Taylor & Francis
Taylor & Francis Group

Expert Review of Medical Devices

ISSN: 1743-4440 (Print) 1745-2422 (Online) Journal homepage: https://www.tandfonline.com/loi/ierd20

THE TREATMENT OF PERIPROSTHETIC JOINT INFECTION: SAFETY AND EFFICACY OF TWO STAGE VERSUS ONE STAGE EXCHANGE ARTHROPLASTY

Joseph R. Palmer, Tejbir S. Pannu, Jesus M. Villa, Jorge Manrique, Aldo M. Riesgo & Carlos A. Higuera

To cite this article: Joseph R. Palmer, Tejbir S. Pannu, Jesus M. Villa, Jorge Manrique, Aldo M. Riesgo & Carlos A. Higuera (2020): THE TREATMENT OF PERIPROSTHETIC JOINT INFECTION: SAFETY AND EFFICACY OF TWO STAGE VERSUS ONE STAGE EXCHANGE ARTHROPLASTY, Expert Review of Medical Devices, DOI: 10.1080/17434440.2020.1733971

To link to this article: https://doi.org/10.1080/17434440.2020.1733971

Accepted author version posted online: 26 Feb 2020.

Publisher: Taylor & Francis & Informa UK Limited, trading as Taylor & Francis Group

Journal: *Expert Review of Medical Devices*

DOI: 10.1080/17434440.2020.1733971

THE TREATMENT OF PERIPROSTHETIC JOINT INFECTION: SAFETY AND EFFICACY OF TWO STAGE VERSUS ONE STAGE EXCHANGE ARTHROPLASTY

Joseph R. Palmer, DO[1]
jpalmer.rg@gmail.com

Tejbir S. Pannu, MD, MS[1]
pannut@ccf.org

Jesus M. Villa, MD[1]
villaj2@ccf.org

Jorge Manrique, MD[1]
manriqj@ccf.org

Aldo M. Riesgo, MD[1]
riesgoa@ccf.org

Carlos A. Higuera, MD[1]
higuerc@ccf.org

1- Cleveland Clinic Florida, 2950 Cleveland Clinic Boulevard, Weston, FL- 33331

Corresponding Author

Carlos A. Higuera, MD

higuerc@ccf.org

Phone: (954) 659-5430

Cleveland Clinic Florida

2950 Cleveland Clinic Blvd.

Weston, Florida, 33331

Review

The treatment of periprosthetic joint infection: safety and efficacy of two stage versus one stage exchange arthroplasty

Joseph R. Palmer, Tejbir S. Pannu, Jesus M. Villa, Jorge Manrique, Aldo M. Riesgo, & Carlos A. Higuera*

Cleveland Clinic Florida, 2950 Cleveland Clinic Boulevard, Weston, FL- 33331, USA

***Corresponding Author:**

Carlos A. Higuera

higuerc@ccf.org

Phone: (954) 659-5430

Cleveland Clinic Florida

2950 Cleveland Clinic Blvd.

Weston, Florida, 33331

USA

ABSTRACT

INTRODUCTION: Periprosthetic joint infection (PJI) remains one of the most dreaded and challenging complications in adult reconstruction. While primary total joint arthroplasty is one of the most successful surgeries in medicine, revisions secondary to infections do not hold as well. As the number of primary procedures increases, so will infections. In North America, two-stage exchange arthroplasty is the standard of care for patients with PJI, especially when the presentation is greater than 4 weeks after the index procedure. However, it is not necessarily the best option for all patients particularly when compared to one-stage arthroplasty.

AREAS COVERED: The aim of this review is to analyze the indications, safety, and efficacy of two-stage exchange arthroplasty for the treatment of PJI and to compare the results reported 10 years ago with the ones of recent publications and those of one-stage arthroplasty.

EXPERT OPINION: Two-stage exchange arthroplasty is a safe and efficacious treatment particularly suited for recalcitrant infections, resistant organisms, and patients with certain host factors that makes it more difficult to eradicate infection. However, one-stage arthroplasty might be well suited as well for infections caused by susceptible organisms and patients with minimal or no comorbidities or those unable to undergo two surgeries.

KEYWORDS: Two-stage exchange arthroplasty, periprosthetic joint infection, total hip arthroplasty, total knee arthroplasty

ARTICLE HIGHLIGHTS:

- Definition of Two-Stage Exchange Arthoplasty
- Diagnosis of Periprosthetic Joint Infection in Revision
- Impact of type of implants used to treat PJI
- Antibiotic treatment and outcomes in two-stage revision
- Two-stage versus one-stage arthroplasty – clinical outcomes
- Clinical outcomes of two-stage revision: Now versus A decade ago

1. INTRODUCTION

Primary total hip arthroplasty (THA) and total knee arthroplasty (TKA) have provided reliable and satisfactory results for decades. Despite the fact that these surgeries have had an overwhelming success rate, periprosthetic joint infection (PJI) remains a devastating complication[1]. Overall, the reported incidence of PJI ranges between 0.5-3% [2–7] and in revision, rates are even higher[8,9] To date, the most common reason for a revision arthroplasty performed in cases with less than 2 years after the index procedure is PJI[10]. Furthermore, there is a substantial economic burden associated with PJIs. In the United States of America, the costs in 2009 were $566 million and it is estimated that by 2020 these will exceed $1.62 billion[1,11]. Using an incidence of PJI of 0.83% for THA and 1.52% for TKA (2010), it is projected that 11 million people will have either a TKA (7.4 million) or a THA (4 million) PJI in 2030[12].

As early as 1983, two-stage exchange arthroplasty has been the gold standard treatment in the United States for chronic PJI[13]. However, there is a lack of consensus in the literature as to what constitutes a success or a failure of this procedure, which makes it difficult to compare different management strategies and success rates[14]. Moreover, due to the comorbidity associated with two surgeries versus one, two-stage might not be the best option for infections caused by susceptible organisms or those patients with either minimal comorbidities or unable to withstand two surgeries. One-stage exchange might be the best answer in those scenarios. Also, two-stage revision has been demonstrated to be associated with five-year mortality of 26%.[15] Therefore, we performed a thorough literature review of two-stage exchange arthroplasty in the setting of periprosthetic joint infection. The aim was to analyze the safety and efficacy of two-stage exchange arthroplasty, to compare the clinical outcomes reported 10 years ago with ones recently reported, and to contrast those results with the ones of one-stage arthroplasty.

This paper was not funded and the authors have no relevant affiliations or financial involvement with any organization or entity with a financial interest in or financial conflict with the subject matter or materials discussed in the manuscript.

2. TWO-STAGE EXCHANGE ARTHROPLASTY

2.1. DEFINITION

Two-stage exchange arthroplasty represents two surgeries with a variable time interval between the two. The first stage involves the removal of implants, a thorough irrigation and debridement and insertion of either an articulating or a static antibiotic-eluding cement spacer. After confirmation of infection eradication, the second surgery involves removal of the cement spacer and the reimplantation of new components. Between the two stages, antibiotics are administered up until 2 weeks before the second stage when they are usually stopped (drug holiday) in order to monitor serologic markers such as erythrocyte sedimentation rate (ESR), C-reactive protein (CRP), and attempt to obtain synovial fluid with a joint aspiration to evaluate for markers of infection[16].

The overall success rate of two-stage exchange arthroplasty has been described from 75-100%[9,17–20] Indeed, while the literature is replete with investigations showing success rates of more than 90% in two-stage revision, the “true” success rate with no infection, no mechanical failure, or no reoperation is 65%[21].

2.2. DIAGNOSIS OF PERIPROSTHETIC JOINT INFECTION AND ERADICATION

A more consistent and accurate method to diagnose PJI is still warranted. The 2011 Musculoskeletal Infection Society (MSIS) criteria[22], slightly modified by the International Consensus Meeting on Infections (ICM) in 2013, is the most commonly used definition for the

diagnosis of PJI (Table 1). According to it, a definitive infection is diagnosed when there is a sinus tract communicating with the joint, or when an organism is isolated by culture from two or more separate tissue or fluid samples, or when 4 out of 6 additional specific minor criteria are present [23]. For PJI diagnosis in patients undergoing revision total joint arthroplasty, this definition has shown a sensitivity and specificity of 86.9% and 99.5%, respectively[24]. Recently, a new evidence-based 2018 ICM PJI definition has been proposed [24], which has been presented in Table 2.

In two-stage exchange arthroplasty, it is essential to confirm the eradication of infection before reimplantation. Unfortunately, the 2013 ICM definition (modified MSIS criteria) was not designed or validated for that purpose. Before reimplantation, and with success or failure determined at a minimum of one-year follow-up, it has demonstrated a limited value in screening for such eradication alone or when combined with frozen sections (sensitivity: 0-25%)[25,26]. Despite the poor screening capabilities, the combination of MSIS criteria and frozen sections are recommended at the time of reimplantation because of its high specificity[25,27].

In view of the absence of a “gold standard” for the diagnosis of PJI, many biomarkers have been tested. One of the most studied biomarkers, alpha-defensin, has not been reliable to confirm infection eradication before reimplantation, either alone or in combination with a preoperative aspiration[28,29]. Similarly, the reliability of other biomarkers such as serum D-dimer or fibrinogen is questionable to confirm the resolution of infection before reimplantation. For the same reason, a newly proposed 2018 PJI definition has been developed. It has demonstrated a higher sensitivity (97.7%) when compared to the previous modified MSIS definition (86.9%)[24]. However, its utility before reimplantation is yet to be determined. As of today, there is no single accurate definitive test or criteria for the diagnosis of PJI which serves as a

foundation for the surgical decision-making process in two-stage revision[30]. Different combinations of tests are usually used in clinical settings.

2.3. TYPES OF IMPLANTS USED IN PJI TREATMENT

2.3.1. Articulating Versus Static Spacers

Aside from providing a conduit for eluding high-dose antibiotics, the cement has the additional role of preventing soft tissue contractures and fibrosis[5]. The cement spacer may articulate or remain static. In a 2013 systematic review of the literature concerning TKA revision, articulating spacers demonstrated an increased range of motion (ROM), lower reinfection rates, and lower postoperative adverse events in addition to making the reimplantation surgery less complex and with lesser bone loss than did static spacers[31]. A recent meta-analysis resonated the same results showing that the articulating spacers provide better ROM and functional outcomes than the static ones with no significance difference in the rate of infection eradication, and pain scores[32]. Though not conclusive due to the absence of definitive randomized prospective studies, when controlling for case complexity such as patients with severe bone loss, articulating spacers still show improved infection eradication while providing greater range of motion and reducing the number of extensile incisions and soft tissue flaps[33]. The UCLA activity score, range of motion, and the Knee Society score (KSS) has been found significantly better in TKA articulating spacers when compared to static ones, but the evidence is also inconclusive[34–36]. On the other hand, Choi et al have shown that the satisfaction and range of motion after reimplantation were not significantly different when using either articulating or static spacers in two-stage arthroplasty[37]. The current recommendation is to use an articulating spacer whenever possible unless a static one is otherwise indicated, such as in severe bone loss, ligamentous insufficiency, or soft tissue compromise[38].

2.3.2. Intramedullary Dowel

Intramedullary (IM) dowels do not seem to provide significant benefit in infection eradication. In a case-series of 21 patients, McPherson et al. showed that 16 of 33 cultures from the medullary canal were positive[39]. Using this information, Zielinski et al. gathered retrospective data to determine if an intramedullary dowel could improve outcomes[40]. The study did not demonstrate any additional benefit with the use of an intramedullary dowel regardless of the patient's medical status or the type of spacer. Interestingly, the success rates were significantly greater in those patients with articulating spacers without IM dowels than in those with static spacers with IM dowels[40].

2.4. ANTIBIOTIC TREATMENT AND CLINICAL OUTCOMES

The standard protocol involves the administration of 4 to 6 weeks of pathogen-specific antibiotics during the interim period/interval[41]. This has been documented for decades, however, the definitive optimum duration remains unclear[42]. In those cases with organisms proven difficult to treat, a longer prosthesis-free interval (> 6 weeks) may be preferred[43]. Afterwards, a 2 week "antibiotic holiday" is usually employed in an attempt to confirm infection eradication and reduce the number of false negatives results[41]. Standard outpatient drug monitoring should be considered in most patients. The assistance of an infectious disease physician and the use of a multidisciplinary team has been shown to improve outcomes[43].

Concerning the inter-stage time period, some authors have proposed that short intervals of antibiotic therapy might be as effective as long term antibiotics in selected patients, which could possibly reduce adverse reactions and decrease resistance[44]. With the availability of an antibiofilm-active agent (such as rifampin), none of the short term cohorts (2-8 weeks) had recurrence of infection, regardless of CRP levels[43].

It seems that oral antibiotics after reimplantation significantly lower recurrent infections[45–47]. Following a positive intraoperative culture, the administration of 6 weeks of antibiotics (2 weeks intravenous and 4 weeks oral) significantly lowered the odds of reinfection[48]. Similarly, Siqueira et al. demonstrated that a suppressive dose of culture-specific antibiotics (minimum six months) significantly improved the 5-year infection free survival rate[49]. On the same lines, Frank et al. showed in a randomized controlled trial that the use of chronic oral antibiotics for at least 3 months after reimplantation decreases the chances of reinfection[45].

2.5.VALUE AND SAFETY OF TWO-STAGE EXCHANGE ARTHROPLASTY

2.5.1. Functional Outcomes

Since the outcomes are not standardized between the studies, it is difficult to compare techniques and functional assessment data. That being said, it has been demonstrated that hip function does improve significantly and for long after reimplantation. One particular study showed that the mean Harris hip score improved from 52 before the first stage to 70 points at 15 years of follow-up after surgery[50]. When compared to primary arthroplasty, revisions do not yield as high satisfaction rates or functional outcomes. The survivorship at 5 years has been around 90% and between 75 and 85% at 10 years[51–54]. Cohorts evaluated more than 10 years ago were assessed and the overall satisfaction rate was 71.7[55]. In comparison to old studies, the recent data concerning functional outcomes after two-stage exchange arthroplasty has shown 65 to 90% success rates[56–58]. Unfortunately, direct comparisons of old and more recent investigations are difficult due to inconsistent subjective and objective metrics between the studies.

2.5.2. Risk Factors for Complications

Infection is not the only reason for revision. In one long-term study, the incidence of revision for any reason other than infection was 6.8% at 1 year, 14.9% at 5 years, and 15.5% at 10 years[50].

Hip dislocation rates vary between 0 and 18%, with a higher risk in patients that were reimplanted with a megaprosthesis or had a greater trochanter deficiency as well as in women and those patients with previous dislocation[50,53,59,60]. The reoperation rates in those patients that have dislocated are as high as 58-79%, or 121 times more likely[50,59]. In patients that had dislocations, 58% of them dislocated more than once. The dislocation rates reported in previous studies performed more than 10 years ago are about 7.4%[61].

Obesity and smoking significantly increase rates of functional failures and significantly lower the 5-year survival of the implant[62], though abstinence from smoking alongside weight control may both provide beneficial[63].

The use of high dose antibiotic spacers can be a cause of adverse reactions such as nephrotoxicity. Patients should be monitored in the perioperative period, cases of acute kidney injury requiring hemodialysis have been reported[64,65]. Fortunately, the peak systemic antibiotic concentration found a few hours after surgery rapidly decreases within 1 to 2 days[66]. In the perioperative period, the surgeon should be cognizant of the systemic administration of antibiotics and the antibiotic eluding from the cement as the combination can put patients at risk for adverse reactions such as nephrotoxicity[64–66].

2.5.3. Recurrence of Infection

Ultimately, the main objective of the two-stage approach is to eradicate the infection. Unfortunately, several studies have reported persistent or new infection rates of 7 to 25%[16,20,25,51,67]. Positive identification of a bacteria during the antibiotic holiday or after reimplantation is defined as either persistent (same organism as original infection) or new (different organism than the initial infection). Tan et al. demonstrated that the organism causing subsequent failure differentiated from the initial organism in 71% of cases[54], which is in

agreement with other studies showing that 31% of recurrent infections were caused by the original organism[43,68].

It is important to note that in one large retrospective study, the overall incidence of positive cultures at the time of reimplantation was 15%[48]. The virulence of the infecting organism influences the outcomes, there are reports of failure rates 33% and higher after reimplantation arthroplasty in patients with culture-proven resistant bacteria[42,67,69,70]. Patients who have failed after a two-stage exchange arthroplasty or were suspected of having a persistent infection are more likely to be infected with more virulent organisms such as staphylococcal species and/or resistant organisms[71,72]. Other risks factors for persistent infection are gram negative bacteria (failure rate of 18%), carbapenem resistance, and polymicrobial infections[73].

Host factors are also predictive and correlated to the outcomes. In a cohort with multiple medical comorbidities, there was a 33% recurrence of infection whereas in the group without comorbidities there was a 0% rate of recurrence[74]. Female gender, heart disease, age greater than 70 years, and psychiatric history are also risk factors for increased odds of recurrent infection[5,71,75].

Spacer exchange is also a risk factor for reinfection, with rates about 20 to 40% which is significantly higher when compared to patients who only had a single spacer[72]. Interestingly, spacer exchange was associated with an increased risk of reinfection and decreased survivorship regardless of whether the exchange was done for mechanical failure or for suspicion of persistent infection[63,72,73,76]. Unfortunately, approximately 15 to 17% of people will undergo at least one spacer exchange, and aside from the reinfection risks, the spacer exchange has been shown to decrease the rate of attempted reimplantation from 80% to 70%[43,72].

In the most recent long-term study of two-stage exchange hip arthroplasty, the recurrence of infection was 9.8% at 1 year, 14.3% at 5 years, and 14.9% at 10 and 15 years, with a mean time to reinfection of 46 weeks[50]. The incidence of reinfection for two-stage exchange knee arthroplasty was 4.1% at 1 year, 9.5% at 2 years, 14.2% at 5 years, and 16.5% at 10 and 15 years[77]. These more recent studies[5,19,20,37,43,46,50,63,70,72,77–80] coincide with studies from the 1990s that demonstrated success rates that ranged between 61 and 92%[13,16,17,27,35,51–53,55,81] (Table 3). However, even though there are seemingly higher success rates in studies performed more than 10 years ago (80% vs. 90%), a direct comparison is difficult as the definitions of success or failure varies between the studies (Table 3).

2.5.4. Others

Concerning the time to reimplantation, mixed results have been reported[42,79–81]. It has been recently demonstrated that an increased time before reimplantation is not beneficial and in fact, patients are close to twice as likely to fail if the reimplantation is performed more than 26 weeks after the first stage when compared to those patients that had the reimplantation performed less than 26 weeks from the initial stage[70].

2.6. ONE-STAGE VERSUS TWO-STAGE EXCHANGE

Not long ago, the rates of reinfection after one-stage and two-stage exchange were found to be comparable with a trend towards better functional outcomes in one-stage in a systematic literature review[82]. Many studies have sought to compare these treatment methods. Through a sophisticated modeling (decision-tree) of the published literature, Bedair et al. gave a valuable insight into the prognosis of different types of treatments for early PJI, including, two-stage exchange arthroplasty[83]. Success was defined as the absence of any additional surgery for

treating infection, with or without long-term suppressive antibiotics at more than 2 years of follow-up. One-stage exchange (93%) had a comparable probability of success to two-stage exchange (92%), two-stage exchange following failed debridement (92%)[84,85], and to two-stage exchange following failed one-stage exchange (92%)[86]. Success was shown to depreciate on repeat two-stage exchange (60%)[87]. In their model, one-stage exchange showed the highest chance of maximum final health-related quality of life (HRQoL). Two-stage exchange led to maximum final HRQoL only when the success of one-stage exchange was below 66%. In short, two-stage exchange was shown to be relatively effective acknowledging additional morbidity caused to the patients on antibiotic spacers for a period from weeks to months.

In one of the most recent investigations, Haddad et al. compared one-stage with two-stage revision in 102 patients with chronic knee periprosthetic joint infection. According to their protocol, one-stage revision was indicated if there was a minimal/moderate bone loss, the absence of immunocompromising conditions, healthy soft tissues, and a known organism with known sensitivities for which appropriate antibiotics are available. While five two-stage patients developed reinfection, none of the one-stage patients had infection recurrence at a minimum follow-up of three years. Superior Knee Society scores were found in one-stage as compared to two-stage revisions. The authors recommended the indication of one-stage versus two-stage based on a strict selection criteria[86].

3. CONCLUSION

The successful treatment of PJI depends largely on multiple factors including the causing microorganisms, soft tissue and bone stock, host factors, prior treatments, and chronicity of infection. Undoubtedly, in the setting of chronic PJI, two-stage exchange arthroplasty is a safe and efficacious treatment. However, it might be best suited for recalcitrant infections, those

caused by resistant organisms, and patients with certain comorbidities that makes them less prone to eradicate infection. One-stage arthroplasty might be a better alternative when in presence of infections caused by susceptible organisms and in those patients with minimal comorbidities or those unable to undergo two surgeries.

4. EXPERT OPINION

Two-stage exchange arthroplasty is a safe and efficacious treatment for PJI. However, this procedure produces clinical outcomes comparable to the one-stage exchange. Two-stage exchange is associated with additional costs, cement spacer morbidity, second procedure morbidity, and bone loss. On the other hand, one-stage exchange represents a single procedure with overall shorter recovery. Despite the lack of concrete evidence, two-stage exchange arthroplasty is the present standard of care for patients with a PJI, especially when the presentation is greater than 4 weeks after the index procedure.

A timely diagnosis of PJI is imperative before considering treatment options. In the past decade, there has been a tremendous change in the diagnosis of PJI. The MSIS definition, later modified by ICM, is widely used as a standardized definition for PJI. While this definition has good sensitivity, it has limited utility in confirming the eradication of infection and deciding the right time of reimplantation in two-stage exchange. Numerous serum and synovial biomarkers of PJI (such as alpha-defensin) have been tested unsuccessfully in the setting of reimplantation, though they are still in development. In the clinical practice, the combination of multiple tests rather than a single test for the diagnosis of PJI is recommended.

Preventative strategies for infection should be implemented in the care of primary arthroplasty patients. These include patient optimization, preoperative skin preparation, the use of proper

prophylactic antibiotic prophylaxis, maintenance of adequate operative room environment, and intraoperative strategies and proper surgical closure.

Unfortunately, two-stage exchange is associated with high complication rates (dislocation and loosening). Improved surgical technique and the identification of the modifiable risk factors can potentially improve clinical outcomes. Even though it seems that the results (including complication rates) have improved when compared to those of studies performed more than ten years ago, the true success rate of this procedure has been questioned by many surgeons and in the international consensus meeting on PJI (2018).

The debate is still ongoing over the choice of the best procedure (two-stage versus one-stage). The decision depends on a set of host factors and infecting organism factors. In the presence of systemic host and local extremity (soft tissues and bone stock)-compromising factors, two-stage revision is the preferred treatment option. In our opinion, strict selection criteria should be used for the indication of two-stage versus one-stage exchange in the setting of PJI. Two-stage exchange should be avoided in elderly patients, in absence of sinus tract, and in presence of good soft tissue coverage. One-stage should be chosen in patients who are unable to tolerate multiple procedures, and in those who have favorable identified organism and favorable antibiotic profile.

With the rising numbers of primary arthroplasties, and eventual increase in the number of infections, the decision to proceed with either a two-stage or a one-stage revision is of paramount importance. There are no definitive established criteria to guide the choice of two-stage over one-stage or vice versa. The present evidence comes from retrospective studies with heterogeneous cohorts. At present, a prospective randomized clinical trial is ongoing to help set a clear paradigm in North America. While awaiting for final results from this trial, future research

should focus on improved prevention and host factor risk stratification in periprosthetic joint infection.

Funding

This paper was not funded.

Declaration of interest

The authors have no relevant affiliations or financial involvement with any organization or entity with a financial interest in or financial conflict with the subject matter or materials discussed in the manuscript. This includes employment, consultancies, honoraria, stock ownership or options, expert testimony, grants or patents received or pending, or royalties.

Reviewer disclosures

Peer reviewers on this manuscript have no relevant financial or other relationships to disclose.

5. REFERENCES

[1] Kurtz SM, Lau E, Watson H, Schmier JK, Parvizi J. Economic burden of periprosthetic joint infection in the united states. J Arthroplasty 2012;27:61–65.e1. doi:10.1016/j.arth.2012.02.022.

[2] Peersman G, Laskin R, Davis J, Peterson M. Infection in total knee replacement : a retrospective review of 6489 total knee replacements. Clin Orthop Relat Res 2001:15–23.

[3] Phillips JE, Crane TP, Noy M, Elliott TSJ, Grimer RJ. The incidence of deep prosthetic infections in a specialist orthopaedic hospital: A 15-Year Prospective Survey. J Bone Joint Surg Br 2006;88:943–8. doi:10.1302/0301-620X.88B7.17150.

[4] Salvati E, Della Valle A G, Masri B, Duncan C. The infected total hip arthroplasty. Instr Course Lect 2003;52:223–45.

[5] Triantafyllopoulos GK, Memtsoudis SG, Zhang W, Ma Y, Sculco TP, Poultsides LA. Periprosthetic Infection Recurrence After 2-Stage Exchange Arthroplasty : Failure or Fate ? J Arthroplasty 2017;32:526–31. doi:10.1016/j.arth.2016.08.002.

[6] Namba RS, Inacio MCS, Paxton EW. Risk Factors Associated with Deep Surgical Site Infections After Primary Total Knee Arthroplasty: An Analysis of 56,216 Knees. J Bone Jt Surg 2013;95:775–82.

[7] Kurtz SM, Ong KL, Lau E, Bozic KJ, Berry D, Parvizi J. Prosthetic Joint Infection Risk after TKA in the Medicare Population. Clin Orthop Relat Res 2010;468:52–6. doi:10.1007/s11999-009-1013-5.

[8] Maoz G, Phillips M, Bosco J, Slover J, Stachel A, Inneh I, et al. The Otto Aufranc Award: Modifiable versus Nonmodifiable Risk Factors for Infection After Hip Arthroplasty. Clin Orthop Relat Res 2015;473:453–9. doi:10.1007/s11999-014-3780-x.

[9] Mortazavi SMJ, Molligan J, Austin MS, Purtill JJ, Hozack WJ, Parvizi J. Failure

following revision total knee arthroplasty : infection is the major cause. Int Orthop 2011;35:1157–64. doi:10.1007/s00264-010-1134-1.

[10] Bozic K, Kurtz S, Lau E, Ong K, Vail T, Berry D. The epidemiology of revision total hip arthroplasty in the United States. J Bone Jt Surg - Am Vol 2009;91:128–33. doi:10.2106/JBJS.H.00155.

[11] Hellmann M, Mehta SD, Bishai DM, Mears SC, Zenilman JM. The Estimated Magnitude and Direct Hospital Costs of Prosthetic Joint Infections in the United States , 1997 to 2004. J Arthroplasty 2010;25:766–771.e1. doi:10.1016/j.arth.2009.05.025.

[12] Kremers HM, Larson DR, Crowson CS, Kremers WK, Washington RE, Steiner CA, et al. Prevalence of Total Hip and Knee Replacement in the United States. J Bone Jt Surg 2015;97:1386–97.

[13] Insall J, Thompson F, Brause B. Two-stage reimplantation for the salvage of infected total knee arthroplasty. J Bone Jt Surg - Am Vol 1983;65:1087–98.

[14] Diaz-Ledezma C, Higuera CA, Parvizi J. Success After Treatment of Periprosthetic Joint Infection : A Delphi-based International Multidisciplinary Consensus. Clin Orthop Relat Res 2013;471:2374–82. doi:10.1007/s11999-013-2866-1.

[15] Zmistowski B, Karam J, Durinka J, Casper D, Parvizi J. Periprosthetic Joint Infection Increases the Risk of One-Year Mortality. J Bone Jt Surgery-American Vol 2013;95:2177–84.

[16] Ghanem E, Azzam K, Seeley M, Joshi A, Parvizi J. Staged Revision for Knee Arthroplasty Infection: What Is the Role of Serologic Tests Before Reimplantation? Clin Orthop Relat Res 2009;467:1699–705. doi:10.1007/s11999-009-0742-9.

[17] Biring G, Kostamo T, Garbuz D, Masri B, Duncan C. Two-stage revision arthroplasty of

the hip for infection using an interim articulated Prostalac hip spacer: a 10- to 15-year follow-up study. J Bone Jt Surg - Br Vol 2009;91:1431–7.

[18] Bejon P, Berendt A, Atkins B, Green N, Parry H, Masters S, et al. Two-stage revision for prosthetic joint infection : predictors of outcome and the role of reimplantation microbiology. J Antimicrob Chemother 2010;65:569–75. doi:10.1093/jac/dkp469.

[19] Westrich GH, Walcott-sapp S, Bornstein LJ, Bostrom MP, Windsor RE, Brause BD. Modern Treatment of Infected Total Knee Arthroplasty With a 2-Stage Reimplantation Protocol. J Arthroplasty 2010;25:1015–1021.e2. doi:10.1016/j.arth.2009.07.017.

[20] Chen S, Hu C, Chen C, Chang Y, Hsieh P. Two-Stage Revision Arthroplasty for Periprosthetic Hip Infection : Mean Follow-Up of Ten Years. Biomed Res Int 2015. doi:10.1155/2015/345475.

[21] Parvizi J, Gehrke T, Chen A. Proceedings of the International Consensus on Periprosthetic Joint Infection. Bone Jt J 2013;95–B:1450–2. doi:10.1302/0301-620X.95B11.33135.

[22] Parvizi J, Zmistowski B, Berbari E, Bauer T, Springer B, Della Valle C, et al. New Definition for Periprosthetic Joint Infection: From the Workgroup of the Musculoskeletal Infection Society. Clin Orthop Relat Res 2011;469:2992–4. doi:10.1007/s11999-016-5088-5.

[23] Parvizi J, Gehrke T. Definition of Periprosthetic Joint Infection. J Arthroplasty 2014;29:1331. doi:10.1016/j.arth.2014.03.009.

[24] Parvizi J, Tan T, Goswami K, Higuera C, Della Valle C, Chen A, et al. The 2018 Definition of Periprosthetic Hip and Knee Infection: An Evidence-Based and Validated Criteria. J Arthroplasty 2018;33:1309–1314.e2. doi:10.1016/j.arth.2018.02.078.

[25] George J, Kwiecien G, Klika AK, Ramanathan D, Bauer TW, Barsoum WK, et al. Are

Frozen Sections and MSIS Criteria Reliable at the Time of Reimplantation of Two-stage Revision Arthroplasty ? Clin Orthop Relat Res 2016;474:1619–26. doi:10.1007/s11999-015-4673-3.

[26] Frangiamore SJ, Siqueira MBP, Saleh A, Daly T, Higuera CA, Barsoum WK. Synovial Cytokines and the MSIS Criteria Are Not Useful for Determining Infection Resolution After Periprosthetic Joint Infection Explantation. Clin Orthop Relat Res 2016;474:1630–9. doi:10.1007/s11999-016-4710-x.

[27] Bori G, Soriano A, García S, Mallofré C, Riba J, Mensa J. Usefulness of Histological Analysis for Predicting the Presence of Microorganisms at the Time of Reimplantation After Hip Resection Arthroplasty for the Treatment of Infection. J Bone Jt Surg 2007;89:1232–7. doi:10.2106/JBJS.F.00741.

[28] Kanwar S, Al-mansoori AA, Chand MR, Villa JM, Suarez JC, Patel PD. What Is the Optimal Criteria to Use for Detecting Periprosthetic Joint Infections Before Total Joint Arthroplasty ? J Arthroplasty 2018;33:S201–4. doi:10.1016/j.arth.2018.02.072.

[29] Samuel LT, Sultan AA, Kheir M, Villa J, Patel P, Parvizi J, et al. Positive Alpha-defensin at Reimplantation of a Two-stage Revision Arthroplasty Is Not Associated with Infection at 1 Year. Clin Orthop Relat Res 2019;477:1615–21. doi:10.1097/CORR.0000000000000620.

[30] Kusuma SK, Ward J, Jacofsky M, Sporer SM, Della Valle CJ. What is the Role of Serological Testing Between Stages of Two-stage Reconstruction of the Infected Prosthetic Knee? Clin Orthop Relat Res 2011;469:1002–8. doi:10.1007/s11999-010-1619-7.

[31] Voleti P, Baldwin K, Lee G. Use of static or articulating spacers for infection following

total knee arthroplasty: a systematic literature review. J Bone Jt Surg - Am Vol 2013;95:1594–9. doi:10.2106/JBJS.L.01461.

[32] Ding H, Yao J, Chang W, Liu F. Comparison of the efficacy of static versus articular spacers in two-stage revision surgery for the treatment of infection following total knee arthroplasty : a meta- analysis. J Orthop Surg Res 2017;12:1–9. doi:10.1186/s13018-017-0644-6.

[33] Guild III G, Wu B, Scuderi G. Articulating Vs . Static Antibiotic Impregnated Spacers in Revision Total Knee Arthroplasty for Sepsis. A Systematic Review. J Arthroplasty 2014;29:558–63. doi:10.1016/j.arth.2013.08.013.

[34] Jaekel DJ, Day JS, Klein GR, Levine H, Parvizi J, Kurtz SM. Do Dynamic Cement-on-Cement Knee Spacers Provide Better Function and Activity During Two-stage Exchange ? Clin Orthop Relat Res 2012;470:2599–604. doi:10.1007/s11999-012-2332-5.

[35] Emerson RJ, Muncie M, Tarbox T, Higgins L. Comparison of a static with a mobile spacer in total knee infection . Clin Orthop Relat Res 2002:132–8. doi:10.1097/00003086-200211000-00023.

[36] Fehring T, Odum S, Calton T, Mason J. Articulating versus static spacers in revision total knee arthroplasty for sepsis . The Ranawat Award . Clin Orthop Relat Res 2000;380:9–16. doi:10.1097/00003086-200011000-00003.

[37] Choi H, Malchau H, Bedair H. Are Prosthetic Spacers Safe to Use in 2-Stage Treatment for Infected Total Knee Arthroplasty ? J Arthroplasty 2012;27:1474–1479.e1. doi:10.1016/j.arth.2012.02.023.

[38] Abdel MP, Barreira P, Battenberg A, Berry DJ, Blevins K, Font-vizcarra L, et al. Hip and Knee Section , Treatment , Two-Stage Exchange Spacer-Related : Proceedings of

International Consensus on Orthopedic Infections. J Arthroplasty 2019;34:S427–38. doi:10.1016/j.arth.2018.09.027.

[39] McPherson E, Patzakis M, Gross J, Holtom P, Song M, LD. D. Infected total knee arthroplasty . Two-stage reimplantation with a gastrocnemius rotational flap. Clin Infect Dis 1997;341:73–81.

[40] Zielinski MR, Ziemba-davis M, Warth LC, Keyes BJ, Meneghini RM. Do Antibiotic Intramedullary Dowels Assist in Eradicating Infection in Two-Stage Resection for Septic Total Knee Arthroplasty ? J Arthroplasty 2019:1–5. doi:10.1016/j.arth.2019.05.022.

[41] Osmon DR, Berbari EF, Berendt AR, Lew D, Zimmerli W, Steckelberg JM, et al. Diagnosis and Management of Prosthetic Joint Infection: Clinical Practice Guidelines by the Infectious Diseases Society of America. Clin Infect Dis 2013;56:1–25. doi:10.1093/cid/cis803.

[42] Babis GC, Sakellariou VI, Pantos PG, Sasalos GG, Stavropoulos NA. Two-Stage Revision Protocol in Multidrug Resistant Periprosthetic Infection Following Total Hip Arthroplasty Using a Long Interval Between Stages. J Arthroplasty 2015;30:1602–6. doi:10.1016/j.arth.2015.04.004.

[43] Akgün D, Müller M, Perka C, Winkler T. High cure rate of periprosthetic hip joint infection with multidisciplinary team approach using standardized two-stage exchange. J Orthop Surg Res 2019;14:1–8.

[44] Yen H, Hsieh RW, Huang C, Hsu T, Yeh T, Chen Y, et al. Short-course versus long-course antibiotics in prosthetic joint infections : a systematic review and meta-analysis of one randomized controlled trial plus nine observational studies. J Antimicrob Chemother 2019;74:2507–16. doi:10.1093/jac/dkz166.

[45] Frank JM, Mse EK, Ms MM, Segreti J, Hansen E, Hartman C, et al. The Mark Coventry , MD , Award : Oral Antibiotics Reduce Reinfection After Two-Stage Exchange : A Multicenter , Randomized Controlled Trial. Clin Orthop Relat Res 2017;475:56–61. doi:10.1007/s11999-016-4890-4.

[46] Johnson AJ, Zywiel MG, Jones LC, Delanois RE, Stroh DA, Mont MA. Reduced re-infection rates with postoperative oral antibiotics after two-stage revision hip arthroplasty. BMC Musculoskelet Disord 2013;14:1. doi:10.1186/1471-2474-14-123.

[47] Zywiel MG, Johnson AJ, Stroh DA, Martin J, Marker DR, Mont MA. Prophylactic oral antibiotics reduce reinfection rates following two-stage revision total knee arthroplasty. Int Orthop 2011;35:37–42. doi:10.1007/s00264-010-0992-x.

[48] Xu C, Tan TL, Chen J. Positive Culture During Reimplantation Increases the Risk of Reinfection in Two-Stage Exchange Arthroplasty Despite Administrating Prolonged Antibiotics : A Retrospective Cohort Study and Meta-Analysis. J Arthroplasty 2019;34:1025–31. doi:10.1016/j.arth.2019.01.039.

[49] Siqueira MBP, Saleh A, Klika AK, Rourke CO, Schmitt S, Higuera CA, et al. Chronic Suppression of Periprosthetic Joint Infections with Oral Antibiotics Increases Infection-Free Survivorship. J Bone Jt Surg 2015;97:1220–32.

[50] Petis SM, Abdel MP, Perry KI, Mabry TM, Hanssen AD, Berry DJ. Long-Term Results of a 2-Stage Exchange Protocol for Periprosthetic Joint Infection Following Total Hip Arthroplasty in 164 Hips. J Bone Jt Surg 2019;101:74–84.

[51] Haleem AA, Berry DJ, Hanssen AD. Mid-Term to Long-Term Followup of Two-stage Reimplantation for Infected Total Knee Arthroplasty. Clin Orthop Relat Res 2004:35–9. doi:10.1097/01.blo.0000147713.64235.73.

[52] Goldman R, Scuderi G, Insall J. 2-stage reimplantation for infected total knee replacement. Clin Orthop Relat Res 1996:118–24. doi:10.1097/00003086-199610000-00016.

[53] Sanchez-sotelo J, Berry DJ, Hanssen AD, Cabanela ME. Midterm to Long-term Followup of Staged Reimplantation for Infected Hip Arthroplasty. Clin Orthop Relat Res 2009:219–24. doi:10.1007/s11999-008-0480-4.

[54] Tan TL, Goswami K, Fillingham YA, Shohat N, Rondon AJ, Parvizi J. Defining Treatment Success After 2-Stage Exchange Arthroplasty for Periprosthetic Joint Infection. J Arthroplasty 2018;33:3541–6. doi:10.1016/j.arth.2018.06.015.

[55] Meek RMD, Masri BA, Dunlop D, Garbuz DS, Greidanus N V., Mcgraw R, et al. Patient Satisfaction and Functional Status After Treatment of Infection at the Site of a Total Knee Arthroplasty with Use of the PROSTALAC Articulating Spacer. J Bone Jt Surg 2003;85–A:1888–92.

[56] Wang Q, Goswami K, Kuo F, Xu C, Tan TL, Parvizi J. Two-Stage Exchange Arthroplasty for Periprosthetic Joint Infection : The Rate and Reason for the Attrition After the First Stage. J Arthroplasty 2019:1–8. doi:10.1016/j.arth.2019.06.021.

[57] Kunutsor SK, Whitehouse MR, Lenguerrand E, Blom AW, Beswick AD. Re-Infection Outcomes Following One- And Two-Stage Surgical Revision of Infected Knee Prosthesis : A Systematic Review and Meta- Analysis. PLoS One 2016;11:1–15. doi:10.1371/journal.pone.0151537.

[58] Lange J, Troelsen A, Thomsen RW, Soballe 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 2012:57–73.

[59] Mcalister IP, Perry KI, Mara KC, Hanssen AD, Berry DJ, Abdel MP. Two-Stage Revision of Total Hip Arthroplasty for Infection Is Associated with a High Rate of Dislocation. J Bone Jt Surg 2019;101:322–9.

[60] Whittaker J, Warren R, Jones R, Gregson P. Is prolonged systemic antibiotic treatment essential in two-stage revision hip replacement for chronic Gram-positive infection? J Bone Jt Surg - Br Vol 2009;91:44–51. doi:10.1302/0301-620X.91B1.20930.

[61] Alberton GM, High WA, Morrey BF. Dislocation After Revision Total Hip Arthroplasty: An Analysis of Risk Factors and Treatment Options. J Bone Jt Surg 2002;84:1788–92.

[62] Ahmad SS, Orlik L, Ahmad SJS, Albers CE, Siebenrock KA, Klenke FM. Orthopaedics & Traumatology : Surgery & Research Obesity and smoking predict the results of two-stage exchange in septic revision hip arthroplasty : A cohort study. Orthop Traumatol Surg Res 2019;105:467–71. doi:10.1016/j.otsr.2019.01.006.

[63] George J, Miller EM, Curtis GL, Klika AK, Barsoum WK, Mont MA, et al. Success of Two-Stage Reimplantation in Patients Requiring an Interim Spacer Exchange. J Arthroplasty 2018;33:S228–32. doi:10.1016/j.arth.2018.03.038.

[64] Edelstein A, Okroj K, Rogers T, Della Valle C, Sporer S. Systemic Absorption of Antibiotics From Antibiotic-Loaded Cement Spacers for the Treatment of Periprosthetic Joint Infection. J Arthroplasty 2018;33:835–9. doi:10.1016/j.arth.2017.09.043.

[65] Salim S, Everitt J, Schwartz A, Agarwal M, Castenada J, Fülöp T, et al. Aminoglycoside impregnated cement spacer precipitating acute kidney injury requiring hemodialysis. Semin Dial 2018;31:88–93. doi:10.1111/sdi.12639.

[66] Sterling G, Crawford S, Potte Jh, Koerbin G, Crawford R. The pharmacokinetics of Simplex-tobramycin bone cement. J Bone Jt Surg - Br Vol 2003;85:646–9.

[67] Kurd MF, Ghanem E, Steinbrecher J, Parvizi J. Two-stage Exchange Knee Arthroplasty: Does Resistance of the Infecting Organism Influence the Outcome ? Clin Orthop Relat Res 2010;468:2060–6. doi:10.1007/s11999-010-1296-6.

[68] Zmistowski B, Tetreault MW, Alijanipour P, Chen AF, Valle CJ Della, Parvizi J. Recurrent Periprosthetic Joint Infection Persistent or New Infection ? J Arthroplasty 2013;28:1486–9. doi:10.1016/j.arth.2013.02.021.

[69] Lim S, Park J, Moon Y, Park Y. Treatment of Periprosthetic Hip Infection Caused by Resistant Microorganisms Using 2-Stage Reimplantation Protocol. J Arthroplasty 2009;24:1264–9. doi:10.1016/j.arth.2009.05.012.

[70] Rezaie AA, Goswami K, Shohat N, Tokarski AT, White AE, Parvizi J. Time to Reimplantation : Waiting Longer Confers No Added Bene fi t. J Arthroplasty 2018;33:1850–4. doi:10.1016/j.arth.2018.01.073.

[71] Fehring K, Abdel M, Ollivier M, Mabry T, Hanssen A. Repeat Two-Stage Exchange Arthroplasty for Periprosthetic Knee Infection Is Dependent on Host Grade. J Bone Jt Surg 2017;99:19–24.

[72] Tan TL, Goswami K, Kheir MM, Xu C, Wang Q, Parvizi J. Surgical Treatment of Chronic Periprosthetic Joint Infection : Fate of Spacer Exchanges. J Arthroplasty 2019;34:2085–2090.e1. doi:10.1016/j.arth.2019.04.016.

[73] Tan TL, Kheir MM, Tan DD, Parvizi J. Polymicrobial Periprosthetic Joint Infections: Outcome of Treatment and Identification of Risk Factors. J Bone Jt Surg 2016;98:2082–8.

[74] Tigani D, Trisolino G, Fosco M, Ayad R Ben, Costigliola P. Two-stage reimplantation for periprosthetic knee infection : Influence of host health status and infecting microorganism. Knee 2019;20:9–18. doi:10.1016/j.knee.2012.06.004.

[75] Leta TH, Lygre SHL, Schrama JC, Hallan G, Gjertsen J-E, Dale H, et al. Outcome of Revision Surgery for Infection After Total Knee Arthroplasty. JBJS Rev 2019;7:1–10.

[76] Kheir M, Tan T, George J, Higuera C, Maltenfort M, Parvizi J. Development and Evaluation of a Prognostic Calculator for the Surgical Treatment of Periprosthetic Joint Infection. J Arthroplasty 2018;33:2986–92. doi:10.1016/j.arth.2018.04.034.

[77] Petis SM, Perry KI, Mabry TM, Hanssen AD, Berry DJ, Abdel MP. Two-Stage Exchange Protocol for Periprosthetic Joint Infection Following Total Knee Arthroplasty in 245 Knees without Prior Treatment for Infection. J Bone Jt Surg 2019;101:239–49.

[78] Ford AN, Holzmeister AM, Rees HW, Belich PD. Characterization of Outcomes of 2-Stage Exchange Arthroplasty in the Treatment of Prosthetic Joint Infections. J Arthroplasty 2018;33:S224–7. doi:10.1016/j.arth.2018.02.043.

[79] Sabry FY, Buller L, Ahmed S, Klika AK, Barsoum WK. Preoperative Prediction of Failure Following Two-Stage Revision for Knee Prosthetic Joint Infections. J Arthroplasty 2014;29:115–21. doi:10.1016/j.arth.2013.04.016.

[80] Kubista B, Hartzler RU, Wood CM, Osmon DR, Hanssen AD, Lewallen DG. Reinfection after two-stage revision for periprosthetic infection of total knee arthroplasty. Int Orthop 2012;36:65–71. doi:10.1007/s00264-011-1267-x.

[81] Lieberman J, Callaway G, Salvati E, Pellicci P, Brause B. Treatment of the infected total hip arthroplasty with a two-stage reimplantation protocol. Clin Orthop Relat Res 1994:205–12.

[82] Leonard MA HAC, Liddle AD, Burke O, Murray DW, Pandit H. Single- or Two-stage Revision for Infected Total Hip Arthroplasty ? A Systematic Review of the Literature. Clin Orthop Relat Res 2014;472:1036–42. doi:10.1007/s11999-013-3294-y.

[83] Bedair H, Ting N, Bozic KJ, Valle CJ Della, Sporer SM. Treatment of Early Postoperative Infections after THA: A Decision Analysis. Clin Orthop Relat Res 2011;469:3477–85. doi:10.1007/s11999-011-2119-0.

[84] Tsukayama DT, Estrada R, Gustilo RB. Infection after Total Hip Arthroplasty: A Study of the Treatment of One Hundred and Six Infections. J Bone Jt Surg 1996;78–A:512–23.

[85] Winkler H, Stoiber A, Kaudela K, Winter F, Menschik F. One stage uncemented revision of infected total hip replacement using cancellous allograft bone impregnated with antibiotics. J Bone Joint Surg Br 2008;90–B:1580–4. doi:10.1302/0301-620X.90B12.20742.

[86] Haddad FS, Sukeik M, Alazzawi S. Is Single-stage Revision According to a Strict Protocol Effective in Treatment of Chronic Knee Arthroplasty Infections ? Clin Orthop Relat Res 2015;473:8–14. doi:10.1007/s11999-014-3721-8.

[87] Pagnano M, Trousdale R, Hanssen A. Outcome after reinfection following reimplantation hip arthroplasty. Clin Orthop Relat Res 1997;May:192–204. doi:10.1097/00003086-199705000-00026.

Reference annotations

*Tan TL, Goswami K, Kheir MM, Xu C, Wang Q, Parvizi J. Surgical Treatment of Chronic Periprosthetic Joint Infection : Fate of Spacer Exchanges. J Arthroplasty 2019;34:2085–2090.e1. doi:10.1016/j.arth.2019.04.016.

This paper demonstrated the association of spacer exchange with lower survivorship in 2-stage exchange arthroplasty.

*Parvizi J, Gehrke T, Chen A. Proceedings of the International Consensus on Periprosthetic Joint Infection. Bone Jt J 2013;95–B:1450–2. doi:10.1302/0301-620X.95B11.33135.
This investigation marked the establishment of the consensus-based 2013 ICM PJI definition.

**Parvizi J, Tan TL, Goswami K, Higuera C, Valle C Della, Chen AF, et al. The 2018 Definition of Periprosthetic Hip and Knee Infection : An Evidence-Based and Validated Criteria. J Arthroplasty 2019;33:1309–1314.e2. doi:10.1016/j.arth.2018.02.078.
This manuscript proposes and investigates an evidence-based new 2018 ICM PJI definition.

** Leonard MA HAC, Liddle AD, Burke O, Murray DW, Pandit H. Single- or Two-stage Revision for Infected Total Hip Arthroplasty ? A Systematic Review of the Literature. Clin Orthop Relat Res 2014;472:1036–42. doi:10.1007/s11999-013-3294-y.
This is an extensive systematic review comparing one-stage and two-stage exchange for total hip arthroplasty.

Table 1. 2013 International Consensus Meeting (ICM) modified Musculoskeletal Infection Society (MSIS) criteria for the diagnosis of periprosthetic joint infection (PJI).

Periprosthetic joint infection is diagnosed when 1 of the major criteria or 3 out of the 5 minor criteria exist.
Major criteria
- There is a sinus tract communicating with the joint; **OR** - Two positive periprosthetic cultures with phenotypically identical organisms; **OR**
Minor criteria
- Having three of the following five minor criteria: a. Elevated serum C-reactive protein (CRP): >10 mg/L AND erythrocyte sedimentation rate (ESR): >30mm/h b. Elevated synovial fluid white blood cell (WBC) count: >3,000 cells/µl OR ++ change on leukocyte esterase test strip c. Elevated synovial fluid polymorphonuclear neutrophil percentage (PMN%): >80% d. Positive histological analysis of periprosthetic tissue e. A single positive culture

C-reactive protein (CRP); Erythrocyte sedimentation rate (ESR)

Table 2. 2018 International Consensus Meeting (ICM) criteria for the diagnosis of periprosthetic joint infection (PJI).

Major criteria		
1. Two positive cultures of the same organism; **OR**	**Decision**	
2. Sinus tract with evidence of communication to the joint or visualization of the joint prosthesis; **OR**	PJI	
Minor criteria		
A. Preoperative diagnosis	**Score**	**Decision**
Serum		≥6: PJI 2-5: Possibly PJI[a] 0-1: No PJI
1. Increase in CRP (>1mg/dL) **OR** D-Dimer (>860 ng/mL)	2	
2. Increase in ESR (>30 mm/h)	1	
Synovial		
1. Increase in Synovial WBC count (>3,000 cells/μL) or LE (++)	3	
2. Positive Alpha-defensin (signal-to-cut-off ratio >1)	3	
3. Increase in Synovial PMN% (>80%)	2	
4. Increase in Synovial CRP (>6.9 mg/L)	1	
B. Intraoperative diagnosis[a]		≥6: PJI 4-5: Inconclusive PJI ≤3: No PJI
1. Preoperative score	-	
2. Positive histology	3	
3. Positive purulence	3	
4. Single positive culture	2	

C-reactive protein (CRP); Erythrocyte sedimentation rate (ESR); Positive (+); Polymorphonuclear neutrophils (PMN); Periprosthetic Joint Infection (PJI)

[a] For cases with inconclusive minor criteria, operative criteria may be included to refute or confirm diagnosis of PJI.

Table 3. Success and infection rates associated with two-stage exchange arthroplasty: Results reported recently versus those results reported ten years ago.

Author, year	Years collected	Patient population	Joint	Success rate (%)	Reinfection rate (%)	Mean follow-up (years)
Outcomes of recent publications						
Petis, 2019	1991-2006	164	Hip	85	15	12
Petis, 2019	1991-2006	245	Knees	83	17	14
Tan, 2019	2000-2017	533	Both	75.1	24.9	5.1
Akgun, 2019	2013-2015	84	Hip	89.3	10.7	2.8
George, 2018	2001-2014	347	Both	77	23	6.3
Ford, 2018	2004-2014	66	Both	72.7	27.3	3.3
Aali Rezaie, 2018	2000-2016	282	Both	87.7	22.3	1
Triantafyllopoulos, 2017	1998-2014	548	Both	91.2	8.76	11
Tan, 2016	1999-2013	259	Both	75.3	24.7	4
Chen, 2015	2001-2010	157	Hip	91.7	8.3	9.7
Sabry, 2014	1996-2010	291	Knee	71.8	28.2	3.3
Choi, 2012	2000-2009	47	Knee	68	32	3.6
Kubista, 2012	1998-2006	368	Knee	84.2	15.8	N/A
Westrich, 2010	1998-2006	75	Knee	73.3	26.7	4.4
Average		235		80	20	5.5
Outcomes reported more than 10 years ago						
Insall, 1983	N/A	11	Knee	100	0	2.8
Lieberman, 1994	N/A	32	Hip	91	9	3.3
Goldman, 1996	1977-1983	64	Knee	91	9	7.5
Emerson, 2002	1986-1999	48	Knee	91.7	8.3	5.6
Meek, 2003	1997-1999	48	Knee	96	4	3.3
Haleem, 2004	1989-1994	96	Knee	91	9	7.2
Bori, 2007	2002-2006	21	Hip	66.7	33.3	N/A
Sanchez-Sotelo, 2008	1988-1998	169	Hip	93	7	7
Ghanem, 2009	1999-2006	109	Knee	79	21	2.8
Biring, 2009	N/A	99	Hip	89	11	12
Average		60		90	10	5.2

N/A=Not available