crobial or antibiofilm activity in either group, thereby raising doubt regarding the latter two hypotheses stated above [15].

As the majority of reported studies are single-center with a limited study population, a large registry data approach may provide more insight. Matharu et al. reviewed the use of TM acetabular components in primary THA and compared their subsequent revision rates to non-TM coated prostheses [16]. The group performed a propensity score matched study from the National Joint Registry for England and Wales and report that five-year revision rates were significantly lower in the TM cohort compared to the control for: 1) all-cause (1.0% vs. 1.8%, p < 0.001), 2) aseptic acetabular loosening (0.1% vs. 0.2%, p = 0.029), and 3) infection (0.5% vs. 0.9%, p = 0.001) [16].

Laaksonen et al. report on a collaborative study by reviewing both the Australian and Swedish National Joint Registries in order to assess the risks of re-revisions between Ta and other cementless revision THAs. Included were 2,442 first-time THA revisions with porous Ta cups, and 4,401 first-time revisions with other uncemented cups. Survivorship with re-revision for any reason was comparable up to seven years between the two groups [86% (Ta) and 87% (control) (p = 0.64)]. Overall survivorship up to seven years with second revision for PJIs as the end-point was 97% for both groups (p = 0.64). Implant survival for a porous Ta cup in first-time THA revision was similar to the uncemented cup control. No benefits in survival with re-revision for infection as an end-point could be ascribed to the Ta group [17].

In summary, the results for the use of highly porous Ta components in revision THA procedures are promising with seemingly lower rates of PJIs than that for their Ti alternatives. The reasons for this reduction in infection rates are not yet known and more work needs to be done in this area.

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5.8. TREATMENT: SALVAGE

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QUESTION 1: Are there differences in outcomes and survivorship between knee arthrodesis (KA) and above-knee amputations (AKA) for chronic knee periprosthetic joint injections (PJIs)?

RECOMMENDATION: Yes, an AKA for the treatment of chronic PJI in total knee arthroplasty (TKA) has a lower functional outcome, and higher mortality rate than KA.

LEVEL OF EVIDENCE: Moderate

DELEGATE VOTE: Agree: 82%, Disagree: 13%, Abstain: 5% (Super Majority, Strong Consensus)

RATIONALE

One of the earliest studies on the outcomes of the salvage procedures was published in 1988 by Pring et al. They reviewed 23 patients who were treated with AKA following a failed TKA and showed that more than half of the patients were ultimately confined to a wheelchair [1]. Isiklar et al. reviewed nine AKAs that were performed after failed multiple revision surgeries for TKA in eight patients. After an average 2.5 years of follow-up, only two out of nine patients were ambulatory with walker, and one patient required wearing a prosthesis. They believed an earlier attempt at KA with preservation of bone stock can prevent poor outcomes of AKA [2]. Sierra et al. reviewed 18,443 TKAs performed between 1970 and 2000. They found that of 67 (0.36%) patients who finally underwent AKA, 19 of them were due to uncontrollable infection. The functional outcomes of patients undergoing AKA were poor, a substantial percentage of these patients were never fitted with a prosthetic, and those who were fitted with a prosthetic seldom obtained functional independence [3].

Blom et al., in a review of 69 revision cases, found a 5.8% infection rate. Two infected cases who underwent KAs demonstrated Oxford scores comparable with patients who were treated with two-stage revisions [4]. Fedorka et al. retrospectively reviewed 35 patients who underwent AKAs after infected TKAs. After a mean follow-up of 39 months, 15 of the patients receiving AKA had died and 11 patients needed repeat surgery. Only 8 of 14 patients who received prosthetics were able to regain functional ambulation [5]. Chen et al. retrospectively studied the functional capacity of 20 cases of patients undergoing KA, and compared them to 6 previously reported cases of AKAs for PJIs after TKAs. Both physical and mental components of the Short Form-12 (SF-12) questionnaire were higher in KA group. The number of community-ambulators increased in KA group and decreased in the AKA group. They concluded that KA as treatment for recalcitrant PJIs after TKAs may have better functional outcomes compared to performing an AKA [6]. Khanna et al. found nine patients who underwent AKAs for recurrent PJIs in TKAs from 2000 to 2013. They studied their functional abilities with SF-12 and asked patients about their satisfaction through developing a questionnaire. Six of seven patients were fitted to a prosthesis and four were able to wear the device more than one hour. Despite having poor functional outcomes, all patients were satisfied with their AKA compared to their preoperative situation. They recommended considering an AKA in chronically infected prosthetic knees in patients with multiple medical comorbidities, failed multiple attempts at revisions, soft tissue compromise of the knee and excessive bone loss or severe vascular disease [7].

Rodríguez-Merchán et al. in a review of 10 papers comparing AKAs vs. KAs after failed TKAs, found that a substantial percentage of the AKA patients were never fitted with a prosthetic and those who were fitted seldom obtained functional independence. They also reported that only 50% of patients were able to walk after AKAs, while KA patients could walk at least inside the house and activity of daily living independence was achieved by majority of the arthrodesis patients. They concluded that since functional outcomes after AKA are poor and KA patients have better function and ambulatory status, KA should be strongly considered as the treatment of choice for patients who have failed treatment for infected TKA [8].

Johnson and Bannister reviewed a small series of 25 knee infections and reported that KA was the most successful treatment modality for achieving pain relief and infection control in 11 of 12 (92%) patients at final follow-up [9].

One of the rare reports on unsatisfactory outcomes of the KA was published by Rohner et al. They reported a 50% rate of persistent infection and a 73% persistent pain in 26 patients who underwent KA with intramedullary (IM) nail. All scores showed marked impairment of quality of life. They concluded that IM nailing following septic failure of revision TKA must be regarded with skepticism [10].

Carr et al. reported on patients in a national database spanning from 2005 to 2012 and found 2,634 patients with KAs and 5,001 patients who underwent AKAs for infected TKAs. They detected an increasing trend towards AKA rather than KA in patients who were older and had a greater number of comorbidities. They also found more common systemic complications, longer hospital stays, higher 90-day readmissions and more in-hospital mortalities after AKA. Arthrodesis cases, however, had significantly higher rates of postoperative infections [11].

Son et al. identified 1,182 KA and 1,864 AKA patients among a cohort of 44,466 patients who underwent revision surgery with diagnoses of infected TKA from 2005 to 2014 using The Medicare 100% National Inpatient Claims Database [12]. Their goal was to determine the frequency, risk factors associated with, and mortality of KA and AKA. They found decreasing trends toward AKAs and KAs since 2005. Clinical factors associated with arthrodesis included acute renal failure, obesity and having additional infection-related revisions. Higher Charlson comorbidity scores, obesity, deep vein thrombosis and additional revisions were factors associated with AKA, which in turn was an independent risk factor for mortality. After adjusting for age, comorbidities and other factors, mortality was higher in AKA patients. The risk of death in KA group did not change compared to patients who underwent revisions [12].

George et al. reviewed 53 cases of AKAs performed for PJIs after TKAs in order to identify the factors predicting ambulatory status after AKAs for PJIs of the knee and to elucidate the effects of this procedure on general health outcomes. After 29 months of follow-up, 43 patients were alive and 28 were available to be contacted. Fourteen patients had infection at the site of stump. A total of 47% of the patients were non-ambulatory and their functional outcomes did not improve compared to their pre-amputation status. Male gender and preoperative community ambulatory status were independent predictors of walking ability after AKA [13].

Hungerer et al. compared functional outcomes, complications and qualities of life between 81 modular KAs and 32 AKAs performed for PJIs after TKAs between 2003 and 2012, with the use of the Lower-Extremity-Functional-Score (LEFS) and the patient reported general health status (SF-12) questionnaire. After a mean interval of 55 months, recurrence of infection was higher in AKA patients (35% vs. 22%). Patients with AKAs and modular KAs showed comparable functional outcomes and qualities of life. Notably, 10 AKA patients that could be fitted with a microprocessor-controlled knee joint demonstrated significantly better functional outcomes than other amputee patients ($p < 0.01$) or modular KA patients ($p < 0.01$). The group concluded that the AKAs should be considered as an option in patients with a good physical and mental condition [14].

Wu et al. performed a systematic review of the literature and a decision analysis to determine the treatment modality likely to yield the highest quality of life for a patient after a failed two-stage reimplantation procedure of an infected TKA. Consistent evidence in the majority of case series and reviews supported that lower functional outcome and higher mortality are expected following AKA compared to KA after failed infected TKA. Based on the data, the authors concluded that KAs should be strongly considered when patients present with failed two-stage revision for infected TKA. KA is most likely to provide infection control while maximizing patient function when there is sufficient residual bone stock and when a repeat two-stage reimplantation procedure has low likelihood of success (i.e., resistant organisms, poor host and inadequate soft tissue envelope) [15].

Kohn et al. performed a review of the literature over a 10-year period. They found that KA after failed infected TKA was a difficult procedure that was associated with complications. The review revealed that bone loss of the distal femur and proximal tibia was the most important prognostic factor [16].

Additionally, in a recent article Parvizi et al. declared that complete eradication of recalcitrant PJIs can be achieved by resection of all components without reimplantation through KA or AKA. They concluded that innovations in the future such as transcutaneous prosthetic fitting may provide an improvement on what we have and allow patients with AKA to achieve functional independence [17].

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QUESTION 2: How many exchange arthroplasties are reasonable before a salvage operation (such as amputation or arthrodesis) should be considered?

RECOMMENDATION: Patients with a failed two-stage exchange arthroplasty that undergo a repeat two-stage exchange arthroplasty demonstrate poor outcomes. Failure of the repeat two-stage exchange arthroplasty appears to be dependent on the host grade and status of the extremity. Surgeons thus should consider the patient's comorbidities and expectations when deciding whether to subject the patient to repeat two-stage exchange arthroplasties. The outcomes of a third or fourth two-stage exchange arthroplasty are dismal.

LEVEL OF EVIDENCE: Limited

DELEGATE VOTE: Agree: 88%, Disagree: 10%, Abstain: 2% (Super Majority, Strong Consensus)

RATIONALE

Two-stage exchange arthroplasty remains the preferred method of treatment for chronic periprosthetic joint infections (PJIs) in the United States. The reported success rate of two-stage exchange arthroplasty is variable with rates ranging from approximately 70 - 90%. However, there is significant morbidity and mortality associated with undergoing multiple surgeries for management of PJIs [1,2]. Furthermore, these patients are often very fragile and poor hosts.

There are several studies in the literature demonstrating poor outcomes after the initial failed two-stage exchange arthroplasty. Kheir et al. found that in patients undergoing a second two-stage exchange arthroplasty, reimplantation occurred in only 65% of cases and successful outcomes occurred in only 61.6%. Furthermore, of the 14 cases that were not reimplanted, there was a high rate of retained spacers (n = 6), amputations (n = 5), PJI-related mortalities (n = 2), and arthrodesis (n = 1) [3]. Kalra et al. reported on a similar cohort where success was achieved in 36.4% (4/11) of patients that underwent re-revision after a prior failed two-stage exchange arthroplasty [4].

Azzam et al. demonstrated that recurrent or persistent infections after a failed two-stage exchange was found in 4 out of 18 patients (22.2%) [5]. In this series, two patients underwent a third two-stage exchange arthroplasty and both were infection-free at two years. Furthermore, Fehring et al. found that in 45 patients undergoing a second two-stage exchange arthroplasty, 22 (49%) had another revision for reinfection [6]. The latter study also evaluated the risk factors for failure and found that poor host and extremity grades were associated with an increased risk of failure. When stratified by host grade, revisions for reinfections were performed in 30% of the uncompromised hosts (type A), 48% of the medically compromised hosts (type B) and 75% of the very medically ill patients (type C). In addition, Backe et al. also investigated the outcomes of 12 patients that failed an initial two-stage exchange arthroplasty, including 9 patients treated with a repeat two-stage and 3 patients treated with an arthrodesis. While there were no instances of reinfections in either group, the three solid fusion patients were dissatisfied with their stiff limb despite its good position [6]. In patients with a failed repeat two-stage exchange arthroplasty, the organism identified is most often different than that identified in the initial two-stage exchange [6].

While the outcomes of a second two-stage exchange arthroplasty are well known, there is minimal literature regarding the expected outcomes of a third and fourth two-stage exchange arthroplasty. However, understanding the risk factors for failure after an initial two-stage exchange arthroplasty may help determine which patients are optimal candidates for additional two-stage exchange arthroplasty attempts. In patients with increased comorbidities, infection with resistant organisms, or an organism associated with