 8 years, all patients reported satisfactory subjective and objective outcomes. One patient had glenoid osteolysis with no adverse effect on functional outcome. Levy et al. retrospectively reviewed outcomes in 9 patients with infected shoulder arthroplasty who elected to not have the second stage reimplantation [7]. These patients had acceptable function with their antibiotic spacers at a mean follow up of 25 months. There was no recurrence of infection (0%) and only one patient (11%) was unsatisfied with the results. Mahure et al. reported no recurrence of infection (0%) in a retrospective case series of patients with shoulder PJI who received an antibiotic loaded cement spacer as definitive treatment after first stage of the two-stage treatment [5,10]. In a retrospective study, Romano et al. reviewed 44 patients with infected shoulder arthroplasty of which 32 patients had treatment with a temporary or permanent antibiotic loaded spacer [11]. There was one recurrence of infection in the definitive spacer group. Lee et al. used an antibiotic loaded cement spacer for the first stage implantation in 12 patients with infected shoulder arthroplasty. All patients received intravenous antibiotics followed by the second stage treatment [12]. There was no recurrence of infection (0%) at mean follow up of 41 months. Improved functional outcomes with the use of antibiotic loaded cement spacer was reported by Jerosch et al. in a retrospective review of 10 patients with shoulder PJI [13]. Patients were able to perform physical therapy with the antibiotic spacer in situ, and 8 patients underwent second stage with no reported recurrence of infection.

There is no consensus on the optimal class of antibiotics to be used in spacer preparation. Heat stable antibiotics (vancomycin, gentamycin and tobramycin) have been used alone or in combination. Spacer design and patient-specific anatomic features have also been studied with regards to infection clearance and patient satis-

TABLE 1. Studies examining the role of antibiotic loaded cement spacer in treatment of infected shoulder arthroplasty

Study	Number of Patients / Shoulders (n) and Follow-up (FU)	Antibiotics Used in the Cement Spacer	Spacer Role	Recurrence of Infection and Complications Associated with Spacer
Jerosch and Schneppenheim, 2003	n = 10 FU:6-30 mos (range)	No information	Temporary: 8 Permanent: 2	Recurrence: 0%
Themistocleous et al., 2007	n = 4 FU:22 mos	Tobramycin Vancomycin	Temporary: 2 Permanent: 2	Recurrence: 0%
Coffey et al., 2010	n = 16 FU:20.5 mos	Gentamicin	Temporary: 12 Permanent: 4	Recurrence: 0%
Jawa et al., 2010	n = 28 FU= 27.6 mos	Tobramycin Vancomycin	Temporary: 16 Permanent: 12	Recurrence: 5 (18%) Dislocation: 1 (3.5%) Fracture of spacer: 3 (11%)
Stine et al., 2010	n = 30 FU: 2.4 yrs	Tobramycin Vancomycin	Temporary: 18 Permanent: 15	Recurrence: 0%
Romano et al., 2012	n = 32 FU:2.4 yrs	No information	Temporary: 17 Permanent: 15	Recurrence: 3% (one in permanent group)
Levy et al., 2014	n = 9 FU:25 mos	Tobramycin Vancomycin	Permanent	Recurrence: 0%
Mahure et al., 2016	n = 9 FU:4 yrs	Tobramycin Vancomycin Gentamycin	Permanent	Recurrence: 0% Glenoid erosion: 2 (22%) Periprosthetic fracture: 1 (11%)
Pellegrini et al., 2017	n = 19 FU:8 yrs	Gentamycin, Clindamycin, Vancomycin	Permanent	Recurrence: 0% Glenoid osteolysis (1; 5.3%)
Padegimas et al., 2018	n = 37 FU:4 yrs	Tobramycin Vancomycin	Temporary	Spacer revision: 1 (2.7%) 6 positive cultures at second stage but no clinical signs of infection
Lee et al., 2018	n = 12 FU:40.8 mos	Vancomycin	Temporary: 9	Recurrence: 0%
Torrens et al., 2018	n = 21	Tobramycin	Temporary	Revision of spacer: 1 3 Positive cultures at second stage (13.6%)

faction. Padegimas et al. retrospectively compared stemless and stemmed antibiotic spacers in a cohort of 37 patients with shoulder PJI [14]. They found no difference between the two types of spacers with respect to their ability to control infection and the percentage transition (70% in both groups) to the second stage of a two-stage procedure for infected shoulder arthroplasty. There is insufficient data to compare handmade versus commercial premade antibiotic loaded cement spacers.

An antibiotic loaded cement spacer is a reasonable treatment option as a temporary antibiotic spacer in conjunction with intravenous antibiotics for the two-stage treatment of shoulder PJI. The majority of studies report no recurrence of infection after revision to second stage. Use of an antibiotic loaded cement spacer as a definitive/permanent treatment can be considered for

a low demand, debilitated patient who is a poor surgical candidate for second stage reimplantation or in cases where patient refuses second stage surgery. There is low rate of infection (5%) with acceptable functional outcome, but glenoid osteolysis is a concern with the use of cement spacer as a definitive treatment. There is no consensus on the ideal class of antibiotic (vancomycin versus aminoglycosides) to be used in cement spacers. There is insufficient data to compare hand-made versus commercial premade antibiotic spacers.

Search Methods

In order to establish guidelines for the use of an antibiotic loaded cement spacer in infected shoulder arthroplasty, a systematic review of literature on PubMed and Embase was performed of all English

literature till January 2018 to query, “(shoulder OR ‘upper extremity’) AND (arthroplasty OR replacement) AND (infection OR infected) AND (PROSTALAC OR ANTIBIOTIC SPACER). After excluding duplicates, a total of 34 articles were screened, and 16 studies focusing on use of an antibiotic loaded cement spacer as a temporary or permanent spacer were extracted for further review. After applying final exclusion (“one-stage revision,” “antibiotic suppression”) and inclusion criteria, a full text review of the articles was conducted, and 12 articles were selected for final analysis. All the articles evaluated the role of antibiotic loaded cement spacer for the treatment of shoulder PJI [2–14].

REFERENCES

- [1] Mook WR, Garrigues GE. Diagnosis and management of periprosthetic shoulder infections. *J Bone Joint Surg Am.* 2014;96:956–965. doi:10.2106/JBJS.M.00402.
- [2] Jawa A, Shi L, O'Brien T, Wells J, Higgins L, Macy J, et al. Prosthesis of antibiotic-loaded acrylic cement (PROSTALAC) use for the treatment of infection after shoulder arthroplasty. *J Bone Joint Surg Am.* 2011;93:2001–2009. doi:10.2106/JBJS.J.00833.
- [3] Grubhofer F, Imam MD MA, Wieser K, Achermann Y, Meyer DC, Gerber C. Staged revision with antibiotic spacers for shoulder prosthetic joint infections yields high infection control. *Clin Orthop Relat Res.* 2018;476:146–152. doi:10.1007/s11999.0000000000000049.
- [4] Coffey MJ, Ely EE, Crosby LA. Treatment of glenohumeral sepsis with a commercially produced antibiotic-impregnated cement spacer. *J Shoulder Elbow Surg.* 2010;19:868–873. doi:10.1016/j.jse.2010.01.012.
- [5] Mahure SA, Mollon B, Yu S, Kwon YW, Zuckerman JD. Definitive treatment of infected shoulder arthroplasty with a cement spacer. *Orthopedics.* 2016;39:e924–e930. doi:10.3928/01477447-20160623-07.
- [6] Pellegrini A, Legnani C, Macchi V, Meani E. Management of periprosthetic shoulder infections with the use of a permanent articulating antibiotic spacer. *Arch Orthop Trauma Surg.* 2018;138:605–609. doi:10.1007/s00402-018-2870-8.
- [7] Levy JC, Triplet J, Everding N. Use of a functional antibiotic spacer in treating infected shoulder arthroplasty. *Orthopedics.* 2015;38:e512–e519. doi:10.3928/01477447-20150603-60.
- [8] Themistocleous G, Zalavras C, Stine I, Zachos V, Itamura J. Prolonged implantation of an antibiotic cement spacer for management of shoulder sepsis in compromised patients. *J Shoulder Elbow Surg.* 2007;16:701–705. doi:10.1016/j.jse.2007.02.118.
- [9] Torrens C, Santana F, Puig L, Sorli L, Alier A. Results of cement spacer sonication in the second stage of two-stage treatment of shoulder arthroplasty infection. *J Orthop Surg Res.* 2018;13:58. doi:10.1186/s13018-018-0763-8.
- [10] Stine IA, Lee B, Zalavras CG, Hatch G, Itamura JM. Management of chronic shoulder infections utilizing a fixed articulating antibiotic-loaded spacer. *J Shoulder Elbow Surg.* 2010;19:739–748. doi:10.1016/j.jse.2009.10.002.
- [11] Romanò CL, Borens O, Monti L, Meani E, Stuyck J. What treatment for periprosthetic shoulder infection? Results from a multicentre retrospective series. *Int Orthop.* 2012;36:1011–1017. doi:10.1007/s00264-012-1492-y.
- [12] Lee SH, Kim SJ, Kook SH, Kim JW. Two-stage revision of infected shoulder arthroplasty using prosthesis of antibiotic-loaded acrylic cement: minimum three-year follow-up. *Int Orthop.* 2018;42:867–874. doi:10.1007/s00264-017-3699-4.
- [13] Jerosch J, Schneppenheim M. Management of infected shoulder replacement. *Arch Orthop Trauma Surg.* 2003;123:209–214. doi:10.1007/s00402-003-0497-9.
- [14] Padegimas EM, Narzikul A, Lawrence C, Hendy BA, Abboud JA, Ramsey ML, et al. Antibiotic spacers in shoulder arthroplasty: comparison of stemmed and stemless implants. *Clin Orthop Surg.* 2017;9:489–496. doi:10.4055/cios.2017.9.4.489.



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QUESTION 2: What are the indications for one- versus two-stage exchange arthroplasty in the management of acute shoulder periprosthetic joint infection (PJI)?

RECOMMENDATION: Unknown. Single-stage exchange for shoulder PJI had a statistically significant lower reinfection rate and lower complication rate than two-stage exchange in aggregate; however, no studies exist directly comparing these treatments for acute shoulder PJI.

LEVEL OF EVIDENCE: Limited

DELEGATE VOTE: Agree: 96%, Disagree: 4%, Abstain: 0% (Unanimous, Strongest Consensus)

RATIONALE

A comprehensive literature review was performed to identify all studies on revision shoulder arthroplasty for PJI. Terms used for the search included “infection,” “shoulder replacement,” “arthroplasty,” “1-stage,” “2-stage,” “reimplantation,” “prosthetic-related infection” and included “resection,” “spacer” or “exchange” among others using PubMed, Scopus and Embase through February 2018. Inclusion criteria for our systematic review were all English studies (Level I-IV evidence) that reported on single or two-stage revision, infection eradication for revision shoulder arthroplasty with a minimum follow up of twelve-months and minimum of five patients for analysis. Exclusion criteria for our review were all non-English studies, papers that exclude single or two-stage exchange, review papers, case reports or technique articles without outcome data. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) criteria were applied. Title and abstract screening was conducted through 248 results; full text review was conducted with 66 results and produced 31 articles that met inclusion and exclusion criteria for review.

Shoulder PJI is a devastating complication with significant morbidity. The incidence of PJI after primary shoulder arthroplasty has reported ranges of 1–4% and up to 4–15% after revision arthroplasty

[1,2]. Historically, treatment for shoulder PJI has been influenced by evidence from hip and knee arthroplasty infection management experience [3,4]. Two-stage exchange arthroplasty with implant removal, irrigation and debridement (I&D), and insertion of antibiotic spacer, followed by delayed re-implantation has been suggested as gold standard for shoulder PJI [3]. However, single-stage exchange has also been advocated to achieve similar infection control with a single surgery [5–7]. The purpose for this review was to understand the roles of single-stage and two-stage exchange revision in the setting of acute shoulder PJI and compare the outcomes.

In this review, varying studies collected demographics, timing of infection, associated pathogens, surgical treatment, antibiotics, eradication rate for infection, surgical complications and functional outcomes with two-year follow-up minimum. We identified 12 articles that evaluated one-stage exchange and 27 articles that evaluated two-stage exchange.

While the definition and diagnosis of shoulder PJI is beyond the scope of this review, it should be noted that the majority of papers reported using preoperative laboratory values (including elevated white blood cell count, C-reactive protein (CRP) and/or erythrocyte sedimentation rate (ESR)), as well as joint aspiration and/or intra-