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, ImamMD 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-

TABLE 1. Reinfection and complication

One-Stage	Patients	Reinfection %	Pathogens	Constant Score	Complications
12 Papers	161 Total	5.6% Reinfection	72 P. acnes	49.1	12.70%
	6 Acute	$p < 0.05$	29 CoNS	44 Patients	79 Patients
	13 Subacute		20 MSSA	$p < 0.11$	$p < 0.05$
	8 Chronic		3 MRSA		
Two-Stage	**Patients**	**Reinfection %**	**Pathogens**	**Constant Score**	**Complications**
27 Papers	325 Patients	11.4%	88 P. acnes	51.1	21.90%
	47 Acute	$p < 0.05$	64 CoNS	102 Patients	205 Patients
	46 Subacute		33 MRSA	$p < 0.05$	$p < 0.05$
	74 Chronic		56 MSSA		

operative cultures with bacterial growth to arrive at the diagnosis of shoulder PJI. Clinical findings, such as draining sinus, erythema or swelling, were inconsistently reported. There was inconsistent reporting and definition of the timing of infection as acute, sub-acute or chronic. The majority of studies report timing of infection using terms from Sperling et al. and Strickland et al. with acute meaning < 3 months, sub-acute meaning 3-12 months and chronic > 12 months [8, 9]. There was relatively consistent reporting of the pathogens found either pre- or intraoperatively. *Cutibacterium acnes* (*C. acnes*) was the most common organism identified with 160 cases or 32.9% of all cases followed by *Coagulase-negative Staphylococcus* (CoNS) with 93 cases or 19.1% [2,4,7–15]. There were 57 reported cases of poly-microbial infections and 27 cultures that resulted in no growth [4,7,10–12].

To address the stated question, we reviewed data on acute shoulder PJI pertaining to infection eradication using single or two-stage exchange and additional functional outcomes, which are summarized in Tables 1 and 2. In total, 161 cases were identified as treated with single-stage revision and 325 cases of two-stage revision. The majority of studies report timing of infection but few report the success of treatment with either single or two-stage exchange based on timing of infection. Beekman et al. performed analysis on three cases of acute PJI treated with single-stage exchange showing no cases with reinfection [5]. Two additional studies with a total of three cases of acute PJI found no patients had reinfection [6,10]. With two-stage exchange, Buchalter et al. [16] described 1 case of acute PJI that had no reinfection. Another study reported 1 case of acute PJI that failed treatment with two-stage exchange and had persistent infection. In total, four studies reported no cases of reinfection with two-stage exchange with specific analysis of an acute PJI subgroup.

This review has highlighted gaps that exist in current literature. All studies identified were retrospective and thus have substantial selection bias. While the findings in aggregate suggest single-stage exchange is a viable option for PJI, the numbers were small, and there are no studies that control for various risk factors and selection biases such as the particular pathogen, its antibiotic resistance profile, timing of infection or diagnostic features such as obvious clinical findings of infection. Furthermore, there are insufficient numbers of studies that provide analysis for treatment of acute

TABLE 2. Functional outcome

One-Stage	Neer (total)	ASES (mean)	SST (mean)	DASH	FF (mean)	ABD (mean)	ER (mean)
12 Papers	1,7,2	60.5	7.8	N/A	78.2	52.4	25.4
	10 Patients	50 Patients	27 Patients	None	57 Patients	42 Patients	59 Patients
Two-Stage	**Neer (total)**	**ASES (mean)**	**SST (mean)**	**DASH**	**FF (mean)**	**ABD (mean)**	**ER (mean)**
	22,33,32	67.6	4.1	57.7	98.9	52.4	29.2
	87 Patients	101 Patients	32 Patients	15 Patients	194 Patients	72 Patients	144 Patients

shoulder PJI using either single or two-stage exchange with regard to complications or functional outcomes.

REFERENCES

[1] Coste JS, Reig S, Trojani C, Berg M, Walch G, Boileau P. The management of infection in arthroplasty of the shoulder. J Bone Joint Surg Br. 2004;86:65–69.
[2] Padegimas EM, Maltenfort M, Ramsey ML, Williams GR, Parvizi J, Namdari S. Periprosthetic shoulder infection in the United States: incidence and economic burden. J Shoulder Elbow Surg. 2015;24:741–746. doi:10.1016/j.jse.2014.11.044.
[3] George DA, Volpin A, Scarponi S, Haddad FS, Romanò CL. Does exchange arthroplasty of an infected shoulder prosthesis provide better eradication rate and better functional outcome, compared to a permanent spacer or resection arthroplasty? a systematic review. BMC Musculoskelet Disord. 2016;17:52. doi:10.1186/s12891-016-0901-6.
[4] Nelson GN, Davis DE, Namdari S. Outcomes in the treatment of periprosthetic joint infection after shoulder arthroplasty: a systematic review. J Shoulder Elbow Surg. 2016;25:1337–1345. doi:10.1016/j.jse.2015.11.064.
[5] Beekman PDA, Katusic D, Berghs BM, Karelse A, De Wilde L. One-stage revision for patients with a chronically infected reverse total shoulder replacement. J Bone Joint Surg Br. 2010;92:817–822. doi:10.1302/0301-620X.92B6.23045.
[6] Ince A, Seemann K, Frommelt L, Katzer A, Loehr JF. One-stage exchange shoulder arthroplasty for peri-prosthetic infection. J Bone Joint Surg Br. 2005;87:814–818. doi:10.1302/0301-620X.87B6.15920.
[7] Klatte TO, Junghans K, Al-Khateeb H, Rueger JM, Gehrke T, Kendoff D, et al. Single-stage revision for peri-prosthetic shoulder infection: outcomes and results. Bone Joint J. 2013;95-B:391–395. doi:10.1302/0301-620X.95B3.30134.
[8] Sperling JW, Kozak TK, Hanssen AD, Cofield RH. Infection after shoulder arthroplasty. Clin Orthop Relat Res. 2001:206–216.
[9] Strickland JP, Sperling JW, Cofield RH. The results of two-stage re-implantation for infected shoulder replacement. J Bone Joint Surg Br. 2008;90:460–465. doi:10.1302/0301-620X.90B4.20002.
[10] Jacquot A, Sirveaux F, Roche O, Favard L, Clavert P, Molé D. Surgical management of the infected reversed shoulder arthroplasty: a French multicenter study of reoperation in 32 patients. J Shoulder Elbow Surg. 2015;24:1713–1722. doi:10.1016/j.jse.2015.03.007.
[11] 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.
[12] Ortmaier R, Resch H, Hitzl W, Mayer M, Stundner O, Tauber M. Treatment strategies for infection after reverse shoulder arthroplasty. Eur J Orthop Surg Traumatol. 2014;24:723–731. doi:10.1007/s00590-013-1251-9.
[13] Sabesan VJ, Ho JC, Kovacevic D, Iannotti JP. Two-stage reimplantation for treating prosthetic shoulder infections. Clin Orthop Relat Res. 2011;469:2538–2543. doi:10.1007/s11999-011-1774-5.
[14] Singh JA, Sperling JW, Schleck C, Harmsen W, Cofield RH. Periprosthetic infections after shoulder hemiarthroplasty. J Shoulder Elbow Surg. 2012;21:1304–1309. doi:10.1016/j.jse.2011.08.067.
[15] Weber P, Utzschneider S, Sadoghi P, Andress H-J, Jansson V, Müller PE. Management of the infected shoulder prosthesis: a retrospective analysis and review of the literature. Int Orthop. 2011;35:365–373. doi:10.1007/s00264-010-1019-3.
[16] Buchalter DB, Mahure SA, Mollon B, Yu S, Kwon YW, Zuckerman JD. Two-stage revision for infected shoulder arthroplasty. J Shoulder Elbow Surg. 2017;26:939–947. doi:10.1016/j.jse.2016.09.056.

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QUESTION 3: What are the indications for one- versus two-stage revision in subacute or chronic shoulder periprosthetic joint infection (PJI)?

RECOMMENDATION: The indications for one-stage versus two-stage exchange are unclear at this time. The pooled data demonstrate one-stage exchange to be superior to two-stage exchange, but this may be a result of selection bias and other factors.

LEVEL OF EVIDENCE: Limited

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

RATIONALE

A comprehensive literature review was performed to identify all studies on revision shoulder arthroplasty for periprosthetic joint infection (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 language 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 language 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 screen was conducted of 248 results and a full text review of 66, identified 31 articles that met inclusion and exclusion criteria for final review.

The purpose for this review was to understand and compare the role of single-stage and two-stage exchange for the treatment of shoulder PJI. Two-stage exchange arthroplasty with implant removal, irrigation and debridement (I&D), insertion of antibiotic spacer, antibiotic treatment, followed by re-implantation has been suggested as gold standard for treatment of shoulder PJI [1]. 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. The majority of papers reported preoperative laboratory values to diagnose PJI based on elevated white blood cell count, C-reactive protein and/or erythrocyte sedimentation rate. Clinical findings such as draining sinus, erythema or swelling were inconsistently reported. Most studies reported the number of joint aspirations performed and resulted positive with microbial growth. Although there was inconsistent reporting of timing of infection, the majority of studies that reported timing of infection used terms from Sperling et al. and Strickland et al. with acute meaning < 3 months, sub-acute meaning 3-12 months and chronic > 12 months [2,3]. There was consistent reporting of the pathogens found either pre- or intraoperatively. *Cutibacterium acnes* (*C. acnes*) was the most common organism identified with 160 cases followed by *Coagulase-negative Staphylococcus* (CoNS) with 93 cases [2,4–14]. There were 57 reported cases of polymicrobial cases and 27 cultures that resulted in no growth [4–8].

To address the stated question, we reviewed studies in aggregate for sub-acute and chronic infection when treated with either single