the mortality increase in a two-stage protocol was most directly responsible for the predicted advantage of a one-stage protocol in this study, failure of reimplantation in some circumstances, time between procedures and a longer total recovery, were also utility values which favored direct exchange. Although the challenges in conducting an adequately powered randomized controlled trial to properly address this question are multiple, important controversy regarding this topic will likely remain until this is done.

Based on the current evidence, one-stage revision procedures can be utilized as an alternative to two-stage revision for PJIs, with comparable success. However, this may not be a suitable option for all patients with an infected prosthesis. Meticulous operative planning and surgical technique is important to achieve excellent outcomes. Future prospective, randomized, adequately powered, and preferably multicenter studies are necessary to delineate the superiority of a one- or two-stage revision approach for PJIs. It is likely that marked controversy regarding this topic will likely remain until such evidence becomes available.

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QUESTION 2: What are the indications and contraindications for a one-stage exchange arthroplasty for the treatment of chronic periprosthetic joint infections (PJIs)?

RECOMMENDATION: One-stage exchange arthroplasty remains a viable option for the management of chronic PJIs. In patients with signs of systemic sepsis, extensive comorbidities, infection with resistant organisms, culture-negative infections and poor soft tissue coverage, one-stage exchange arthroplasty may not be a good option.

LEVEL OF EVIDENCE: Moderate

DELEGATE VOTE: Agree: 93%, Disagree: 5%, Abstain: 2% (Super Majority, Strong Consensus)

RATIONALE

The evidence for best practice in the management of PJIs is an evolving science with increasing popularity for one-stage revision arthroplasty over recent years. This popularity is mainly driven by a number of studies reporting comparable [1,2], if not better [3] outcomes of one-stage vs.two-stage exchange surgery and the potential for reduced patient morbidity, mortality and socio-economic burden with the former [4–6]. Excellent outcomes for infection-free survival are documented in the literature, especially where strict criteria for patient selection is met. Haddad et al. [3] in 2015 reported their series of 28 highly selected patients undergoing one-stage exchange for chronically infected knee arthroplasties with a 0% re-infection rate at a minimum of three years follow-up. Their cohort

accurately matched the host, local and microbiological criteria proposed in this updated consensus document. Earlier results from Oussedik et al. in 2010 reported a similar success rate of infection-free survival of one-stage exchange arthroplasty of hip patients in the presence of a strict patient selection protocol [7].

Despite these aforementioned studies, there still remains a lack of high-quality literature addressing the subject matter. Hence, in the absence of published randomized controlled trials, many of our conclusions have been drawn from a combination of retrospective and prospective cohort studies and systematic reviews of these.

Early experience of one-stage exchange arthroplasty by Buchholz et al. [8] in 1981 reported an overall success rate of 77% in a large series of 583 patients. In this study, the microbiological profile appeared to play an important role onthe outcomes, with polymicrobial infections and atypical and gram-negative organisms being associated with a higher failure rate. These findings have later been echoed by Jackson et al. [9] in their literature review in 2000, where they concluded that in addition to these factors, infection with methicillin-resistant *Staphylococcus aureus* (MRSA)/methicillin-resistant *Staphylococcus epidermidis* (MRSE) resistant organisms were associated with poor outcomes. It is important to note, however, that despite these reports, evidence from the HELIOS ENDO-Klinik, where a high volume of one-stage procedures are performed (85% of all septic revision), does not consider these factors as absolute contraindications to one-stage surgery and still has presented promising long-term follow-up [10].

Excellent results have also been reported in a number of series, with 92 - 100% infection free survival, where known microbiological susceptibility had been established preoperatively [3,10–12]. Despite this, the importance of predetermined microbiology has also been indirectly questioned by one or more studies recently [13–15]. Buchholz et al. noted best results in negative culture cases, a criterion previously considered an absolute contraindication for the one-stage strategy. Lange et al., in their series of 56 patients report a 91% infection-free period, despite 15 patients having negative tissue cultures. Furthermore, in their series, only one of the five failures had documented negative culture [13]. Hence, it may be proposed that a lack of preoperative microbiological diagnosis may be considered a relative, rather than absolute, contraindication for one-stage exchange arthroplasty.

Host and local factors have also been highlighted as important determinants of outcome of one-stage revision. A study by Goksan et al. in 1992, on a small cohort of 18 cases, reported a 94% success rate with knees, success defined as eradication of infection. Host profile in this series matched some of the indications criteria later set out by the International Consensus Group in 2013 to include the absence of systemic sepsis and gross tissue inflammation. Of the two reported cases of failure, both patients were noted to have severe immunosuppression [16]. In a retrospective study by Wolf et al. [17], their patient cohort was classified using the McPherson classification system based upon host status and local status. Their series concluded better outcomes in terms of infection eradication with two-stage vs. one-stage procedures being performed in the presence of host systemic compromise (95 vs. 33% eradication for McPherson type B + C patients) and local soft tissue and bony compromising factors (95 vs. 0% eradication for McPherson stage 3 patients). More recently, Bori et al. published their series of 19 consecutive one-stage revision hip cases and reported a 95% cure rate. They noted an absence of important bone defects intraoperatively (with only four cases requiring bone grafting) as a potential contributing factor to their successful outcomes [15].

The presence of soft tissue defects and sinus tracts also appear to have a negative impact on outcomes in some studies with a 27% reinfection rate (6 out of 22 cases) [18]. Similarly, of the five recurrent infections in the series by Lang et al., three patients had soft tissue lesions in the form of a sinus tract at initial presentation and one had an abscess. It is important to note, however, that despite these reported findings, Jenny et al., in an earlier series of 47 patients documented an 87% infection-free survival period at 3 years despite a large number of their cohort of patients (43%) presenting with a fistula. In their series, only two patients with a sinus tract subsequently fell into their reinfection group [19]. Hence, it may be proposed that a discharging fistula is, in itself, not an absolute contraindication to one-stage exchange arthroplasty, a conclusion also drawn by Raut et al. [20].

It may be concluded that one-stage exchange arthroplasty remains a plausible option for the management of chronic prosthetic joint infections in a selected group of individuals with the prospect of promising results for infection-free survival of the revised prosthesis. Much of this evidence, however, is based upon analysis of prospective and retrospective observational studies. Furthermore, the fact that outcomes following one-stage exchange are affected by multiple factors, it is often difficult to assess the impact an individual criterion has. There is no doubt that stronger conclusions may be drawn in the future following results from established randomized controlled trials that are underway in the United Kingdom, United States, and elsewhere. In the meantime, we offer the following as indications and relative contraindications for one-stage exchange arthroplasty.

Indications for One-stage

Host/Local

- Non-immunocompromised host
- Absence of systemic sepsis
- Minimal bone loss/soft tissue defect allowing primary wound closure
- Microbiology
- Isolation of pathogenic organism preoperatively
- Known sensitivities to bactericidal treatment

Relative Contraindication to One-stage

- Severe damage of soft tissues where the direct closure of the joint and the wound is not possible. A complex sinus tract which cannot be excised along with the old scar.
- Culture-negative PJI, where the causative organism and its susceptibility are not known.
- No radical debridement of infected soft tissues or bone is possible (for whatever reason).
- No local antimicrobial treatment is possible (for whatever reason).
- No proper bone stock exists for the fixation of the new implant.

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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 Bucholz'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].