successfully and the other was treated with two-stage conversion, ultimately resulting in above the knee amputation [4].

In the setting of UKA, recommendations are weak as only five published papers examine the results of failed UKA, including infection and the rate of infection is very low (Table 1). Two of the infected UKA cases in one study [1] had been post-traumatic infections prior to implantation of the UKA and thus represent more complex scenarios potentially predisposing to treatment failure. There is no literature directly evaluating the role of DAIR in the setting of UKA. However, subsequent failure due to progression of osteoarthritis (OA) occurred in two cases (survival 49%) at an average of three years. Therefore, it may be advisable to proceed with one- or two-stage conversion to TKA at the time of infection in the setting of UKA to minimize the need for additional revision procedures in the future and prevent associated morbidity.

In general, the surgeon should assess prior UKA function, component position and fixation and condition of alternate knee compartments to determine whether retention of implants with DAIR is an appropriate initial treatment in the setting of infection.

REFERENCES

[1] Labruyère C, Zeller V, Lhotellier L, Desplaces N, Léonard P, Mamoudy P, et al. Chronic infection of unicompartmental knee arthroplasty: one-stage conversion to total knee arthroplasty. Orthop Traumatol Surg Res. 2015;101:553–557. doi:10.1016/j.otsr.2015.04.006.

[2] Vasso M, Corona K, D'Apolito R, Mazzitelli G, Panni AS. Unicompartmental knee arthroplasty: modes of failure and conversion to total knee arthroplasty. Joints. 2017;5:44–50. doi:10.1055/s-0037-1601414.

[3] Kim KT, Lee S, Lee JI, Kim JW. Analysis and treatment of complications after unicompartmental knee arthroplasty. Knee Surg Relat Res. 2016;28:46–54. doi:10.5792/ksrr.2016.28.1.46.

[4] Böhm I, Landsiedl F. Revision surgery after failed unicompartmental knee arthroplasty: a study of 35 cases. J Arthroplasty. 2000;15:982–989.

[5] Saragaglia D, Bonnin M, Dejour D, Deschamps G, Chol C, Chabert B, et al. Results of a French multicentre retrospective experience with four hundred and eighteen failed unicondylar knee arthroplasties. Int Orthop. 2013;37:1273–1278. doi:10.1007/s00264-013-1915-4.

Authors: Dwikora Novembri Utomo, Nicolaas Budhiparama, Andrew Battenberg, Ferdiansyah Mahyudin, KuKuh Dwiputra Hernugrahanto, I. Lumban-Gaol

QUESTION 8: Can debridement, antibiotics and implant retention (DAIR) be utilized in the treatment of acute periprosthetic joint infection (PJI) with a megaprosthesis?

RECOMMENDATION: DAIR is a viable treatment option in acute PJI of a megaprosthesis. The effectiveness of DAIR is still unclear due to lack of comparative data among the treatment options and limited evidence to suggest superiority of any one treatment. The treatment decision must be made on a case-by-case basis and account for underlying medical conditions, infection history, organism characteristics and surgical history. DAIR is most appropriate for acute PJI without complicating factors, such as extensive and pervasive infection by a high virulence or resistant organism.

LEVEL OF EVIDENCE: Limited

DELEGATE VOTE: Agree: 96%, Disagree: 1%, Abstain: 3% (Unanimous, Strongest Consensus)

RATIONALE

Acute PJI of megaprostheses is a terrible complication and a difficult situation for treatment [1]. Infection rates in patients with megaprostheses have been reported to range from 3% to greater than 30% [1–3]. In principle, the treatment of acute PJI with a megaprosthesis is similar to treatment of other acute PJI, except there is significantly more potential space and a greater soft tissue infectious burden requiring more extensive exposure and debridement [4,5]. The surgical options include DAIR [6–8], one-stage revision surgery [4], two-stage revision with an interval cement spacer [9–11], arthrodesis and amputation [5,8]. Unfortunately, there is limited data on the outcome of these different procedures [1,9]. The lack of comparative data is due to the limited indications for a megaprosthesis as well as the clinical heterogeneity of the affected patients [5]. Additionally, treatment details vary greatly, particularly for DAIR. Specific information on the debridement, the type of irrigation solutions, modular component exchange and local and systemic antibiotic use and duration are generally lacking.

Two-stage revision remains the preferred method for treatment of PJI [8–10]. However, two-stage revision significantly increases surgical and perioperative risks and includes a substantial period of reduced mobility between stages, which has heightened interest in alternative surgical options such as DAIR. DAIR is an attractive option as it may prevent the unnecessary removal of implants, which could result in further bone loss and fracture [6,11,12]. DAIR is also the simpler and less costly procedure with a demonstrated shorter length of hospital stay [13]. The overall goal of attempting DAIR should be to select the cohort of patients in whom successful treatment is most likely.

Sujith et al. summarized the absolute and relative contraindication for DAIR [13]: The absolute contraindications are loose prosthesis, poor soft tissue coverage and compromised bone cement mantle. The relative contraindications are the presence of sinus tracts, methicillin-resistant and methicillin-susceptible *Staphylococcus aureus* (MRSA and MSSA) infection, previously revised joints, immunosuppression, rheumatoid arthritis, polymicrobial involvement, bacteremia, C-reactive protein (CRP) >100 mg/L, erythrocyte sedimentation rate (ESR) >60 mm/h, two or more previous debridements and >3 weeks of symptoms.

The decision to perform DAIR can also be based on the classification of the infection. According to Pilge et al.if intraoperative cultures are positive without other signs of infection (Tsukayama Type I), implant retention is attempted and prolonged systemic antibiotic treatment is recommended. Implant retention should also be attempted with stable arthroplasties in type II or III infections (early postoperative infection or acute hematogenous infection). If there are radiological signs of implant loosening, a one- or two-stage revision must be performed [14,15].

During DAIR, thorough debridement is necessary to improve outcome. All infected and nonviable tissue around a well-fixed prosthesis must be removed. Retained components are irrigated and

scrubbed in an effort to remove biofilm [11,13]. Various antibiotic solutions can be used intraoperatively, including dilute betadine and Dakin's solution. Culture-driven systemic antibiotics are also important for successful treatment and co-treatment with rifampin should be utilized in Staphylococcal PJIs [6]. Prolonged or chronic antibiotic suppression may also be necessary. The use of local antibiotics in addition to the administration of systemic antibiotic agents is an area of consideration. Modular components and the exposed metal of megaprostheses can be covered with antibiotic eluting cement, though there is no clinical evidence comparing the efficacy of such methods versus more simple modular exchange.

The most important factors contributing to treatment failure are longer duration of symptoms, a longer time after initial arthroplasty, the need for multiple debridements, the retention of exchangeable components and PJI caused by MRSA [6,11,12]. One- or two-stage revision should be performed if DAIR fails [11,13].

In general, DAIR is a treatment option for acute PJI with a megaprosthesis with varying levels of success in selected and non-complicated patients. The heterogeneity inherent in these cases makes comparisons difficult and there is always some degree of individualization in choice of treatment.

REFERENCES

[1] Ercolano LB, Christensen T, McGough R, Weiss K. Treatment solutions are unclear for perimegaprosthetic infections. Clin Orthop Relat Res. 2013;471:3204–3213. doi:10.1007/s11999-013-2852-7.

[2] Hardes J, Gebert C, Schwappach A, Ahrens H, Streitburger A, Winkelmann W, et al. Characteristics and outcome of infections associated with tumor endoprostheses. Arch Orthop Trauma Surg. 2006;126:289–296. doi:10.1007/s00402-005-0009-1.

[3] Henderson ER, Groundland JS, Pala E, Dennis JA, Wooten R, Cheong D, et al. Failure mode classification for tumor endoprostheses: retrospective review of five institutions and a literature review. J Bone Joint Surg Am. 2011;93:418–429. doi:10.2106/JBJS.J.00834.

[4] Holzer G, Windhager R, Kotz R. One-stage revision surgery for infected megaprostheses. J Bone Joint Surg Br. 1997;79:31–35.

[5] Kapoor SK, Thiyam R. Management of infection following reconstruction in bone tumors. J Clin Orthop Relat Res Trauma. 2015;6:244–251. doi:10.1016/j.jcot.2015.04.005.

[6] Kuiper JW, Willink RT, Moojen DJF, van den Bekerom MP, Colen S. Treatment of acute periprosthetic infections with prosthesis retention: review of current concepts. World J Orthop. 2014;5:667–676. doi:10.5312/wjo.v5.i5.667.

[7] Rodríguez-Pardo D, Pigrau C, Lora-Tamayo J, Soriano A, del Toro MD, Cobo J, et al. Gram-negative prosthetic joint infection: outcome of a debridement, antibiotics and implant retention approach. A large multicentre study. Clin Microbiol Infect. 2014;20:O911-O919. doi:10.1111/1469-0691.12649.

[8] McDonald DJ, Fitzgerald RH, Ilstrup DM. Two-stage reconstruction of a total hip arthroplasty because of infection. J Bone Joint Surg Am. 1989;71:828–834.

[9] Eralp L, Ozger H, Kocaoglu M. Treatment strategies for infected megaprosthesis. Orthopaedic Proceedings. 2009;91-B:301–301. doi:10.1302/0301-620X.91BSUPP_II.0910301a.

[10] Hardes J, Ahrens H, Gosheger G, Nottrott M, Dieckmann R, Henrichs MP, et al. [Management of complications in megaprostheses]. Unfallchirurg. 2014;117:607–613. doi:10.1007/s00113-013-2477-z.

[11] Grammatopoulos G, Kendrick B, McNally M, Athanasou NA, Atkins B, McLardy-Smith P, et al. Outcome following debridement, antibiotics, and implant retention in hip periprosthetic joint infection - an 18-year experience. J Arthroplasty. 2017;32:2248–2255.

[12] Kuiper JWP, Vos SJC, Saouti R, Vergroesen DA, Graat HCA, Debets-Ossenkopp YJ, et al. Prosthetic joint-associated infections treated with DAIR (debridement, antibiotics, irrigation, and retention): analysis of risk factors and local antibiotic carriers in 91 patients. Acta Orthop. 2013;84:380–386. doi:10.3109/17453674.2013.823589.

[13] Kendoff D, Morgan-Jones R, Haddad FS, editors. Periprosthetic Joint Infections: Changing Paradigms. Springer International Publishing; 2016.

[14] Pilge H, Gradl G, von Eisenhart-Rothe R, Gollwitzer H. Incidence and outcome after infection of megaprostheses. Hip Int. 2012:S83-S90. doi:10.5301/HIP.2012.9576.

[15] Brandt CM, Duffy MC, Berbari EF, Hanssen AD, Steckelberg JM, Osmon DR. Staphylococcus aureus prosthetic joint infection treated with prosthesis removal and delayed reimplantation arthroplasty. Mayo Clin Proc. 1999;74:553–558. doi:10.4065/74.6.553.

Authors: Marjan Wouthuyzen-Bakker, Alex Soriano

QUESTION 9: What factors are associated with the successful treatment of acute periprosthetic joint infection (PJI) using debridement, antibiotics and implant retention (DAIR)?

RECOMMENDATION: The following factors have been shown to be associated with treatment success in acute PJIs treated with DAIR:

- Exchanging the modular components during debridement
- Performing a debridement within at least seven days, but preferably as soon as possible, after the onset of symptoms
- Adding rifampin to the antibiotic regimen, particularly when combined with a fluoroquinolone, in cases of susceptible staphylococci
- Treatment with fluoroquinolones in cases of susceptible gram-negative bacilli

The following factors have been shown to be associated with treatment failure in acute PJIs treated with DAIR:

- Host related factors: rheumatoid arthritis, old age, male sex, chronic renal failure, liver cirrhosis and chronic obstructive pulmonary disease
- Prosthesis indication: fracture as indication for the prosthesis, cemented prostheses and revised prostheses
- Clinical presentation representing the severity of the infection: a high C-reactive protein (CRP), a high bacterial inoculum and the presence of bacteremia
- Causative microorganisms: *S. aureus* and Enterococcoci

LEVEL OF EVIDENCE: Moderate

DELEGATE VOTE: Agree: 92%, Disagree: 5%, Abstain: 3% (Super Majority, Strong Consensus)

RATIONALE

The success of DAIR depends on multiple host- and implant-related factors, clinical presentation, intraoperative variables, causative microorganism(s) and their antibiotic sensitivities and the antibiotic regimen. It is of note, that the described factors related to treatment outcome in some studies, are not always confirmed by others. Most factors associated with success of DAIR are demonstrated in retrospective studies, entailing a high risk of selection bias, especially for those factors involving certain treatment strategies. Therefore, prospective validation is critical for most of the described variables and differences between cohorts should be taken into consid-