Management strategies for prosthetic joint infection: long-term infection control rates, overall survival rates, functional and quality of life outcomes

Theofilos Karachalios¹,²
George A. Komnos¹

DAIR (debridement, antibiotics, and implant retention), one-stage and two-stage revision surgery are the most common management strategies for prosthetic joint infection (PJI) management. Our knowledge concerning their efficacy is based on short to medium-term low-quality studies. Most studies report infection recurrence rates or infection-free time intervals. However, long-term survival rates of the infection-free joints, functional and quality of life outcome data are of paramount importance. DAIR, one-stage and two-stage revision strategies are not unique surgical techniques, presenting several variables. Infection control rates for the above strategies vary from 75% to 90%, but comparisons are difficult because different indications and patient selection criteria are used in each strategy. Recent outcome data show that DAIR and one-stage revision in selected patients (based on host, bacteriological, soft tissue and type of infection criteria) may present improved functional and quality of life outcomes and reduced costs for health systems as compared to those of two-stage revision. It is expected that health system administrators and providers will apply pressure on surgeons and departments towards the wider use of DAIR and one-stage revision strategies. It is the orthopaedic surgeon’s responsibility to conduct quality studies in order to fully clarify the indications and outcomes of the different revision strategies.

Keywords: functional recovery; PJI clinical outcomes; quality of life

Cite this article: EFORT Open Rev 2021;6:727-734. DOI: 10.1302/2058-5241.6.210008

Introduction

Prosthetic joint infection (PJI) represents one of the most devastating complications in joint arthroplasty, with a prevalence of 1–2% after primary joint replacement and 4% after revision.¹⁻² It is also the most common reason for early revision (Fig. 1).³ PJI has a severe impact on morbidity and mortality rates, and quality of life is severely affected in these patients.⁴ Diagnosis of PJI is sometimes difficult and any delays can lead to multiple surgeries, lower survival rates and impairment of function and quality of life.⁵ Optimal treatment of PJI remains controversial. The most widely used management strategies are one-stage and two-stage revisions.⁶ DAIR (debridement, antibiotics, and implant retention) is also indicated for early or acute infections. Other strategies, with specific indications, which are less popular and produce poorer results, include antibiotic suppression, arthrodesis, and even amputation.⁶ The cost of management of PJI patients is quite high when compared to primary arthroplasties.⁷⁻⁸ As a result, economic health providers and health administrators have recently focused on the PJI problem, asking for detailed comparative clinical outcome data and the introduction of multi-disciplinary management approaches.⁸⁻¹⁰ In order to throw light on this topic, a detailed review of medium and long-term outcomes of the various PJI management strategies is presented. We also focus on the few studies which report on survival rates of infection-free joints and on functional and quality of life outcomes.

Fig. 1 Intra-operative picture of early steps of one-stage revision surgery for infected total hip arthroplasty (THA)
Observations and arguments based on literature search

Initially, four quality (systematic reviews) studies were identified which have compared one-stage to two-stage revision for both total hip and total knee arthroplasties.11–14 A common observation in these reviews has been that the quality of the studies included was poor and the strength of the conclusions weak. Subsequently, a thorough literature review (PubMed) of PJI management related outcome studies was performed. Selection criteria for the published articles to be evaluated were studies reporting on survival rates with re-infection as an end point, on survival rates of infection-free joints and on functional and quality of life outcomes. Exclusion criteria included follow-up of less than six years, case reports or reviews, studies not referring to aseptic loosening and non-English language. A total of 53 studies were identified and evaluated and, of those, 11 which fulfilled the above criteria were reviewed (Table 1). Due to several methodological problems MOOSE and PRISMA guidelines and Cochrane methodology were not applied and thus data presentation from these papers is not considered as a systematic review. Most of the rest studies were retrospective, with a small number of patients and a short to medium-term (2–8 years) follow-up evaluation period. Prospective randomized studies were not found. Additionally, the following confounding factors of outcome evaluation were identified: (1) Indications for DAIR and one and two-stage revision strategies are different, and the few comparative studies found are restricted by patient selection bias. (2) PJI treatment outcomes depend on various factors,3,15 and for technical reasons no studies are able to stratify patients (in reasonable numbers) according to these factors (Fig. 2, Fig. 3). Management strategies (especially one-stage and two-stage revisions) are not uniform and

Table 1. Outcomes of prosthetic joint infection (PJI) management strategies. Medium to long-term outcome studies presenting survival rates of the infection-free joints are shown

| Author                  | Year | Strategy                        | THAs | TKAs | Type of study                           | Survival rates with infection as an end point | Survival rates with aseptic loosening as an end point | Follow-up |
|-------------------------|------|---------------------------------|------|------|----------------------------------------|----------------------------------------------|------------------------------------------------------|-----------|
| Grammatopoulos et al27  | 2017 | DAIR                            | 122  |      | Retrospective consecutive case series   | 85%                                          | 77% for aseptic loosening                           | 18 yrs    |
| Sendi et al13           | 2017 | DAIR                            | 46   |      | Retrospective case series               | 90%                                          | 100% for aseptic loosening                           | 2–10 yrs  |
| Claus et al20          | 2020 | DAIR                            | 57   |      | Retrospective double cohort             | 93%                                          | 76% for any reason                                  | 6 yrs     |
| Zahar et al12          | 2019 | One-stage cemented fixation     | 85   |      | Retrospective cohort study              | 94%                                          | 75.9% for any reason                                | 10 yrs    |
| Wolff et al13          | 2021 | One-stage cemented fixation     | 26   |      | Retrospective cohort study              | 96.2%                                        | 76.9% for any reason                                | 10–24 yrs |
| Born et al34           | 2016 | One-stage cementless fixation   | 28   |      | Retrospective cohort study              | 96%                                          | 97% for aseptic loosening                            | 7 yrs     |
| Petis et al36          | 2019 | Two-stage mixed cemented/less   | 164  |      | Retrospective cohort study              | 85%                                          | 96.7% for aseptic loosening                           | 10–15 yrs |
| Born et al34           | 2016 | Two-stage cementless fixation   | 53   |      | Retrospective cohort study              | 94%                                          | 97% for aseptic loosening                            | 7 yrs     |
| Hoberg et al43         | 2016 | Two-stage revision              | 45   |      | Retrospective double cohort             | 4.4% reinfection rate                         | 82.7% for any reason                                | 10 yrs    |
| Bongers et al37        | 2020 | Two-stage revision              | 113  |      | Retrospective cohort study              | 85.7%                                        | 92% for aseptic loosening                            | 8 yrs     |
| Petis et al38          | 2019 | Two-stage revision              | 245  |      | Retrospective cohort study              | 83%                                          | 93% for aseptic loosening                            | 15 yrs    |

Note. DAIR, debridement, antibiotics, and implant retention; THA, total hip arthroplasty; TKA, total knee arthroplasty.

Fig. 2 Factors affecting the outcome of different prosthetic joint infection (PJI) treatment strategies are shown.
present several controlled and uncontrolled variables (Fig. 3, Fig. 4). Furthermore, the majority of studies report on either infection recurrence rates or infection-free time intervals, and present survival curves with revision for re-infection as an end point, and when reporting functional outcomes the conventional Harris Hip Score (HHS) and Knee Society Score (KSS) scales are mostly used.\textsuperscript{11–14,16,17} It has to be stressed that Jafari et al have shown that 25 (22%) of their 112 septic total hip arthroplasty (THA) revisions failed due to reinfection and 21 (19%) failed due to other reasons.\textsuperscript{18} Therefore, medium to long-term outcome data related to infection-free reconstructed joints are also needed (Table 1) and appropriate functional and quality of life outcome data are also of major importance.

**Outcomes of the DAIR procedure**

The DAIR procedure, with or without exchange of modular parts, is technically less demanding, and can therefore be considered as an option for the treatment of early infections.\textsuperscript{19,20} DAIR is indicated in early post-operative infections (less than four weeks from index operation), late haematogenous PJIs with short duration of symptoms (less than four weeks), good soft tissue envelope, known gram-positive pathogen with good antibiotic sensitivity and minimally inhibitory bacterial concentrations, stable implant and when host grade is not compromised.\textsuperscript{21,22} Higher success rates (above 80%) are expected when strict patient selection criteria are introduced.\textsuperscript{21,22} In a systematic review and meta-analysis, Kunutsor et al reported an overall 61.4% pooled estimate for rate of infection control for DAIR.\textsuperscript{23} Tözün et al also reported that DAIR infection control rates for infected total knee arthroplasty (TKA) vary across different studies, ranging from 16% to 82%.\textsuperscript{24} Exchange of mobile components also improves outcomes.\textsuperscript{25} Sendi et al reported a 90% survival rate for aseptic loosening in 46 THAs treated with DAIR at 8–10 year follow-up.\textsuperscript{26} Grammatopoulos et al reported an 85% infection irradiation rate and 77% survival rate for aseptic loosening at 18-year follow-up in 122 THAs treated with DAIR (Oxford database).\textsuperscript{27} Finally, Clauss et al analysed implant survival rates after successful treatment of infection in 57 THAs treated with DAIR.\textsuperscript{28} A 16% revision rate for any reason and 9% for aseptic loosening of any component were reported at six-year follow-up, with both figures being comparable to those of the control group.\textsuperscript{28}
Outcomes of one-stage revision

One-stage revision can be a viable and efficient strategy when appropriate indications are fulfilled. It is indicated in acute (less than four weeks from index operation), rather than chronic post-operative infections, good soft tissue envelope, known gram-positive pathogen with good antibiotic sensitivity and minimally inhibitory bacterial concentrations, and when host grade is not compromised. Extensive debridement with removal of all devitalized tissue material during the operation is one of the most important factors affecting the final outcome. Local and systemic antibiotic delivery tailored to the known pathologic organism is an integral part of the technique, but the duration of systematic antibiotic administration is still being discussed. Early to medium-term infection control, for properly indicated single-stage revision, varies from 77–100% across a variety of studies. The Hamburg Group reported a minimum 10-year infection-free survival of 94% and surgery-free survival of 75.9% in 85 hips undergoing one-stage revision with cemented implants. Born et al reported a seven-year infection-free survival of 96% and an aseptic-loosening-free survival of 97% in 28 hips undergoing one-stage revision with cementless implants.

Outcomes of two-stage revision

Two-stage revision is still considered the gold standard of treatment. It is indicated more in chronic infections (more than four weeks from index operation), late hematogenous PJJ with long duration of symptoms (more than four weeks), when the host grade and local tissue are compromised, in gram-negative, methicillin-resistant staphylococcus and fungal infections and when the organism is unknown. It involves resection of the prosthesis with or without placement of an antibiotic spacer, antibiotic treatment, following the patient’s response to treatment and re-implantation of a new prosthesis. Numerous studies have reported that two-stage revision with the use of antibiotic spacers can result in infection eradication rates at the level of 80–95%, and the use of articulating spacers improves functional outcomes. Petis et al reported an infection recurrence of 15%, an incidence of aseptic revisions of 3.3% and an incidence of all revisions of 16%, at 10 to 15 years, in 164 patients with infected THAs treated with two-stage revision using mixed cemented.
and cementless implants (Mayo Clinic Group).³⁶ Born et al reported a seven-year infection-free survival of 94% and an aseptic-loosening-free survival of 97% in 53 infected THAs undergoing two-stage revision with cementless implants.³⁴ There is no evidence to suggest that the type of fixation at the time of re-implantation affects infection recurrence rates, but it may affect long-term implant survival. Bongers et al reported, at eight-year follow-up, 17% re-revision surgery, 11% due to infection and 6% due to aseptic loosening, in 113 infected TKAs treated with two-stage revision.³⁷ Petis et al reported 17% infection recurrence, 7% incidence of aseptic revisions and 8.4% incidence of all revisions at 15 years in 245 patients with infected TKAs treated with two-stage revision (Mayo Clinic Group).³⁸

Comparative studies

In an early systematic review and meta-analysis evaluating 36 infected THA studies, Lange et al reported a 13.1% re-infection rate in one-stage and 10.4% in the two-stage cohorts.¹¹ Kunutsor evaluated 44 cohorts across four continents on behalf of the Global Infection Orthopaedic Management Collaboration, and reported re-infection rates per 1000 person-years of follow-up (mean four years) as 16.8% for a one-stage and 32.3% for a two-stage revision strategy.³⁹ Engesæter et al evaluated patients from the Norwegian Arthroplasty Registry and found a 1.4 times increased risk of re-revision for any reason and two times increased risk of re-revision for infection in a one-stage as compared to a two-stage infected THA revision strategy.⁴⁰ Svensson et al evaluated patients from the Swedish arthroplasty registry and found a similar risk for re-revision for infection (0.7) and aseptic loosening (1.2) when they compared patients who had undergone one-stage and two-stage revision for infected THA.⁴¹ Pangaud et al, in a systematic review, analysed 14 articles with one-stage (687 patients) and 19 articles with two-stage (1086 patients) revision for infected TKA, and reported an average eradication rate of 87.1% in the one-stage and 84.8% in the two-stage procedure.⁴² Although one-stage revision can provide better results than the two-stage revision procedure, one should keep in mind that one-stage revision is indicated in selected patients (based on host, bacteriological, soft tissue and type of infection criteria).

Hoberg et al evaluated 37 hips which underwent revision surgery for aseptic loosening, and 45 hips which underwent revision for septic loosening, using cementless implants, and found a similar survival rate of 85.6% and 82.7%, respectively, at 10 years with revision for aseptic loosening as an end point.⁴³ Konrads et al compared patients who underwent two-stage revision for septic TKA (52 patients) and one-stage aseptic total knee revision arthroplasty (83 patients).⁴⁴ Early outcomes were similar in both groups in terms of KSS, Oxford Knee and SF-36 scores.

To the best of our knowledge, no studies comparing DAIR to either one-stage or to two-stage revision have been ever published.

Functional and quality of life outcomes

In 2010, Oussedik et al were the first to show significant improvements in mean HHS and visual analogue scores for satisfaction at five years, in one-stage septic THA revisions as compared to two-stage revisions.⁴⁵ In a systematic review comparing one-stage to two-stage revision for infected THA, a trend towards better functional outcomes was shown in the one-stage group.¹² One-stage revision strategy for infected THA showed improved functional outcome, reduced cost and improved survival rates in the most recent studies in a systematic review and meta-analysis.⁴⁶ Two-stage revision for infected TKA using articulating spacers in comparison to static ones resulted in better infection eradication rates as well as better functional outcomes and improved quality of life.⁴⁷ Grammatopoulos et al showed that DAIR for infected THA is better than a two-stage revision regarding functional outcome.⁴⁸ Barros et al also showed that DAIR for infected THA and TKA is safe, effective and has satisfactory functional results when compared to two-stage revision.⁴⁹ Abolins et al showed that infected THA and TKA treated with DAIR had a similar improvement in quality of life (according to the SF-12 survey) from pre to 12 months post arthroplasty as compared to arthroplasty patients without infection.⁵⁰ Poulsen et al suggested that patients who undergo two-stage revision after infected THA have lower scores on health-related quality of life than the general population.⁵¹ Palmer et al showed that, at 18 months, patients undergoing two-stage revision with an excised THA or a cement spacer described severe mobility restrictions which affected all aspects of their lives, while those undergoing one-stage revision, or two-stage revision with an articulating spacer were more mobile and independent, with some limitations.⁵² Participants in all treatment groups also expressed considerable emotional resilience during recovery from revision.⁵² Rietbergen et al, in a systematic review of 12 papers describing two-stage revision for infected THA, assessed health-related quality of life (HRQoL).⁵³ Patients presented substantially lower physical component HRQoL scores, but mental scores were comparable to the general population.⁵³ Kildow et al, in a review paper, observed the increasing popularity of one-stage revision for infected total joint arthroplasty (TJA) as compared to two-stage revision based on recent literature demonstrating comparable success rates, lower morbidity rates, potential functional benefits to the patients, and a decreased economic burden on the healthcare system.⁵⁴
Conclusions

Despite current advances in orthopaedic adult reconstruction practices, PJI still represents one of the most devastating complications in implant surgery. Concerning management outcomes, our knowledge is based on poor-quality studies. DAIR, one-stage and two-stage revision surgery strategies have different indications and are not uniform techniques, with the relevant importance of their various parameters and steps remaining to be evaluated. Recent studies show that all three strategies show variable satisfactory infection control rates; however, a considerable number of infection-free joints fail for other reasons. This has also been confirmed in the Swedish Joint Registry, in which lower survival rates in revision THA for infection were observed. Orthopaedic surgeons should pay attention to performing high-quality infected joint revision surgery as in revision cases for aseptic loosening. Recent data show that DAIR and one-stage revision result in superior functional and quality of life outcomes and reduced costs for health systems. However, one should keep in mind that the outcomes of the DAIR procedure vary and that both DAIR and one-stage procedures are indicated for selected patients only.

REFERENCES

1. Kurtz S, Ong K, Lau E, Mowat F, Halpern M. Projections of primary and revision hip and knee arthroplasty in the United States from 2005 to 2030. J Bone Joint Surg [Am] 2007;89-A:780–785.
2. Ong KL, Kurtz SM, Lau E, Bozic KJ, Berry DJ, Parvizi J. Prosthetic joint infection risk after total hip arthroplasty in the Medicare population. J Arthroplasty 2009;24:105–109.
3. Karachalios T, Komnos G, Koutalos A. Total hip arthroplasty: survival and modes of failure. EFORT Open Rev 2018;3:232–239.
4. Kurtz SM, Lau EC, Son MS, Chang ET, Zimmerli W, Parvizi J. Are we winning or losing the battle with periprosthetic joint infection? Trends in periprosthetic joint infection and mortality risk for the Medicare population. J Arthroplasty 2018;33:3238–3245.
5. Izakovicova P, Borens O, Trampuz A. Periprosthetic joint infection: current concepts and outlook. EFORT Open Rev 2019;4:482–494.
6. Karachalios T, Koutalos A, Komnos G. Management strategies for infected total hip arthroplasty: a critical appreciation of problems and techniques. Hip Int 2014;24:544–547.
7. Tansey R, Mirza Y, Sukeik M, Shaeth M, Haddad FS. Definition of periprosthetic hip and knee joint infections and the economic burden. Open Orthop 2016;10:662–668.
8. Akindolire J, Morales MW, Marsh JD, Howard JL, Lanting BA, Vasarhelyi EM. The economic impact of periprosthetic infection in total hip arthroplasty. Can J Surg 2020;63:E52–E56.
9. Parisi TJ, Konopka JF, Bedair HS. What is the long-term economic societal effect of periprosthetic infections after THA? A Markov analysis. Clin Orthop Relat Res 2017;475:1891–1900.
10. Poultsides LA, Liaropoulos LL, Malizos KN. The socioeconomic impact of musculoskeletal infections. J Bone Joint Surg [Am] 2010;92-A:103.
11. 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. BMJ Open 2012;2:437–53.
12. Leonard 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;472:1036–1042.
13. Nagra NS, Hamilton TW, Ganatra S, Murray DW, Pandit H. One-stage versus two-stage exchange arthroplasty for infected total knee arthroplasty: a systematic review. Knee Surg Sports Traumatol Arthros 2016;24:3106–3114.
14. Pangaud C, Ollivier M, Argenson JN. Outcome of single-stage versus two-stage exchange for revision knee arthroplasty for chronic periprosthetic infection. EFORT Open Rev 2019;4:495–502.
15. McPherson EJ, Woodson C, Holtom P, Roidis N, Shufelt C, Patzakis M. Periprosthetic total hip infection: outcomes using a staging system. Clin Orthop Relat Res 2002;403:8–15.
16. Senthil S, Munro JT, Pittro RP. Infection in total hip replacement: meta-analysis. Int Orthop 2011;35:253–260.
17. Slulitila PA, Onativia JJ, Buttaro MA, et al. State-of-the-art diagnosis and surgical treatment of acute peri-prosthetic joint infection following primary total hip arthroplasty. EFORT Open Rev 2018;3:434–441.
18. Jafari SM, Coyle C, Mortazavi SM, Sharkey PF, Parvizi J. Revision hip arthroplasty: infection is the most common cause of failure. Clin Orthop Relat Res 2010;468:2046–2051.
19. Byren I, Bejon P, Atkins BL, et al. One hundred and twelve infected arthroplasties treated with ‘DAIR’ (debridement, antibiotics and implant retention): antibiotic duration and outcome. J Antimicrob Chemother 2009;63:1264–1271.

20. Toms AD, Davidson D, Massi BA, Duncan CP. The management of peri-prosthetic infection in total joint arthroplasty. J Bone Joint Surg [Br] 2006;88-B:149–155.

21. Manrique J, Kommos GA, Tan TL, Sedgh S, Shohat N, Parvizi J. Outcomes of superficial and deep irrigation and debridement in total hip and knee arthroplasty. J Arthroplasty 2019;34:1452–1457.

22. Qu GX, Zhang CH, Yan SG, Cai XZ. Debridement, antibiotics, and implant retention for periprosthetic knee infections: a pooling analysis of 1266 cases. J Orthop Surg Res 2019;14:358.

23. Kunutsor SK, Beswick AD, Whitehouse MR, Wylde V, Blom AW. Debridement, antibiotics and implant retention for peri-prosthetic joint infections: a systematic review and meta-analysis of treatment outcomes. J Infect 2017;77:479–488.

24. Tözün IR, Ozden VE, Dikmen G, Karayükg K. Trends in the treatment of infected knee arthroplasty. EFORT Open Rev 2020;5:672–683.

25. Svensson K, Rolfson O, Naucier E, et al. Exchange of modular components improves success of debridement, antibiotics, and implant retention: an observational study of 575 patients with infection after primary total hip arthroplasty. JBJS Open Access 2020;2:e00110.

26. Sendi P, Lötscher PO, Kessler B, Graber P, Zimmerli W, Clauss M. Debridement and implant retention in the management of hip periprosthetic joint infection: outcomes following guided and rapid treatment at a single centre. J Bone Joint Surg [Br] 2017;99-B:330–336.

27. Grammatopoulos G, Kendrick B, McNally M, et al. Outcome following debridement, antibiotics, and implant retention in hip periprosthetic joint infection: an 18-year experience. J Arthroplasty 2017;32:2248–2255.

28. Clauss M, Hunkeler C, Manzioni I, Sendi P. Debridement, antibiotics and implant retention for hip periprosthetic joint infection: analysis of implant survival after cure of infection. J Bone Joint Surg [Br] 2020;5:35–42.

29. Lum ZC, Holland CT, Meehan JP. Systematic review of single stage revision for prosthetic joint infection. World J Orthop 2020;11:550–572.

30. Thakrar RR, Horrati S, Kayani B, Haddad FS. Indications for a single-stage exchange arthroplasty for chronic prosthetic joint infection: a systematic review. J Bone Joint Surg [Br] 2019;101-B:879–824.

31. Vaghjmour KM, Chisari E, Khan WS. Single-stage revision surgery in infected total knee arthroplasty: a PRISMA systematic review. J Clin Med 2019;8:1741–1753.

32. Zahar A, Klaber I, Gerken AM, et al. Ten-year results following one-stage septic hip exchange in the management of periprosthetic joint infection. J Arthroplasty 2019;34:1221–1226.

33. Wolff M, Laussmann C, Gehrke T, Zahar A, Ohlmeier M, Citak M. Results at 10–24 years after single-stage revision arthroplasty of infected total hip arthroplasty in patients under 45 years of age. Hip Int 2021;31:237–241.

34. Born P, Ichmann T, Zimmerli W, et al. Eradication of infection, survival, and radiological results of unrevised revision stems in infected total hip arthroplasties. Acta Orthop 2016;87:637–643.

35. Charette RS, Melnic CM. Two-stage revision arthroplasty for the treatment of prosthetic joint infection. Curr Rev Musculoskelet Med 2018;11:332–340.

36. 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 Joint Surg [Am] 2019;101-A:74–84.

37. Bongers J, Jacobs AME, Smulders K, van Helmond  GT, Goosen JHM. Reinfection and re-revision rates of 113 two-stage revisions in infected TKA. J Bone Jt Infect 2020;5:137–144.

38. 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 Joint Surg [Am] 2019;101-A:239–249.

39. Kunutsor SK, Whitehouse MR, Blom AW, et al; Global Infection Orthopaedic Management Collaboration. One- and two-stage surgical revision of peri-prosthetic joint infection of the hip: a pooled individual participant data analysis of 44 cohort studies. Eur J Epidemiol 2018;33:935–946.

40. Engesæter LB, Dale H, Schrama JC, Hallan G, Lie SA. Surgical procedures in the treatment of 784 infected THAs reported to the Norwegian Arthroplasty Register. Acta Orthop 2019;82:510–537.

41. Svensson K, Rolfson O, Kährholm J, Mohaddes M. Similar risk of re-revision in patients after one or two stage surgical revision of infected total hip arthroplasty: an analysis of revisions in the Swedish Hip Arthroplasty Register 1979–2019. J Clin Med 2019;8:485.

42. Penna O, Ollivier M, Argenson JN. Outcome of single-stage versus two-stage exchange for revision knee arthroplasty for chronic periprosthetic infection. EFORT Open Rev 2019;4:495–502.

43. Hoberg M, Konrads C, Engelien J, et al. Similar outcomes between two-stage revisions for infection and aseptic hip revisions. Int Orthop 2016;40:459–464.

44. Konrads C, Franz A, Hoberg M, Rudert M. Similar outcomes of two-stage revisions for infection and one-stage revisions for aseptic revisions of knee endoprostheses. J Knee Surg 2019;32:897–899.

45. Ousseski SI, Dodd MB, Haddad FS. Outcomes of revision total hip replacement for infection after grading according to a standard protocol. J Bone Joint Surg [Br] 2019;102-B:1222–1226.

46. Kunutsor SK, Whitehouse MR, Blom AW, Beswick AD; INFORM Team. Re-infection outcomes following one- and two-stage surgical revision of infected hip prosthesis: a systematic review and meta-analysis. PLoS One 2015;10:e0131966.

47. Preobrazhensky PM, Bozhkova SA, Kazemirsky AV, Tikhilov RM, Kulaba TA, Kornilov NN. Functional outcome of two-stage reimplantation in patients with periprosthetic joint infection after primary total knee arthroplasty. Int Orthop 2019;43:2503–2509.

48. Grammatopoulos G, Bolduc ME, Atkins BL, et al. Functional outcome of debridement, antibiotics and implant retention in periprosthetic joint infection involving the hip: a case-control study. J Bone Joint Surg [Br] 2017;99-B:614–622.

49. Barros LH, Barbosa TA, Esteves J, Abreu M, Soares D, Sousa R. Early debridement, antibiotics and implant retention (DAIR) in patients with suspected acute infection after hip or knee arthroplasty: safe, effective and without negative functional impact. J Bone Jt Infect 2019;4:300–305.

50. Abolts C, Dowsey M, Peel T, Lim WK, Choong P. Good quality of life outcomes after treatment of prosthetic joint infection with debridement and prosthesis retention. J Orthop Res 2016;34:898–902.
53. Rietbergen L, Kuiper JW, Walgrave S, Hak L, Colen S. Quality of life after staged revision for infected total hip arthroplasty: a systematic review. Hip Int 2016;26:311–318.

54. Kildow BJ, Della-Valle CJ, Springer BD. Single vs 2-stage revision for the treatment of periprosthetic joint infection. J Arthroplasty 2020;35:S24–S30.

55. Swedish Hip Arthroplasty Register annual report 2018. https://registercentrum.blob.core.windows.net/shpr/Annual-report-2014-BJv-q8pil.pdf (date last accessed 4 January 2021).