

- [5] Ibrahim MS, Raja S, Khan MA, Haddad FS. A multidisciplinary team approach to two-stage revision for the infected hip replacement. *Bone Joint J.* 2014;96-B:1312-1318. doi:10.1302/0301-620X.96B10.32875.
- [6] Gomez MM, Tan TL, Manrique J, Deirmengian GK, Parvizi J. The fate of spacers in the treatment of periprosthetic joint infection. *J Bone Joint Surg.* 2015;97:1495-1502. doi:10.2106/jbjs.n.00958.
- [7] Oussedik SIS, Dodd MB, Haddad FS. Outcomes of revision total hip replacement for infection after grading according to a standard protocol. *J Bone Joint Surg Br.* 2010;92-B:1222-1226. doi:10.1302/0301-620X.92B9.23663.
- [8] Buchholz HW, Elson RA, Engelbrecht E, Lodenkämper H, Röttger J, Siegel A. Management of deep infection of total hip replacement. *J Bone Joint Surg Br.* 1981;63-B:342-353.
- [9] Jackson WO, Schmalzried TP. Limited role of direct exchange arthroplasty in the treatment of infected total hip replacements. *Clin Orthop Relat Res.* 2000;381:101-105.
- [10] Zahar A, Kendoff DO, Klatt TO, Gehrke TA. Can good infection control be obtained in one-stage exchange of the infected TKA to a rotating hinge design? 10-year results. *Clin Orthop Relat Res.* 2016;474:81-87. doi:10.1007/s11999-015-4408-5.
- [11] George DA, Konan S, Haddad FS. Single-stage hip and knee exchange for periprosthetic joint infection. *J Arthroplasty.* 2015;30:2264-2270. doi:10.1016/j.arth.2015.05.047.
- [12] Tibrewal S, Malagelada F, Jeyaseelan L, Posch F, Scott G. Single-stage revision for the infected total knee replacement: Results from a single centre. *Bone Joint J.* 2014;96 B:759-764. doi:10.1302/0301-620X.96B6.33086.
- [13] Lange J, Troelsen A, Solgaard S, Otte KS, Jensen NK, Søballe K, et al. Cementless one-stage revision in chronic periprosthetic hip joint infection. Ninety-one percent infection free survival in 56 patients at minimum 2-year follow-up. *J Arthroplasty.* 2017. doi:10.1016/j.arth.2017.11.024.
- [14] Castellani L, Daneman N, Mubareka S, Jenkinson R. Factors associated with choice and success of one- versus two-stage revision arthroplasty for infected hip and knee prostheses. *HSS J.* 2017;13:224-231.
- [15] Bori G, Navarro G, Morata L, Fernández-Valencia JA, Soriano A, Gallart X. Preliminary results after changing from two-stage to one-stage revision arthroplasty protocol using cementless arthroplasty for chronic infected hip replacements. *J Arthroplasty.* 2018;33:527-532 [16] Göksan SB, Freeman MA. One-stage reimplantation for infected total knee arthroplasty. *J Bone Joint Surg Br.* 1992;74:78-82.
- [17] Wolf M, Clar H, Friesenbichler J, Schwantzer G, Bernhardt G, Gruber G, et al. Prosthetic joint infection following total hip replacement: results of one-stage versus two-stage exchange. *Int Orthop.* 2014;38:1363-1368. doi:10.1007/s00264-014-2309-y.
- [18] Jenny JY, Lengert R, Diesinger Y, Gaudias J, Boeri C, Kempf JF. Routine one-stage exchange for chronic infection after total hip replacement. *Int Orthop.* 2014;38:2477-2481. doi:10.1007/s00264-014-2466-z.
- [19] Jenny JY, Barbe B, Gaudias J, Boeri C, Argenson JN. High infection control rate and function after routine one-stage exchange for chronically infected TKA. *Clin Orthop Relat Res.* 2013;471:238-243. doi:10.1007/s11999-012-2480-7.
- [20] Raut VV, Siney PD, Wroblewski BM. One-stage revision of infected total hip replacements with discharging sinuses. *J Bone Joint Surg Br.* 1994;76:721-724.



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### QUESTION 3: Is there a role for single-stage exchange arthroplasty in acute periprosthetic joint infections (PJIs) of cementless total hip arthroplasties (THAs)?

**RECOMMENDATION:** Yes. Single-stage exchange arthroplasty can be employed to treat patients with acute PJIs of cementless THAs.

**LEVEL OF EVIDENCE:** Moderate

**DELEGATE VOTE:** Agree: 89%, Disagree: 7%, Abstain: 4% (Super Majority, Strong Consensus)

#### RATIONALE

Debridement and retention of implants, single-stage revision and two-stage revision are all described treatment options in the management of PJIs [1]. Since the 1970s, when Buchholz introduced the concept of single-stage revision arthroplasty as an alternative to two-stage revision for PJIs, multiple authors have published similar encouraging results on single-stage revision for infected THA [2-4]. With shorter total hospital stays, less risk of perioperative complications and lower overall healthcare costs, single-stage revision has been considered an attractive treatment option for the devastating complication of hip PJIs [5].

Single-stage exchange arthroplasty for acute PJIs in cementless THAs is a unique situation with pros and cons. On the one hand, the acetabular and femoral components may not have had time to fully osseointegrate. This not only facilitates extraction of implants without incurring significant bone loss, but also allows for the use of “primary type” components for the reimplantation portion of the procedure [6]. On the other hand, one of the primary tenets and keys to the success of Buchholz’s original one-stage exchange arthroplasty was the preoperative identification of the infecting organism to help guide the choice of microbe-directed antibiotic cement during the reimplantation of components. In the case of standard “cementless” revision arthroplasty, this is not feasible. As a result, more recently, some surgeons have employed adjunct techniques to achieve similar supra-therapeutic concentrations of antibiotics into the periarticular space during a cementless single-stage revision hip arthroplasty [7,8].

The literature on the topic of one-stage exchange arthroplasty is quite heterogenous, specifically in regards to inclusion criteria,

infecting organisms, surgical technique and length of follow-up. Therefore, reaching a definitive conclusion for the role of one-stage exchange arthroplasty in the treatment of acute PJIs of cementless THAs is challenged by the limited available data [6-10]. We identified three clinical studies which reviewed their results of cementless one-stage exchange arthroplasty for acute PJIs of THAs. In a multicenter, retrospective series of 27 patients, Hansen et al. demonstrated a 70% success rate of component retention at a minimum follow-up of 27 months and a mean follow-up of 50 months. However, 4 of the 19 patients required further operative debridement to obtain control of the infection, indicating that an isolated one-stage exchange arthroplasty was successful in only 15 of the 27 patients (56%) [6]. In a study by Wolf et al., which included 24 acute THA infections treated with one-stage cementless exchange arthroplasty, eradication of the infection was achieved in 75% (18/24) at two years mean follow-up [9]. Unfortunately, the study with the longest mean follow-up of 8.6 years only included 6 patients who had undergone one-stage cementless exchange. While they reported no cases of reinfection, they had very strict inclusion criteria for deciding on the one-stage exchange (e.g., negligible pus, healthy patients, no evidence of acute systemic infection) and their infecting organism profile only included *Staphylococcus epidermidis* and one case of *Clostridium*, so the applicability of their results must be interpreted in this light. Similarly, the one study that investigated cementless one-stage exchange arthroplasty for chronic PJIs of THAs by Yoo et al. reported component retention in 10 of 12 patients (83%) at a mean follow-up of 7.2 years, but excluded all patients with PJIs caused by methicillin-resistant *Staphylococcus aureus* (MRSA) [11].

As mentioned earlier, one of the keys to the historical success of the one-stage exchange arthroplasty was the ability to deliver supra-therapeutic concentrations of antibiotics into the periarticular space, which is not feasible in standard cementless two-stage revision arthroplasty. Two authors have developed novel techniques to provide adjunct antimicrobials locally in the hopes of improving their infection-free survival.

Using antibiotic-impregnated allograft bone during single-stage revision for PJI, Winkler et al. showed no recurrence of infection in 34 of 37 (92%) of their patients at a mean follow-up of 4.4 years. They calculated supra-therapeutic concentrations of vancomycin in the drainage fluid up to three days postoperative without systemic adverse renal effects and demonstrated that the antibiotic-impregnated grafts had similar incorporation as the normal allografts [7]. Whiteside and Roy introduced a new concept of antibiotic infusion within the periarticular space after single-stage revision for PJIs using Hickman lines, and by this means they have achieved no reinfections and complete clinical eradications of infection in their 21 cases at five years mean follow-up [8].

Considering the fact that the evidence available to address this question is based on retrospective small case series with heterogeneous methodologies, the level of recommendation is moderate at best. Taken as a whole, it appears that single-stage revision for acute PJIs may achieve eradication of infection in approximately 70% of patients, which is superior to many reported rates of success for irrigation/debridement and implant retention in the same setting [6]. Furthermore, this technique limits the perioperative morbidity, surgical complexity and healthcare costs associated with a two-stage exchange arthroplasty, and as such, should be strongly considered in the setting of acute PJIs of a THA.

## REFERENCES

- [1] Bedair H, Ting N, Bozic KJ, Della Valle CJ, Sporer SM. Treatment of early postoperative infections after THA: a decision analysis. *Clin Orthop Relat Res.* 2011;469:3477–3485. doi:10.1007/s11999-011-2119-0.
- [2] Buchholz HW, Elson RA, Engelbrecht E, Lodenkämper H, Röttger J, Siegel A. Management of deep infection of total hip replacement. *J Bone Joint Surg Br.* 1981;63-B:342–353.
- [3] Winkler H. Rationale for one stage exchange of infected hip replacement using uncemented implants and antibiotic impregnated bone graft. *Int J Med Sci.* 2009;6:247–252.
- [4] Raut VV, Siney PD, Wroblewski BM. One-stage revision of total hip arthroplasty for deep infection. Long-term followup. *Clin Orthop Relat Res.* 1995;202–207.
- [5] Jackson WO, Schmalzried TP. Limited role of direct exchange arthroplasty in the treatment of infected total hip replacements. *Clin Orthop Relat Res.* 2000;101–105.
- [6] Hansen E, Tetreault M, Zmistowski B, Della Valle CJ, Parvizi J, Haddad FS, et al. Outcome of one-stage cementless exchange for acute postoperative periprosthetic hip infection. *Clin Orthop Relat Res.* 2013;471:3214–3222. doi:10.1007/s11999-013-3079-3.
- [7] 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;90:1580–1584. doi:10.1302/0301-620X.90B12.20742.
- [8] Whiteside LA, Roy ME. One-stage revision with catheter infusion of intra-articular antibiotics successfully treats infected THA. *Clin Orthop Relat Res.* 2017;475:419–429. doi:10.1007/s11999-016-4977-y.
- [9] Wolf M, Clar H, Friesenbichler J, Schwantzer G, Bernhardt G, Gruber G, et al. Prosthetic joint infection following total hip replacement: results of one-stage versus two-stage exchange. *Int Orthop.* 2014;38:1363–1368. doi:10.1007/s00264-014-2309-y.
- [10] Li P, Hou M, Zhu ZQ, Shi ZJ. Cementless revision for infected hip arthroplasty: an 8.6 years follow-up. *Orthop Surg.* 2015;7:37–42. doi:10.1111/os.12159.
- [11] Yoo JJ, Kwon YS, Koo KH, Yoon KS, Kim YM, Kim HJ. One-stage cementless revision arthroplasty for infected hip replacements. *Int Orthop.* 2009;33:1195–1201. doi:10.1007/s00264-008-0640-x.

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## QUESTION 4: Does the morbidity and mortality differ between single-stage and two-stage exchange arthroplasty?

**RECOMMENDATION:** Putting aside the effect on successful treatment of periprosthetic joint infections (PJIs), it is logical that a single surgical procedure puts patients at lower risk for both mortality and morbidity compared to a two-stage exchange arthroplasty that involves two separate operations.

**LEVEL OF EVIDENCE:** Moderate

**DELEGATE VOTE:** Agree: 83%, Disagree: 13%, Abstain: 4% (Super Majority, Strong Consensus)

### RATIONALE

PJIs are associated with major patient morbidity and mortality. Browne et al. [1] put this in context with a contemporary comparison of two-stage revision hip arthroplasty to major non-orthopaedic surgery. In their study of over 10,386 patients, implant removal and spacer placement had a 30-day readmission rate of 11.1% and a 90-day mortality rate of 2.6%. Major complications were found in 15.3% of the patients. Ninety-day mortality rates were significantly higher compared with carotid endarterectomy, prostatectomy and kidney transplant (odds ratio (ORs) between 2.1 and 12.5;  $p < .0001$ ). Readmission rates at 30 days were significantly higher than all other groups including coronary artery bypass grafting and Whipple procedures (ORs between 1.4 and 8.2;  $p < .0001$ ). A recent analysis of a large, prospectively collected, national

database has also suggested that revision total knee arthroplasty (TKA) for PJIs is associated with increased postoperative morbidity and mortality in the first 30 postoperative days relative to non-infectious revisions [2].

Traditionally, it has been considered that a two-stage revision strategy may be the gold standard for the management of PJIs as this allows for a more targeted antimicrobial plan; however, it also exposes the patient to the risks of an additional procedure [3]. Historically, studies have concentrated on the successful eradication of infection as an end-point for comparing one and two-stage surgery. Considering reinfection, several recent systematic reviews have been published that show equivalence in terms of infection eradication for single and two-stage exchange [4–8].