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QUESTION 3: Is there a role for preoperative joint aspiration prior to second-stage revision after treatment of elbow periprosthetic joint infection (PJI)?

RECOMMENDATION: Preoperative joint aspiration may play a role in the evaluation of the elbow arthroplasty for PJI before second-stage revision.

LEVEL OF EVIDENCE: Consensus

DELEGATE VOTE: Agree: 96%, Disagree: 0%, Abstain: 4% (Unanimous, Strongest Consensus)

RATIONALE

There are no studies that specifically investigate and prove that there is a role for preoperative aspiration of the elbow prior to second-stage revision arthroplasty. However, in a review of published studies that have addressed total elbow infection, aspiration was found to be the standard of practice in these studies. Furthermore, there is a logical rationale that preoperative aspiration provides useful information for both the diagnosis and treatment of total elbow arthroplasty (TEA) infections. When the risk factors for infection are higher (such as in patients with diabetes, obesity or rheumatoid arthritis), preoperative aspiration prior to second-stage revision has an even stronger recommendation. Currently, no evidence exists regarding what constitutes a positive aspiration. Therefore, the significance of the results should be assessed on a case-by-case basis.

Rudge et al. discussed the management of infected elbow arthroplasty by two-stage revision in 19 patients managed at their center [1]. In their algorithm for management, the authors state, "If the infective organism and sensitivities had been identified before the first stage, further antibiotics were added as necessary. If at the six-week postoperative review there were clinical signs of ongoing infection or inflammatory markers had not normalized, an aspiration was performed. If the aspirate analysis was positive, then patients underwent a repeat first-stage procedure (debridement and washout). If the aspirate analysis was negative, then a second-stage procedure was planned, but with a low threshold for making an intraoperative decision to repeat the first stage rather than re-implanting prosthetic components, if concerned about possible ongoing infection." These authors therefore recommend aspiration prior to second-stage revision as a means of determining when to proceed to the second stage, what procedure to perform

and which antibiotics to use.

Using this protocol, the authors were able to treat the majority of TEA infections successfully — "Of the 19 patients undergoing a first-stage procedure, 16 (84%) remained infection free, of whom 11 had proceeded to a second stage and five had not. Of 14 patients undergoing a two-stage revision, 11 (79%) remained infection free. Of patients requiring further surgery due to recurrent infection, 2 (67%) remained infection free after a repeat two-stage revision, with the third patient still awaiting the second-stage procedure."

When aspiration is performed, the joint fluid should be evaluated for white blood cell (WBC) count, with particular attention to the differential (polymorphonuclear percentage). In addition, the fluid should be sent for aerobic and anaerobic cultures. Gram stains lack sensitivity and specificity and are not routinely recommended [2,3]. Cultures remain the most effective method for specific organism identification. The addition of Acid-Fast Bacilli (AFB) and fungal cultures should be performed if there is concern for atypical infecting organisms. Additionally, incubating cultures for a longer period (21 days) may assist in identifying fastidious organisms such as *Cutibacterium acnes*.

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QUESTION 4: What is the role of permanent resection when treating a chronic elbow periprosthetic joint infection (PJI)?

RECOMMENDATION: Permanent resection is a salvage treatment for chronic elbow PJI. Preservation of medial and lateral condyles should be considered to improve functional outcomes.

LEVEL OF EVIDENCE: Limited

DELEGATE VOTE: Agree: 100%, Disagree: 0%, Abstain: 0% (Unanimous, Strongest Consensus)

RATIONALE

Methodology

A comprehensive literature review was performed to identify all studies on permanent resection treatment for elbow PJI. Searches for the terms “elbow,” “total elbow arthroplasty,” “infection,” “periprosthetic,” “permanent resection” and “resection arthroplasty” were performed on the PubMed/Medline, Cochrane, Google Scholar and Embase databases through March of 2018. Our systematic review includes English studies (only level IV evidence) regarding permanent resection treatment for the elbow PJI. Non-English studies, technique papers without patient data, studies with inadequate patient follow-up and studies regarding resection treatment for non-elbow PJI were not included. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) statement was followed for this review.

Discussion

PJI is a serious complication of total elbow arthroplasty (TEA) and is difficult to treat [1,2]. Treatment options include debridement with retention of implants, single or two-stage reimplantation, permanent resection and arthrodesis [1–5]. There are only a few studies with limited evidence comparing the outcomes of these treatment procedures [3–7]. Many authors have emphasized that good functional outcomes are only possible with reimplantation [8,9]. However, the success of the reimplantation treatment depends on remaining bone stock [9,10]. On the other hand, high recurrence rates of infection limits the success of the treatment [8]. Arthrodesis and permanent resection are defined as a salvage procedure in low-demand patients [1,2,5,7]. However, arthrodesis has a very limited role in the treatment of this circumstance, even as a salvage treatment, as it often results in a painful nonunion or infection recurrence [3].

Permanent resection is suggested as a salvage procedure for the treatment of elbow PJI in patients in whom debridement and reimplantation therapy had failed or in medically frail patients [2,7]. Rhee et al. reported that infections in nine patients (90%) could be eradicated with permanent resection for elbow PJI [11]. Despite the high successes of eradication of the infection, it was noted that sufficient stability was essential for the successful functional outcomes. It was emphasized that the condyles which articulate with the olecranon fossa are important for the stability in resection arthroplasty. Moreover, the authors have examined the role of poor bone stock in the condyles (which is common in this patient group) on the success of resection arthroplasty. It has been reported that the best functional results were obtained in patients in whom both condyles could be preserved, whereas the weakest functional results were reported to be obtained in the group of patients in whom only the medial condyle could be preserved. Figgie et al. reported that achieving stability has a key role in the success of resection arthroplasty following failed TEA [12]. Therefore, the authors emphasized that the epicondyles should be preserved.

In a study by Zarkadas et al., resection arthroplasty has been defined as an effective salvage procedure [1]. This study appears to be noteworthy due to fact that it reported the long-term outcomes of 29 patients (30 elbows) after resection arthroplasty for the failed TEA (11 years, range 2.7 to 28 years). In the study, it was noted that the increase in the Mayo Elbow Performance Score was reported to be mostly in the pain component, whereas the stability was directly related to good functional outcomes. However, the authors reported complications such as persistent infection in 24 elbows (47%), intraoperative fracture in 18 elbows (35%) and permanent nerve injury in 9 elbows (18%).

Specifically, the difficulties experienced during removal of the well-fixed humeral component were thought to be responsible for the high complication rates. For this reason, the authors suggested performing an osteotomy in the form of a trapezoidal window, which has a larger distal border in order to facilitate removal of the humeral component and cement. In addition, the authors pointed to the importance of the development of soft tissue scar utilizing a brace or a cast for a minimum of six weeks to surpass instability, which is thought to be responsible for the poor functional outcomes.

PJI following an elbow arthroplasty has a reported rate ranging from 22 to 41%, based on limited literature [1,2]. Diagnosis of chronic elbow PJI has remained a challenge, however, as many presentations are subclinical in nature, leaving cultures still as the recommended diagnostic tool [3]. Treatment of elbow PJI has primarily centered on intravenous antibiotics, debridement and retention as well as staged reimplantation, all of which have been proven to be relatively successful under the right indications [3–5]. There is limited literature regarding the success of this treatment modality. Permanent resection may be considered if previous attempts to resolve elbow PJI fail [3,6,7]. Zarkadas et al. found that 47% of their case series required additional surgery after permanent resection to resolve the infection [6].

There are no level I or II studies available, though one level III and two level IV studies exist examining permanent resection as a treatment modality for chronic TEA PJI. Both level IV studies are case series with sample sizes of 51 and 10 patients, respectively [3,7]. Both level IV studies demonstrated that successful eradication of PJI is heavily dependent on surgical technique and more experienced TEA surgeons are correlated with higher eradication rates for elbow PJI via permanent resection.

One study reported patient outcomes and showed higher functional Disabilities of the American Shoulder and Hand scores with resolution of elbow PJI via permanent resection [6]. Therefore, even with the paucity of literature available, permanent resection should be considered for chronic elbow PJI that fails to respond to other treatment modalities.

In brief, the permanent resection has been suggested for frail patients with low functional demands or for patients who are not interested in additional reconstructive surgeries [1,2,7,11]. The aim of treatment should be the eradication of infection, relief of pain and improved functions [1,4,11]. Contrary to what is known, persistent infection is a frequent complication [8]. Given this finding, all of the infected tissue and foreign materials should be removed [1,7,11,12]. However, aggressive debridement and removal of the well-fixed implants result in loss of bone stock [1,11]. This condition increases the instability risk which is directly correlated with poor functional outcomes [1]. Both condyles should be preserved as much as possible so that a new effective fulcrum might be created, which would make it possible to achieve a stable new elbow joint [8,9,11]. In order to achieve favorable functional outcomes and soft tissue stability, the integrity of the triceps mechanism should be preserved [12] and immobilization should be ensured for a minimum of six weeks postoperatively by casting or bracing [1].

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QUESTION 5: What is the role of arthrodesis when treating a chronic elbow periprosthetic joint infection (PJI)?

RECOMMENDATION: There is a very limited role for arthrodesis of an infected elbow, as this procedure usually results in painful nonunion and poor functional outcomes.

LEVEL OF EVIDENCE: Limited

DELEGATE VOTE: Agree: 100%, Disagree: 0%, Abstain: 0% (Unanimous, Strongest Consensus)

RATIONALE

The incidence of deep infection after total elbow arthroplasty (TEA) has been reported to be 3–13.3% [1–4]. It has been widely accepted that elbow PJI is difficult to treat and has poor outcomes [1,2,5]. Compared to knee and hip arthroplasties, relatively high infection rates [2] and poor outcomes [6] have led to an assessment of the efficacy of different treatment procedures [2,5]. Treatment modalities include debridement with prosthetic retention, resection with subsequently staged reimplantation, staged reconstruction with composite allograft, permanent resection and arthrodesis [2–9].

Among the aforementioned treatment modalities, arthrodesis must be the last choice and should be regarded as a salvage procedure. Functional limitation after arthrodesis cannot be compensated by adjacent joints [8,10,11]. Small contact areas of the remaining bone stock and high moments generated by the long lever arm preclude obtaining solid bone fusion [8,11,12]. Even if fusion can be achieved, it has been reported that humerus fracture risk increases in longer follow-up [13]. Arthrodesis has been reported to be a successful treatment only if there is adequate bone stock, good soft tissue envelope and sufficient vascular supply [8,14,15]. However, in majority of patients with elbow PJI, there are bone defects due to the destructive effect of infection, removal of bone as part of treatment of infection, vascularity is impaired and soft tissue coverage may be insufficient secondary to recurrent surgical interventions [2,5,12–16].

Wolfe et al. described two patients treated with arthrodesis after elbow PJI [9]. The authors reported a painful fibrous union in one patient and a persistent infection in the other. In the limited literature evaluating the treatment of arthrodesis after elbow PJI, the largest series (by Otto et al.) consists of five patients [11]. The authors reported that no union was achieved in any of the patients, and there was asymptomatic fibrous union in only two patients (40%) at the last follow-up. In that study, high reoperation rates and high complication rates were emphasized, and arthrodesis was not recommended for the elbow PJI.

Severe bone loss in this patient group was seen as an important cause of treatment failure. Thus, Koller et al. described an arthrodesis technique using double fibular strut graft and reported favorable results in a patient at the 12-month follow-up [10]. The arthrodesis of the radius to the humerus described by Presnal et al. aimed to surpass nonunion caused by the massive bone loss in the ulna [8]. Nevertheless, according to widely accepted view, arthrodesis treatments for the elbow PJI have poor outcomes and high reoperation rates, and it is not recommended except in special conditions [4,9,14–18]. It might be considered in the case of a failure of resection arthroplasty due to instability [15,17], especially when control of sepsis due to the mobility of the articulation is not possible [14] and also in young patients who do heavy bodily work [18]. Because of the limited literature and small case series, the role of arthrodesis in the treatment of elbow PJI could be evaluated with a limited level of strength.

Treatment of elbow PJI has centered on antibiotics, surgical debridement and retention or staged reimplantation [1]. In some cases where the joint is extremely damaged or seems unsalvageable, arthrodesis may be a viable treatment choice to avoid amputation [1]. Traditionally arthrodesis of the elbow has only been used when all other motion-preserving interventions are declared not possible and studies have reported elbow arthrodesis results in more impairment than hip, knee or ankle joint arthrodesis [2,3]. Koch and Lipscomb report that arthrodesis should be considered only when there is sufficient tissue damage to prevent reimplantation following TEA PJI, and in these cases they reported a 15% delayed complication rate [13].

Literature examining the success of elbow arthrodesis for chronic PJI is limited. There have been no level I, II or III studies, and only two level IV studies have examined the use of arthrodesis for chronic elbow PJI related to tuberculosis [5,6]. A recent review article suggested that evidence to support the use of arthrodesis is