Orthopaedics & Traumatology: Surgery & Research 106 (2020) 5–15

Contents lists available at ScienceDirect

Orthopaedics & Traumatology: Surgery & Research

journal homepage: www.elsevier.com

Review article

# One- or two-stage exchange for periprosthetic shoulder infection: Systematic review and meta-analysis☆

Florence Aïm[a,b,*], Blandine Marion[a,b], Younes Kerroumi[a], Vanina Meyssonnier[a], Simon Marmor[a,b]

[a] Groupe hospitalier Diaconnesses Croix Saint-Simon, centre de référence des infections ostéo-articulaires, 125, rue d'Avron, 75020 Paris, France
[b] Service de chirurgie orthopédique, groupe hospitalier Diaconnesses Croix Saint-Simon, 125, rue d'Avron, 75020 Paris, France

ARTICLE INFO

*Article history:*
Received 4 July 2019
Accepted 21 October 2019

*Keywords:*
Shoulder
Prosthesis
Sepsis
Infection
1-stage
2-stage

ABSTRACT

*Introduction:* One-stage exchange is the gold-standard for management of periprosthetic shoulder infection. The present review compares efficacy between 1- and 2-stage exchange in this indication.
*Material and methods:* We performed a systematic literature review and meta-analysis following the "Preferred Reporting Items for Systematic Reviews and Meta-Analyses" (PRISMA) criteria. The literature search used the Medline, Embase and Central data-bases. The studies included assessed 1- and 2-stage exchange in periprosthetic shoulder infection. The main outcome was reinfection rate, and the secondary outcome postoperative complications rate.
*Results:* Twenty-one studies, for 501 patients, were included: 5 assessing 1-stage exchange, 11 2-stage, and 5 both. Mean follow-up was 4.3 years (range, 2–6.1 years). Mean reinfection rates ranged between 0 and 50% in 1-stage exchange and between 0 and 36.8% in 2-stage exchange. The combined rate was 7% (95% CI, 3.8–12.5%) in 1-stage and 21.3% (95% CI, 16–27.9%) in 2-stage exchange. Mean complications rates ranged between 0 and 50% in 1-stage exchange and between 5.7% and 73%% in 2-stage exchange. The combined rate was 17% (95% CI, 11.9–23.9%) in 1-stage and 32.8% (95% CI, 25.8–40.6%) in 2-stage exchange.
*Discussion:* To our knowledge, the present meta-analysis is the first to assess results in 1- and 2-stage exchange for chronic periprosthetic shoulder infection.
*Conclusion:* One-stage exchange seemed to provide better results, with less reinfection and fewer complications than 2-stage exchange.
*Level of evidence:* I, meta-analysis.



## 1. Introduction

Prosthetic infection is a severe complication in joint replacement surgery. The increasing number of shoulder replacements inevitably leads to an increase in periprosthetic shoulder infection, directly impacting morbidity and health-care costs. Infection is the main cause of revision surgery in the first 2 years following shoulder replacement [1].

The rate of postoperative periprosthetic shoulder infection is 0.98%, and higher in case of revision surgery and arthroplasty for trauma. The main bacterium involved is *Cutibacterium acnes* [2–10].

Treatment strategies are inspired by those in total knee or hip prosthetic infection, and comprise: long-course suppressive antibiotic therapy [11,12], synovectomy without implant exchange [13–16], resection arthroplasty [13,17–22], arthrodesis [23], and 1- or 2-stage implant exchange [24–29]. Isolated suppressive antibiotic therapy or synovectomy show high failure rates in chronic infection. Resection arthroplasty has better results in terms of recurrence but poorer functional results [13,17,30].

Two-stage exchange is often considered the gold-standard, but involves multiple surgery, greater number and duration of hospital stays, and functional impairment [31,32].

One-stage exchange consists in extensive synovectomy associated to removal of all implants and any cement, with reimplantation in the same step. This requires a single admission and single anesthesia, with lower cost and better functional results [33]. Superiority over 2-stage exchange, however, is unproven. To our knowledge, no randomized controlled trials have compared 1- versus 2-stage exchange in periprosthetic shoulder infection.

☆ Prospero registration nº CRD42018115928.

* Corresponding author at: Groupe hospitalier Diaconnesses Croix Saint-Simon, centre de référence des infections ostéo-articulaires, 125, rue d'Avron, 75020 Paris, France.
*E-mail address:* florenceaim@gmail.com (F. Aïm).

https://doi.org/10.1016/j.otsr.2019.10.016
1877-0568/

Several observational studies compared reinfection rates, involving different bacteria and/or recurrence, in 1- versus 2-stage exchange, with conflicting results.

We performed what is, to our knowledge, the first systematic review and meta-analysis comparing reinfection after 1- and 2-stage exchange in periprosthetic shoulder infection.

The objective was to compare efficacy between 1- and 2-stage exchange to manage chronic periprosthetic shoulder infection. The main study hypothesis was that reinfection and complications rates are the same on both strategies.

## 2. Materiel and methods

The systematic literature review and meta-analysis were conducted according to "Preferred Reporting Items for Systematic Reviews and Meta-Analyses" (PRISMA) guidelines [34].

### 2.1. Search strategy

The literature search was conducted in 3 data-bases: MEDLINE via PubMed, the Cochrane Central Register of Controlled Trials (CENTRAL 2018, number 10), and EMBASE. Search-terms concerned surgery ("shoulder", "arthroplasty", "prosthesis", "one-stage", "two-stage"), and complications ("sepsis", "infection"). A specific search algorithm was drawn up for each data-base; the reference lists of retrieved articles and previous systematic reviews were examined. Ongoing trials were identified on the ClinicalTrials.gov website. The search was closed on October 15 2018.

### 2.2. Selection of studies

Studies were included that assessed results in 1- or 2-stage exchange for periprosthetic shoulder infection, in whatever language. No systematic reviews or expert opinions were included. Relevant studies were selected by 2 authors (FA and BM), working independently and resolving differences by consensus. Excluded studies and reasons for exclusion were listed.

### 2.3. Study quality assessment

Study quality was assessed on "Methodological Index for Non-Randomized Studies" (MINORS) score [35], taking account of: stated aim, consecutive inclusion, prospective data collection, unbiased evaluation of endpoint, follow-up appropriate to endpoint (2 years for sepsis), <5% loss to follow-up, prospective calculation of study size, adequate control group, baseline equivalence of groups, and adequate statistical analysis.

Two authors (FA and BM) performed this assessment, with systematic discussion of divergences.

### 2.4. Data extraction

Data were extracted on a standardized form by 2 authors (FA and BM), working independently. Data comprised: publication date, journal, country, patient demographics (age, gender), implant type, follow-up after revision, type of procedure (1-stage, 2-stage), microbiology (germs) and clinical data (reinfection, complications other than reinfection, functional score), and sample size.

The main endpoint was reinfection at 2 years post-revision (number of reinfected patients as a proportion of all patients). The secondary endpoint was complications (number of complications as a proportion of all patients) rate.

### 2.5. Statistical analysis

Data were analyzed on R software (R Core Team 2014). Reinfection and complications rates were assessed with 95% confidence intervals (95% CI). Statistical heterogeneity was assessed on the $I^2$ statistic as: 25–49%, low heterogeneity; 50–74%, moderate heterogeneity; >75%, high heterogeneity. Relative risk with 95% CI was computed using a fixed effects model when heterogeneity was low and a random effects model otherwise. Funnel plots were constructed to assess publication bias.

## 3. Results

### 3.1. Study identification and selection

The initial search identified 1,118 eligible studies. After elimination of duplicates, the predefined inclusion/exclusion criteria were applied, selecting 21 studies, for 501 patients and 503 shoulders. [7,13,29,31,36–52] (Fig. 1: flowchart).

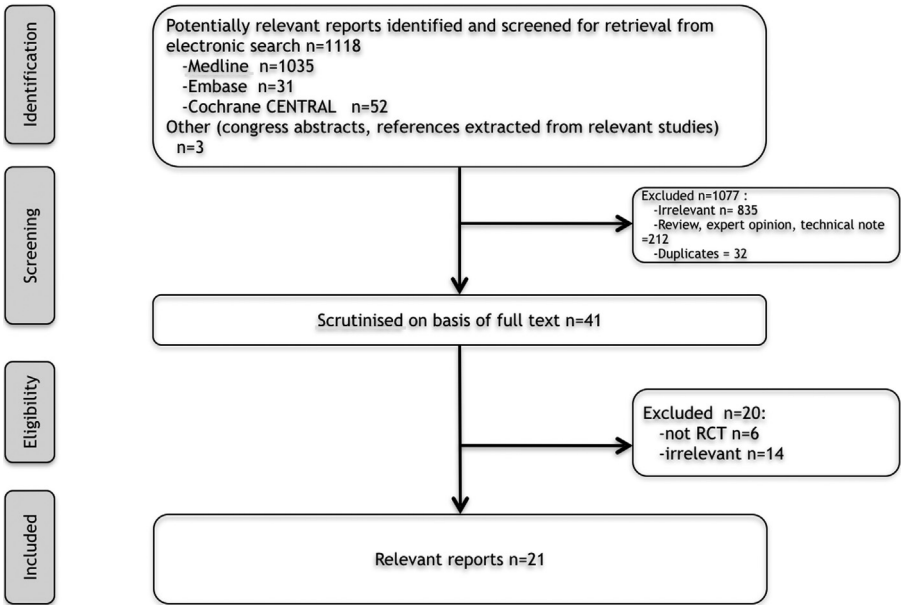


**Fig. 1.** Flow chart.

### 3.2. Study characteristics and quality

There were no randomized controlled or comparative studies. Ten studies assessed 1-stage ($n = 170$) [13,29,38,40,42–44,46,50,51] and 16 2-stage exchange ($n = 228$) [7,13,29,31,36,37,39–41,44,45,47–49,51,52]. Five reported results for both, and their data were split for analysis.

Studies were published between 2001 and 2018. Mean follow-up was 4.3 years (range, 2–6.1 years) (Tables 1 and 2).

Mean MINORS score was 12.2 (range, 9–14) (Table 3).

### 3.3. Characterization of infection

Five studies reported type of infection in 1-stage exchange and 11 in 2-stage exchange, all following Sperling's classification: 5 acute infections (<3 months postoperatively), 25 subacute (3 months to 1 year) and 29 late (>1 year) in 1-stage and respectively 12, 40 and 101 in 2-stage exchange [29].

### 3.4. Microbiology

Germs were reported in 8 of the 9 1-stage and 13 of the 16 2-stage studies. They comprised *C. acnes* in at least 71 cases of the 168 infections (42%) in the 1-stage group, and 32 of the 228 (14%) in the 2-stage group. Prevalences were, however, not precisely reported in all studies. Other isolates comprised coagulase-negative *Staphylococci* and *Staphylococcus aureus*.

### 3.5. Reinfection rates

Mean reinfection rates at a minimum 2 years' follow-up ranged between 0 and 50% in 1-stage and between 0 and 36.8% in 2-stage exchange.

Overall reinfection rate in 1-stage exchange was 7% (95% CI, 3.8–12.5%) (Fig. 2). $I^2$ was 0%: i.e., absence of heterogeneity. The funnel graph was symmetrical: i.e., absence of publication bias (Fig. 3).

In 2-stage exchange, the rate was 21.3% (95% CI, 16–27.9%) (Fig. 4). $I^2$ was 18.9%: i.e., low heterogeneity. The funnel graph was symmetrical: i.e., absence of publication bias (Fig. 5).

### 3.6. Complications rates

Mean complications rates were reported in 9 studies for 1-stage [13,29,38,40,42,43,46,50,51] and 13 for 2-stage exchange [7,13,31,37,39–41,44,47–49,51,52], and ranged between 0 and 50% and between 5.7% and 73.7%, respectively.

Complications comprised unexpected intra- and post-operative events requiring specific treatment. Eighty-four revision procedures were reported, for all causes beside reinfection. The most frequent complication was implant dislocation requiring conversion to reverse prosthesis or insert exchange. Others comprised hematoma, acromial non-union and periprosthetic fracture. Overall there were 85 revisions. It was not possible to analyze complications as specific to one or other strategy.

The combined complications rate in 1-stage exchange was 17% (95% CI, 11.9–23.9%) (Fig. 6). $I^2$ was 0%. The funnel graph was symmetrical (Fig. 7).

In 2-stage exchange, the rate was 32.8% (95% CI, 25.8–40.6%) (Fig. 8). $I^2$ was 65.8%. The funnel graph was asymmetrical: i.e., greater publication bias in small-sample studies (Fig. 9).

## 4. Discussion

Periprosthetic shoulder infection is a rare but severe complication. The present review reports results for 1- and 2-stage exchange. One-stage exchange led to less reinfection and fewer complications.

Given the expected rise in periprosthetic shoulder infection with increasing numbers of shoulder replacements, well-defined treatment strategies are needed.

To date, diagnostic and treatment strategies for periprosthetic shoulder infection are based on those for total knee and hip prostheses. The present results agree with previous reports on periprosthetic knee and hip infection. Two-stage exchange has been the reference attitude in periprosthetic infection [9,29,53–55]. However, lower-limb studies show that 1-stage exchange has a role to play, for medical, functional and economic reasons [32,56]. The present results, in favor of 1-stage exchange, confirm this trend.

The main complication was dislocation requiring surgical revision for polyethylene insert exchange. Other complications comprised hematoma and fracture. Given the small number of studies and the even smaller number reporting complications, it was not possible to analyze complications according to strategy.

The present review had certain limitations. In the absence of any randomized controlled trials, only retrospective and non-randomized studies could be included. Secondly, no pooled analysis of functional results could be made, as this was not systematically dealt with in the studies. One-stage exchange seemed to give better functional results, but it may be that these candidates were in better preoperative health. Further, ideally randomized controlled, studies are needed to assess functional results.

Perioperative antibiotic therapy was not taken into account, as studies did not systematically report type of bacterium, antibiogram, antibiotics administered and duration of administration.

*C. acnes*, methicillin-resistant *S. aureus* and coagulase-negative staphylococci were the most frequent isolates. [29,57–66] We also included negative culture results, on the hypothesis that the cultures had not been kept long enough to reveal slow-growing strains such as *C. acnes*. In case of recurrence of infection after 1- or 2-stage exchange, isolates were not always reported, making it impossible to distinguish new infection from reinfection by the same bacterium.

Several systematic reviews have collated results for 1- and 2-step exchange in periprosthetic shoulder infection[18,67], but this is the first meta-analysis on the subject, to our knowledge.

Bonnevialle reported that 1-stage exchange was feasible if the bacterium was identified preoperatively; otherwise, 2-stage exchange was recommended in active patients, with resection arthroplasty as treatment of choice for patients with low functional demand [1]. George and Nelson, in a systematic review of 1- and 2-step exchange in periprosthetic shoulder infection, reported reinfection rates of respectively 9.2% and 6.2% [68,69]. Garrigues, Torrens et al., in the International Consensus Meeting on Musculoskeletal Infection, considered indications for 1- and 2-step exchange to be difficult to specify; analysis showed superiority of 1-stage exchange in subacute periprosthetic shoulder infection [70].

We were not able to perform subgroup analysis between acute and subacute versus chronic infection, for lack of data. Most studies used Sperling's 3-stage classification (acute, subacute, late), which cannot be superimposed on the Tsukayama classification classically used to distinguish acute (<1 month) from chronic (>1 month) infection in guiding treatment [29,71]. Studies also failed to specify whether strategy differed in late infection or in case of comorbidity. Although demographic data were sparse, the 1- and 2-stage groups were comparable.

**Table 1**
Description of studies assessing 1-stage exchange.

| Reference | Number of infected shoulders | Mean follow-up (years) | Microbiology | Classification of infection according to Sperling | Implant type | Active anterior elevation (°) (pre to post) | External rotation (pre to post) | Functional assessment | Reinfection rate (%) | Complications rate (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| Beekman et al. | 11 | 2 | *C. acnes*: *n* = 6, polymicrobial *n* = 2 *S. aureus*: *n* = 1, CNS *n* = 3 | Acute: *n* = 3 Subacute: *n* = 7 Chronic: *n* = 1 | RSA: *n* = 11 | | | Constant 45 to 55 | 9.1 | 28 |
| Coste et al. | 3 | | CNS *S. albus*, *C. acnes* | Subacute: *n* = 1 Chronic: *n* = 1 | | | | Constant 35 to 66 | 0 | 0 |
| Cuff et al. | 10 | 3.58 | *S. aureus*: *n* = 2, none: *n* = 4, CNS: *n* = 1, *C. albicans*: *n* = 1 *E. faecalis*: *n* = 1 | | HA: *n* = 10 | | | ASES 36 to 62.6 | 0 | 30 |
| Hsu et al. | 27 | 3.8 | *C. acnes*: *n* = 27 | Chronic: *n* = 27 | HA: *n* = 12, TSA: *n* = 9 | | | SST 3.2 to 7.8 | 0 | 11 |
| Ince et al. | 16 | 5.8 | *C. acnes*: *n* = 2, *S. capitis*: *n* = 2, CNS, *M. tuberculosum* | | TSA: *n* = 15, RSA: *n* = 1 | | | Constant 33.6 | 0 | 18.75 |
| Jacquot et al. | 5 | NR | | | RSA: *n* = 5 | | | | 0 | Nr |
| Klatte et al. | 35 | 4.7 | CNS: *n* = 13, *C. acnes*: *n* = 12 | Acute: *n* = 4 Subacute: *n* = 15 Chronic: *n* = 16 | HA: *n* = 23, TSA: *n* = 5, RSA: *n* = 6 | | | Constant 51.1 | 6 | 14.2 |
| Sevelda et al. | 14 | 5.8 | *C. acnes*: *n* = 8, CNS: *n* = 3, polymicrobial: *n* = 3 | | HA: *n* = 11, RSA *n* = 3 | | | Constant 27 to 65 | 7 | 7 |
| Stone et al. | 45 | 3.8 | *C. acnes*: *n* = 16, CNS: *n* = 17, *S. aureus*: *n* = 10 | | | 23 to 32° | 57 to 113° | ASES 33.6 to 60 SST 1.8 to 5 | 4 | 16 |
| Sperling et al. | 2 | 2 | CNS, *Acinetobacter calcoaceticus*, *Corynebacterium* | Subacute: *n* = 2 | HA: *n* = 2 | Up to 180° | Up to 30° | | 50 | 50 |

NR: not reported; CNS: coagulase-negative *staphylococcus*; *C. acnes*: *Cutibacterium acnes*; *M. Tuberculosis*: *Mycobacterium tuberculosis*; *S. aureus*: *Staphylococcus aureus*; *S. capitis*: *Staphylococcus capitis*; *C. albicans*: *Candida albicans*, *E. faecalis*: *Enterococcus faecalis*. HA: hemiarthroplasty; TSA: total shoulder arthroplasty; RSA reverse l shoulder arthroplasty.

**Table 2**
Description of studies assessing 2-stage exchange.

| Reference | Number of infected shoulders | Mean follow-up (years) | Microbiology | Classification of infection according to Sperling | Implant type | Active anterior elevation (°) (pre to post) | External rotation (pre to post) | Functional assessment | Reinfection rate (%) | Complications rate (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| Achermann et al. | 7 | 3.8 | MRSA, *E. coli*, *Corynebacterium bovis*, *S. aureus*, *Streptococcus dysgalactiae* | Acute: *n* = 1<br>Subacute: *n* = 2<br>Chronic: *n* = 4 | | | | | 85.70 | Nr |
| Assenmacher et al. | 35 | 4.1 | *C. acnes* (*n* = 13), CNS (*n* = 12), MRSA (*n* = 2), *Pseudomonas* sp (*n* = 2), *Bacillus* sp (*n* = 1), polymicrobial (*n* = 1), no growth (*n* = 4) | Acute: *n* = 1<br>Subacute: *n* = 6<br>Chronic: *n* = 28 | HA: *n* = 10, TSA: *n* = 24, RSA: *n* = 1 | 64 to 118 | 14 to 41 | | 85 | 5.7 |
| Buchalter et al. | 19 | 5.3 | *C. acnes* (*n* = 8), *E. faecalis* *n* = 1, Polymicrobial: *n* = 6, CNS: *n* = 1, *Corynebacterium*: *n* = 1 | Acute: *n* = 1<br>Subacute: *n* = 7<br>Chronic: *n* = 10 | HA: *n* = 4<br>TSA: *n* = 13<br>RSA: *n* = 2 | 58 to 119 | 14 to 19 | | 79 | 16 |
| Coste et al. | 10 | 2.6 | Nr | Acute: *n* = 1<br>Subacute: *n* = 2<br>Chronic: *n* = 7 | TSA, HA | | 11 to 14 | Constant 15 to 35 | 60 | 10 |
| Cuff et al. | 12 | 3.6 | E. cloacae, CNS, *C. acnes*, *S. aureus* | | HA | 43 to 79 | 10 to 25 | ASES 28 to 48 | 100 | 58.3 |
| Ghiselings et al. | 3 | 4.7 | *C. acnes*: *n* = 1, CNS: *n* = 1 | Acute: *n* = 1<br>Subacute: *n* = 2 | RSA | | | Constant 22.7 post operative | 100 | 33 |
| Ortmaier et al. | 12 | 6.1 | *Corynebacterium*: *n* = 1, *C. acnes*: *n* = 4, CNS: *n* = 1, *polymicrobial*: *n* = 6 | Subacute: *n* = 2<br>Chronic: *n* = 10 | RSA | To 80 | | Constant up to 52.2 post operative | 75% | 41.7 |
| Jacquot et al. | 14 | 3 | *C. acnes*, CNS | | RSA | | | Constant 39 to 44 | 64 | 36 |
| Jerosh et al. | 8 | Nr | Nr | Chronic: *n* = 8 | HA | | | Constant to 48 post operative | 100 | Nr |
| Lee et al. | 12 | 3.4 | Nr | | | 81.7 | 40.4 | Constant 32.9 to 66.8 | 100 | 16.7 |
| Sabesan et al. | 17 | 3.8 | *Staphylococci* spp: *n* = 7, *C. acnes*: *n* = 5 | Acute: *n* = 2<br>Subacute: *n* = 8<br>Chronic: *n* = 7 | RSA, TSA, HA | 123 | 26 | | 94 | 35 |
| Romano et al. | 17 | 3.8 | MRSA, CNS, *C. acnes*, polymicrobia | | RSA, HA | 55 | 12 | Constant 26 to 38 | 100 | 15.9 |
| Sperling et al. | 3 | 2 | CNS, *S. aureus*, *C. acnes* | Chronic: *n* = 3 | TSA | | up to 30 | | 100 | Nr |
| Stone et al. | 19 | 3.8 | *S. aureus*, CNS, *C. acnes*: *n* = 7, polymicrobial: *n* = 6 | | RSA, TSA HA | 45 to 127 | 11 to 39 | | 79 | 11 |
| Strickland et al. | 19 | 2.9 | *C. acnes*, CNS, no growth *n* = 4, *S. aureus*: *n* = 3, *Enterococcus*: *n* = 1 | Acute: *n* = 3<br>Subacute: *n* = 7, chronic: *n* = 9 | TSA, HA | 42 to 89 | 30 to 43 | | 63.2 | 73.7 |
| Torrens et al. | 21 | Nr | CNS: *n* = 4, *C. acnes*: *n* = 8, polymicrobial: *n* = 3, no bacteria = 9 | Acute: *n* = 2, subacute: *n* = 4<br>Chronic: *n* = 15 | HA, RSA | 46.1 to 78.2 | | Constant 16.3 to 34.1 | 85.8 | 42.8 |

NR: not reported; CNS: coagulase-negative *staphylococcus*; *C. acnes*: *Cutibacterium acnes*; *S. aureus*: *Staphylococcus aureus*; *S. capitis*: *Staphylococcus capitis*; MRSA: methicillin-resistant: *staphylococcus aureus*; sp: species. HA: hemiarthroplasty; TSA: total shoulder arthroplasty; RSA: reverse shoulder arthroplasty.

**Table 3**
Quality analysis of studies on MINORS criteria.

| Authors | Criteria | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A stated aim of the study | Inclusion of consecutive patients | Prospective collection of data | Endpoint appropriate to the aim of the study | Unbiased evaluation of endpoint | Follow-up period appropriate to the major endpoint | Loss to follow-up less than 5% | Prospective calculation of the study size | An adequate control group | Contemporary group | Baseline equivalence of groups | Adequate statistical analysis | Total |
| Achermann et al. | 1 | 0 | 0 | 1 | 2 | 2 | 1 | 0 | n/a | n/a | n/a | 2 | 9 |
| Assemmacher et al. | 2 | 0 | 0 | 2 | 2 | 2 | 0 | 0 | n/a | n/a | n/a | 2 | 10 |
| Beekman et al. | 1 | 2 | 0 | 1 | 2 | 2 | 0 | 0 | n/a | n/a | n/a | 2 | 10 |
| Buchalter et al. | 2 | 0 | 0 | 2 | 2 | 2 | 2 | 0 | n/a | n/a | n/a | 2 | 12 |
| Coste et al. | 1 | 2 | 0 | 2 | 2 | 2 | 1 | 0 | n/a | n/a | n/a | 2 | 12 |
| Cuff et al. | 1 | 2 | 0 | 2 | 2 | 2 | 1 | 0 | n/a | n/a | n/a | 2 | 12 |
| Ghiselings et al. | 2 | 0 | 0 | 2 | 2 | 2 | 0 | 0 | n/a | n/a | n/a | 2 | 10 |
| Hsu et al. | 2 | 2 | 0 | 2 | 2 | 2 | 2 | 0 | n/a | n/a | n/a | 2 | 14 |
| Ince et al. | 2 | 2 | 0 | 2 | 2 | 2 | 2 | 0 | n/a | n/a | n/a | 2 | 14 |
| Jacquot et al. | 1 | 0 | 1 | 1 | 2 | 2 | 0 | 0 | n/a | n/a | n/a | 2 | 11 |
| Jerosh et al. | 1 | 0 | 0 | 2 | 2 | 2 | 0 | 0 | n/a | n/a | n/a | 2 | 9 |
| Klatte et al. | 1 | 2 | 0 | 1 | 2 | 2 | 1 | 0 | n/a | n/a | n/a | 2 | 11 |
| Lee et al. | 2 | 2 | 0 | 2 | 2 | 2 | 1 | 0 | n/a | n/a | n/a | 2 | 13 |
| Ortmaier et al. | 1 | 2 | 0 | 2 | 2 | 2 | 2 | 0 | n/a | n/a | n/a | 2 | 13 |
| Romano et al. | 1 | 2 | 1 | 2 | 2 | 2 | 1 | 0 | n/a | n/a | n/a | 2 | 13 |
| Sabesan et al. | 2 | 2 | 0 | 2 | 2 | 2 | 0 | 0 | n/a | n/a | n/a | 2 | 12 |
| Sevelda et al. | 2 | 2 | 1 | 2 | 2 | 2 | 0 | 0 | n/a | n/a | n/a | 2 | 13 |
| Stone et al. | 2 | 2 | 0 | 2 | 2 | 2 | 0 | 0 | n/a | n/a | n/a | 2 | 12 |
| Sperling et al. | 2 | 2 | 0 | 2 | 2 | 2 | 1 | 0 | n/a | n/a | n/a | 2 | 13 |
| Strickland et al. | 2 | 2 | 0 | 2 | 2 | 2 | 1 | 0 | n/a | n/a | n/a | 2 | 11 |
| Torrens et al. | 2 | 0 | 0 | 2 | 2 | 2 | 0 | 0 | n/a | n/a | n/a | 2 | 12 |

n/a: not applicable. 0: not reported; 1: reported but inadequate; 2: reported and adequate.

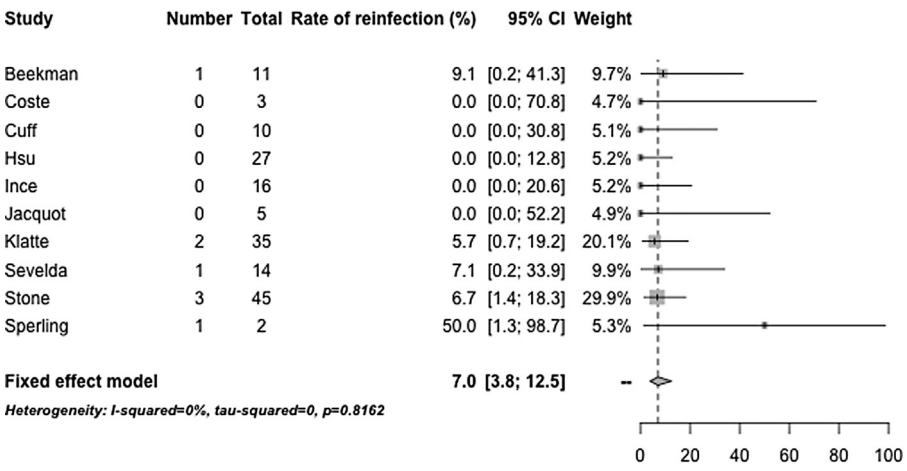


**Fig. 2.** Forrest plot: rate of reinfection one-stage exchange.

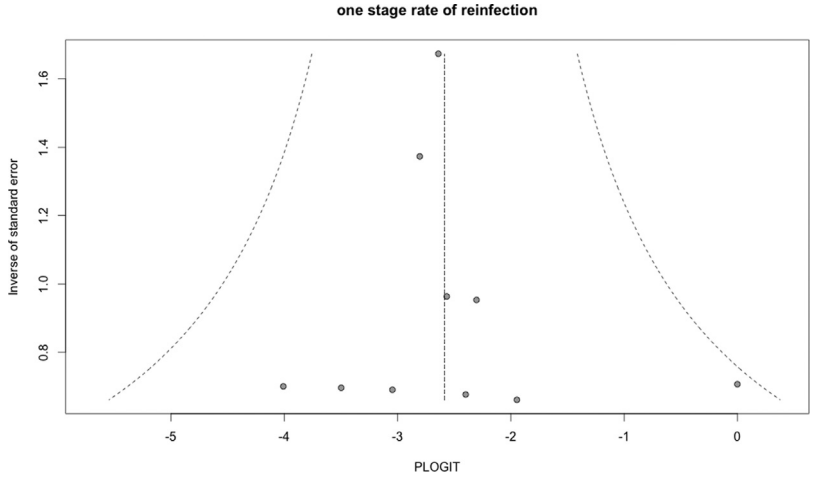


**Fig. 3.** Funnel plot: rate of reinfection one-stage exchange.

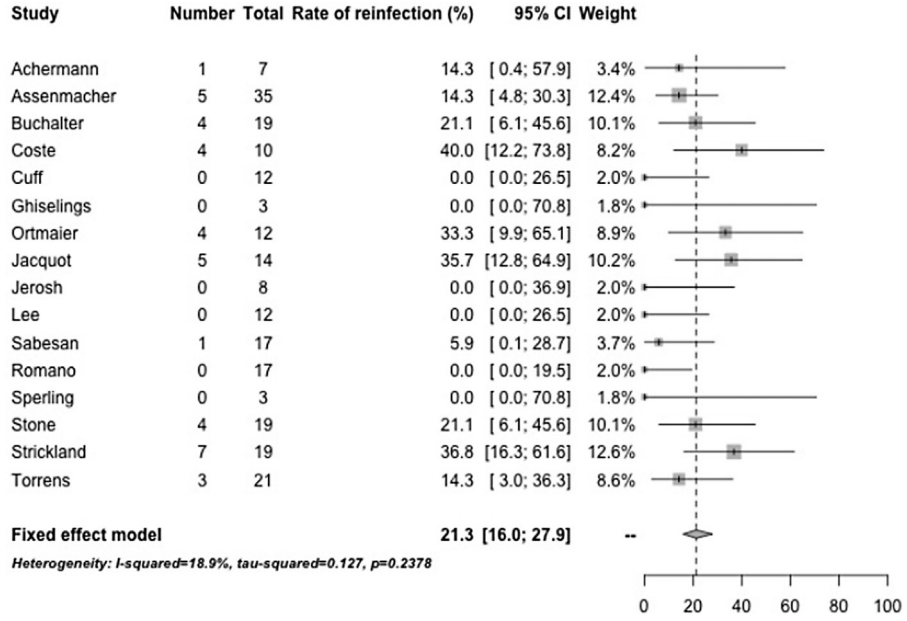


**Fig. 4.** Forrest plot: rate of reinfection two-stage exchange.

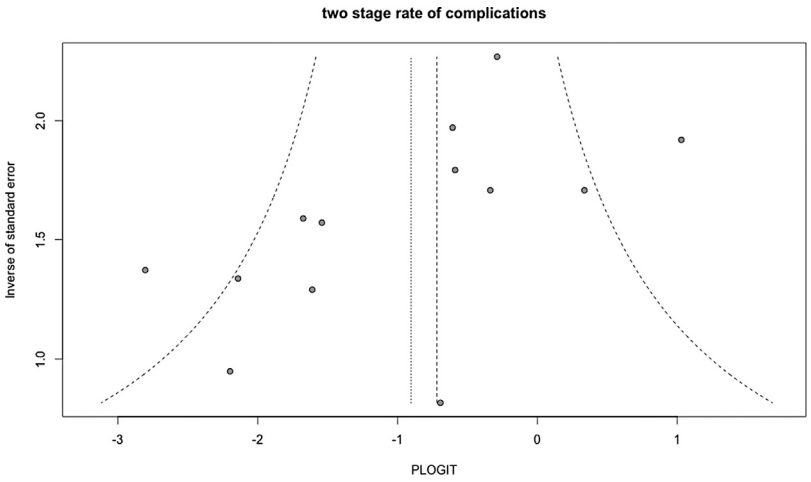


**Fig. 5.** Funnel plot: rate of reinfection two-stage exchange.

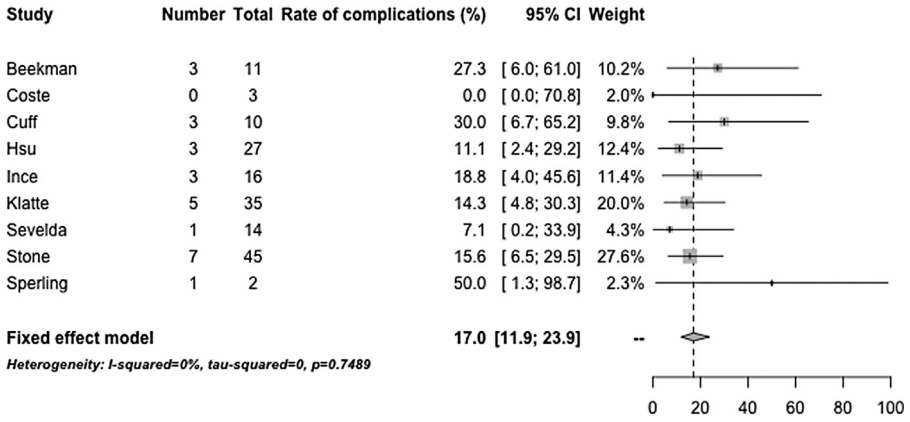


**Fig. 6.** Forrest plot: rate of complications one-stage exchange.

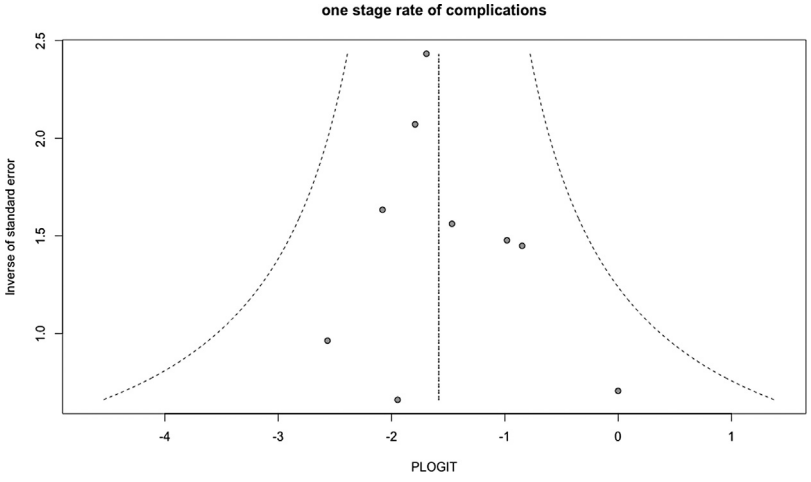


**Fig. 7.** Funnel plot: rate of complications one-stage exchange.

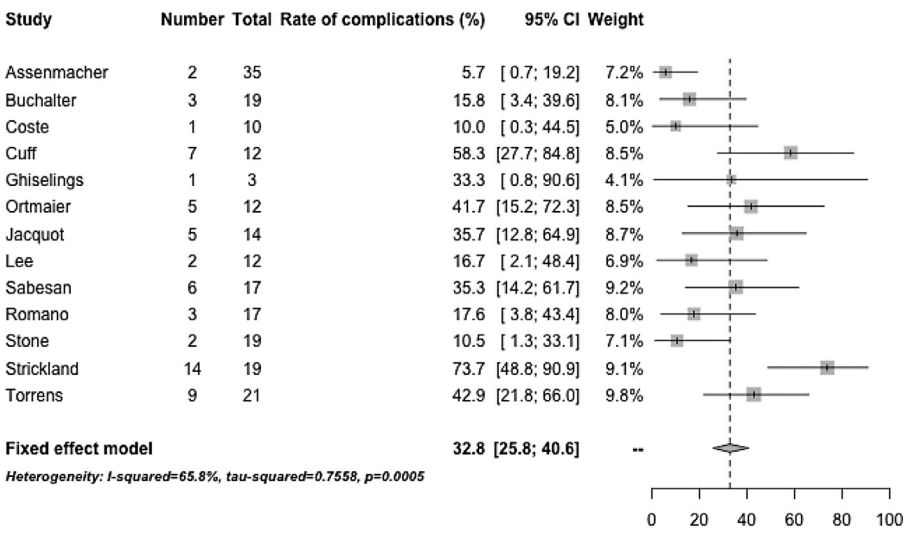


**Fig. 8.** Forrest plot: rate of complications two-stage exchange.

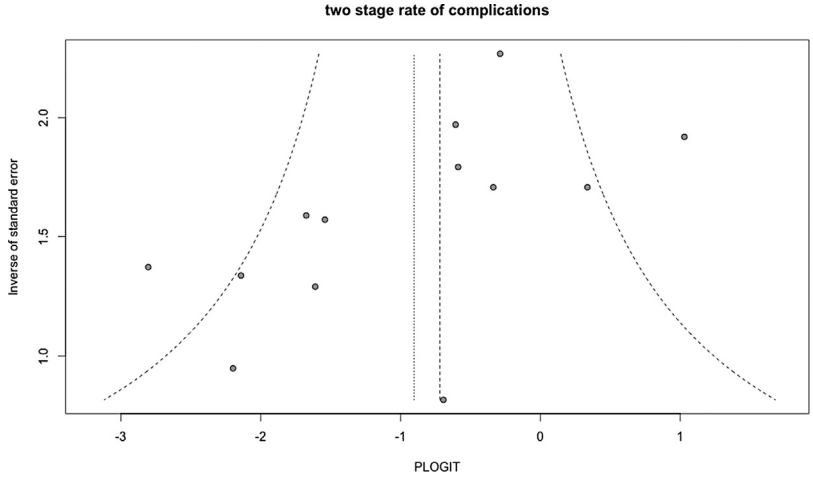


**Fig. 9.** Funnel plot: rate of complications two-stage exchange.

## 5. Conclusion

In periprosthetic shoulder infection, 1-stage exchange gives better results than 2-stage exchange, with 3-fold less reinfection (7% [95% CI, 3.8–12.5%] versus 21.3% [95% CI, 16–27.9%]) and almost 2-fold fewer complications (17% [95% CI, 11.9–23.9%] versus 32/8% [95% CI, 25.8–40.6%]). Functional benefit, however, remains undetermined, and further studies are needed.

## Disclosure of interest

The authors declare that they have no competing interest.

## Funding

None.

## Contribution

Florence Aim wrote the manuscript.

Blandine Marion contributed to article selection and data extraction.

Younes Kerroumi read the manuscript and helped with statistics.

Vanina Meyssonnier checked the microbiological data.

Simon Marmor corrected the manuscript.

## References

[1] Bonnevialle N, Dauzères F, Toulemonde J, Elia F, Laffosse J-M, Mansat P. Periprosthetic shoulder infection: an overview. EFORT Open Rev 2017;2:104–9.
[2] Boileau P. Complications and revision of reverse total shoulder arthroplasty. Orthop Traumatol Surg Res 2016;102:S33–43.
[3] Favard L, Levigne C, Nerot C, Gerber C, De Wilde L, Mole D. Reverse prostheses in arthropathies with cuff tear: are survivorship and function maintained over time? Clin Orthop Relat Res 2011;469:2469–75.
[4] Kiet TK, Feeley BT, Naimark M, Gajiu T, Hall SL, Chung TT, et al. Outcomes after shoulder replacement: comparison between reverse and anatomic total shoulder arthroplasty. J Shoulder Elbow Surg 2015;24:179–85.
[5] Meijer ST, Paulino Pereira NR, Nota SPFT, Ferrone ML, Schwab JH, Lozano Calderón SA. Factors associated with infection after reconstructive shoulder surgery for proximal humerus tumors. J Shoulder Elbow Surg 2017;26:931–8.
[6] Morris BJ, O'Connor DP, Torres D, Elkousy HA, Gartsman GM, Edwards TB. Risk factors for periprosthetic infection after reverse shoulder arthroplasty. J Shoulder Elbow Surg 2015;24:161–6.
[7] 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;24:723–31.
[8] Smucny M, Menendez ME, Ring D, Feeley BT, Zhang AL. Inpatient surgical site infection after shoulder arthroplasty. J Shoulder Elbow Surg 2015;24:747–53.
[9] Zimmerli W, Trampuz A, Ochsner PE. Prosthetic-joint infections. New Engl J Med 2004;351:1645–54.

[10] Zumstein MA, Pinedo M, Old J, Boileau P. Problems, complications, reoperations, and revisions in reverse total shoulder arthroplasty: a systematic review. J Shoulder Elbow Surg 2011;20:146–57.
[11] Jiang JJ, Piponov HI, Mass DP, Angeles JG, Shi LL. Septic arthritis of the shoulder: a comparison of treatment methods. J Am Acad Orthop Surg 2017;25:e175–84.
[12] Prendki V, Zeller V, Passeron D, Desplaces N, Mamoudy P, Stirnemann J, et al. Outcome of patients over 80 years of age on prolonged suppressive antibiotic therapy for at least 6 months for prosthetic joint infection. Int J Infect Dis 2014;29:184–9.
[13] 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;86:65–9.
[14] Dennison T, Alentorn-Geli E, Assenmacher AT, Sperling JW, Sánchez-Sotelo J, Cofield RH. Management of acute or late hematogenous infection after shoulder arthroplasty with irrigation, debridement, and component retention. J Shoulder Elbow Surg 2017;26:73–8.
[15] Dilisio MF, Miller LR, Warner JJP, Higgins LD. Arthroscopic tissue culture for the evaluation of periprosthetic shoulder infection. J Bone Joint Surg Am 2014;96:1952–8.
[16] Mook WR, Garrigues GE. Diagnosis and management of periprosthetic shoulder infections. J Bone Joint Surg Am 2014;96:956–65.
[17] Braman JP, Sprague M, Bishop J, Lo IK, Lee EW, Flatow EL. The outcome of resection shoulder arthroplasty for recalcitrant shoulder infections. J Shoulder Elbow Surg 2006;15:549–53.
[18] Marcheggiani Muccioli GM, Guerra E, Roberti di Sarsina T, Alesi D, Fratini S, Cammisa E, et al. Diagnosis and treatment of infected shoulder arthroplasty: current concepts review. Joints 2018;6:173–6.
[19] 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;92:567–74.
[20] 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;138:605–9.
[21] Richards J, Inacio MCS, Beckett M, Navarro RA, Singh A, Dillon MT, et al. Patient and procedure-specific risk factors for deep infection after primary shoulder arthroplasty. Clin Orthop Relat Res 2014;472:2809–15.
[22] Skedros JG, Keenan KE, Updike WS, Oliver MR. Failed reverse total shoulder arthroplasty caused by recurrent candida glabrata infection with prior serratia marcescens coinfection. Case Rep Infect Dis 2014;2014:142428.
[23] Clare DJ, Wirth MA, Groh GI, Rockwood CA. Shoulder arthrodesis. J Bone Joint Surg Am 2001;83:593–600.
[24] Coffey MJ, Ely EE, Crosby LA. Treatment of glenohumeral sepsis with a commercially produced antibiotic-impregnated cement spacer. J Shoulder Elbow Surg 2010;19:868–73.
[25] 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;93:2001–9.
[26] Li FL, Jiang CY, Lu Y, Zhu YM, Li X. Efficacy analysis of two-stage reverse total shoulder arthroplasty for treating postoperative deep infection after surgeries for proximal humeral fractures. Beijing Da Xue Xue Bao 2016;48:263–7.
[27] Lucas RM, Hsu JE, Whitney IJ, Wasserburger J, Matsen FA. Loose glenoid components in revision shoulder arthroplasty: is there an association with positive cultures? J Shoulder Elbow Surg 2016;25:1371–5.
[28] Seitz WH, Damacen H. Staged exchange arthroplasty for shoulder sepsis. J Arthroplasty 2002;17:36–40.
[29] Sperling JW, Kozak TK, Hanssen AD, Cofield RH. Infection after shoulder arthroplasty. Clin Orthop Relat Res 2001;382:206–16.
[30] Rispoli DM, Sperling JW, Athwal GS, Schleck CD, Cofield RH. Pain relief and functional results after resection arthroplasty of the shoulder. J Bone Joint Surg Br 2007;89:1184–7.
[31] Strickland JP, Sperling JW, Cofield RH. The results of two-stage re-implantation for infected shoulder replacement. J Bone Joint Surg Br 2008;90:460–5.
[32] Klouche S, Leonard P, Zeller V, Lhotellier L, Graff W, Leclerc P, et al. Infected total hip arthroplasty revision: one- or two-stage procedure?; 2012 [Accessed on 21th January 2019. Available from: https://www.em-consulte.com/en/article/702272].
[33] Lange J, Troelsen A, Thomsen RW, Søballe K. Chronic infections in hip arthroplasties: comparing risk of reinfection following one-stage and two-stage revision: a systematic review and meta-analysis. Clin Epidemiol 2012;4:57–73.
[34] Moher D, Liberati A, Tetzlaff J, Altman DG, Group PRISMA. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. PLoS Med 2009;6:e1000097.
[35] Slim K, Nini E, Forestier D, Kwiatkowski F, Panis Y, Chipponi J. Methodological index for non-randomized studies (minors): development and validation of a new instrument. ANZ J Surg 2003;73:712–6.
[36] Achermann Y, Sahin F, Schwyzer HK, Kolling C, Wüst J, Vogt M. Characteristics and outcome of 16 periprosthetic shoulder joint infections. Infection 2013;41:613–20.
[37] Assenmacher AT, Alentorn-Geli E, Dennison T, Baghdadi YMK, Cofield RH, Sánchez-Sotelo J, et al. Two-stage reimplantation for the treatment of deep infection after shoulder arthroplasty. J Shoulder Elbow Surg 2017;26:1978–83.
[38] 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;92:817–22.
[39] Buchalter DB, Mahure SA, Mollon B, Yu S, Kwon YW, Zuckerman JD. Two-stage revision for infected shoulder arthroplasty. J Shoulder Elbow Surg 2017;26:939–47.
[40] Cuff DJ, Virani NA, Levy J, Frankle MA, Derasari A, Hines B, et al. The treatment of deep shoulder infection and glenohumeral instability with debridement, reverse shoulder arthroplasty and postoperative antibiotics. J Bone Joint Surg Br 2008;90:336–42.
[41] Ghijselings S, Stuyck J, Debeer P. Surgical treatment algorithm for infected shoulder arthroplasty: a retrospective analysis of 17 cases. Acta Orthop Belg 2013;79:626–35.
[42] Hsu JE, Gorbaty JD, Whitney IJ, Matsen FA. Single-stage revision is effective for failed shoulder arthroplasty with positive cultures for propionibacterium. J Bone Joint Surg Am 2016;98:2047–51.
[43] 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;87:814–8.
[44] 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;24:1713–22.
[45] Jerosch J, Schneppenheim M. Management of infected shoulder replacement. Arch Orthop Trauma Surg 2003;123:209–14.
[46] 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;95:391–5.
[47] 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;42:867–74.
[48] Romanò CL, Borens O, Monti L, Meani E, Stuyck J. What treatment for periprosthetic shoulder infection? Results from a multicenter retrospective series. Int Orthop 2012;36:1011–7.
[49] Sabesan VJ, Ho JC, Kovacevic D, Iannotti JP. Two-stage reimplantation for treating prosthetic shoulder infections. Clin Orthop Relat Res 2011;469:2538–43.
[50] Sevelda F, Fink B. One-stage exchange of septic shoulder arthroplasty following a standardized treatment algorithm. J Shoulder Elbow Surg 2018;27:2175–82.
[51] Stone GP, Clark RE, O'Brien KC, Vaccaro L, Simon P, Lorenzetti AJ, et al. Surgical management of periprosthetic shoulder infections. J Shoulder Elbow Surg 2017;26:1222–9.
[52] 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.
[53] Duncan CP, Beauchamp C. A temporary antibiotic-loaded joint replacement system for management of complex infections involving the hip. Orthop Clin North Am 1993;24:751–9.
[54] Hackett DJ, Crosby LA. Evaluation and treatment of the infected shoulder arthroplasty. Bull Hosp Jt Dis 2013;71:88–93.
[55] Haddad FS, Muirhead-Allwood SK, Manktelow AR, Bacarese-Hamilton I. Two-stage uncemented revision hip arthroplasty for infection. J Bone Joint Surg Br 2000;82:689–94.
[56] Zeller V, Lhotellier L, Marmor S, Leclerc P, Krain A, Graff W, et al. One-stage exchange arthroplasty for chronic periprosthetic hip infection: results of a large prospective cohort study. J Bone Joint Surg Am 2014;96:e1.
[57] Ahsan ZS, Somerson JS, Matsen FA. Characterizing the Propionibacterium load in revision shoulder arthroplasty: a study of 137 culture-positive cases. J Bone Joint Surg Am 2017;99:150–4.
[58] Dodson CC, Craig EV, Cordasco FA, Dines DM, Dines JS, Dicarlo E, et al. Propionibacterium acnes infection after shoulder arthroplasty: a diagnostic challenge. J Shoulder Elbow Surg 2010;19:303–7.
[59] Grosso MJ, Frangiamore SJ, Yakubek G, Bauer TW, Iannotti JP, Ricchetti ET. Performance of implant sonication culture for the diagnosis of periprosthetic shoulder infection. J Shoulder Elbow Surg 2018;27:211–6.
[60] Horneff JG, Hsu JE, Voleti PB, O'Donnell J, Huffman GR. Propionibacterium acnes infection in shoulder arthroscopy patients with postoperative pain. J Shoulder Elbow Surg 2015;24:838–43.
[61] Hou C, Gupta A, Chen M, Matsen FA. How do revised shoulders that are culture positive for Propionibacterium differ from those that are not? J Shoulder Elbow Surg 2015;24:1427–32.
[62] Hsu JE, Bumgarner RE, Matsen FA. Propionibacterium in shoulder arthroplasty: what we think we know today. J Bone Joint Surg Am 2016;98:597–606.
[63] Kim SJ, Kim JH. Unexpected positive cultures including isolation of Propionibacterium acnes in revision shoulder arthroplasty. Chin Med J 2014;127:3975–9.
[64] Moroder P, Trampuz A, Scheibel M. Propionibacterium: we found it, now we have to deal with it: commentary on an article by Jason E. Hsu MD, et al.: "Single-Stage Revision Is Effective for Failed Shoulder Arthroplasty with Positive Cultures for Propionibacterium". J Bone Joint Surg Am 2016;98:e112.
[65] Padegimas EM, Lawrence C, Narzikul AC, Zmistowski BM, Abboud JA, Williams GR, et al. Future surgery after revision shoulder arthroplasty: the impact of unexpected positive cultures. J Shoulder Elbow Surg 2017;26:975–81.
[66] Tashjian RZ, Granger EK, Zhang Y. Utility of prerevision tissue biopsy sample to predict revision shoulder arthroplasty culture results in at-risk patients. J Shoulder Elbow Surg 2017;26:197–203.
[67] Fink B, Sevelda F. Periprosthetic joint infection of shoulder arthroplasties: diagnostic and treatment options. Biomed Res Int 2017;2017:4582756.
[68] 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.
[69] 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;25:1337–45.
[70] Garrigues G, Torrens C, Willems J, Belay E, Ledbetter L. What are the indications for one versus two stage revision in subacute or chronic shoulder PJI?; 2018. p. 288 [International Consensus Meeting on Prosthetic Joint Infection Shoulder Q & A].
[71] Tsukayama DT, Estrada R, Gustilo RB. Infection after total hip arthroplasty. A study of the treatment of one hundred and six infections. J Bone Joint Surg Am 1996;78:512–23.