Based on our evaluation of the shoulder arthroplasty literature and consideration of data on hip and knee arthroplasty, we believe that aspiration of the shoulder joint being investigated for PJI may provide important information and should be attempted, when possible. We realize that a substantial number of these joint aspirations are likely to be dry or yield inadequate synovial fluid to allow all analyses. We also realize that shoulder joint aspiration can be performed with minimal risk and could provide critical information regarding the infective organism(s) and allow determination of the antibiotic sensitivity prior to surgical intervention.

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2.5. DIAGNOSIS: SAMPLING

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QUESTION 1: Should tissue samples be obtained for culture in all revision shoulder arthroplasties?

RECOMMENDATION: Tissue samples should be obtained for culture in all revision shoulder arthroplasties when there is suspicion for infection.

LEVEL OF EVIDENCE: Consensus

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

RATIONALE

Prosthetic ioint infection (PJI) is a devastating complication following shoulder arthroplasty and varies between 0-5% with increasing risk in revision arthroplasty [1,2]. As such, organism identification and appropriate antibiotic administration is essential.

The failure to address infection without the relevant antimicrobial therapy results in poor outcomes with Coste et al. [3], reporting 30% residual infection when infected shoulder arthroplasty was treated with resection arthroplasty alone and 60% residual infection when purely antibiotic treatment was advocated. The appropriate surgical procedure, combined with the relevant antibiotic therapy, is therefore integral to the effective management of revision shoulder arthroplasty.

Aseptic loosening can be indistinguishable from acute infection and unexpected positive cultures are not uncommon and can be as high as 29% [4,5]. This is particularly relevant when considering the indolent nature of *Cutibacterium acnes*, a common shoulder pathogen, which can be isolated in as high as 60% of revision shoulder arthroplasties in which there were no positive preoperative or intraoperative investigations suggesting infection [5]. Tissue samples for culture should therefore be undertaken at the time of the procedure to both diagnose and confirm infection. Indeed, even in the presence of known infection, alternative organisms can be reported at the time of revision, which can also influence postoperative antibiotic therapy.

Interpreting positive cultures in a previously regarded aseptic revision can, however, be difficult due to false positives from contaminates. False negative results can also prove a challenge, particularly with regard to *Cutibacterium*, which can take 8-10 days to grow [6]. Extended culture incubation for a minimum of 10-14 days is, therefore, recommended [6,7]. Notwithstanding this, the multifocal and low-grade nature of chronic infection can lead to false negative cultures, and sampling bias must, therefore, be considered as a cause for negative cultures.

Mathematical modelling techniques have been utilised to mitigate the risk of false negatives, and it has been proposed that, following five or six specimens in predominantly revision hip and knee arthroplasty, infection can be diagnosed in the presence of three or more positive cultures [8]. In shoulder specific publications a minimum of four specimens have been advocated [9]. Furthermore, aseptic sampling techniques are imperative to minimize the risks of false positives [7,8,10].

Despite this, however, the staged treatment of infected shoulder arthroplasty can still result in residual infection with persistent infection reported in up to 22% of two-stage revisions which had completed implant explantation, debridement, antibiotic spacer and intravenous antibiotics for six weeks [11]. Tissue sampling and culture at the second stage of a two-stage revision shoulder arthroplasty is, therefore, still recommended to ensure optimal outcomes.

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QUESTION 2: Is there a role for obtaining tissue cultures when performing an irrigation and debridement (I&D) for hematoma after shoulder (primary or revision) arthroplasty?

RECOMMENDATION: Deep tissue samples should be routinely obtained and sent for culture when performing an I&D for hematoma after shoulder (primary or revision) arthroplasty.

LEVEL OF EVIDENCE: Limited

DELEGATE VOTE: Agree: 64%, Disagree: 28%, Abstain: 8% (Super Majority, Weak Consensus)

RATIONALE

A literature search of PubMed and Medline using the terms "shoulder" and "hematoma" resulted in 337 citations. After review of the abstracts, 11 articles that pertained to the topic of hematoma after shoulder arthroplasty were identified for full review. Due to the limited literature on hematoma and shoulder arthroplasty, references on the management of hematoma after total hip and knee arthroplasty were used in the development of this recommendation.

Postoperative hematoma is a known risk factor for prosthetic joint infection following hip and knee arthroplasty [1–3]. Although the supporting literature is scant, hematoma is often cited as a risk factor for the development of deep infection following shoulder arthroplasty as well [4–9]. A study by Cheung et al. retrospectively reviewed 3,541 primary and 606 revision shoulder arthroplasties and found that hematoma formation following shoulder arthroplasty was often accompanied by positive intraoperative cultures [9]. However, only 12 patients (30%) required hematoma evacuation. Nine of these patients had intraoperative cultures sent, and the cultures were positive in six patients. Two of the 12 patients ultimately required resection arthroplasty for deep infection.

In a case-control study Nagaya et al. found that patients with local hematoma formation after total shoulder arthroplasty and hemiarthroplasty had an increased risk for prosthetic joint infection (odds ratio (OR) = 7.10, 95% confidence interval (CI) 1.09-46.09, p = .04) on univariate analysis [10]. This association was lost in the multivariate analysis likely secondary to the low reported infection rate, although a trend towards significance persisted (OR = 6.51. 95% CI .84-50.70, p = .074).

While multiple other studies examining risk factors for the development of prosthetic joint infection following shoulder arthroplasty have been published, most do not specifically address the issue of hematoma formation. Some studies simply did not systemically collect data pertaining to hematoma formation [11–13] or, if they did, did not explore the statistical relationship between hematoma formation and subsequent prosthetic joint infection [8,14–19]. A few studies combined hematoma formation with other complications (e.g., wound dehiscence, superficial infection) when determining statistical associations with infection, making it difficult to determine the specific impact of hematoma formation alone [20,21].

Werner et al. reported on 58 consecutive patients undergoing reverse total shoulder arthroplasty and found that of the 12 patients (20%) requiring treatment for postoperative hematoma none developed any further complications requiring revision [22]. The rate of hematoma formation in the latter study, however, appeared to be very high compared to other reports, which may limit the generaliz-