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QUESTION 3: Should bone graft be removed in patients with postoperative spine infection? If yes, should a distinction be made between allograft and autograft?

RECOMMENDATION: Bone graft need not be routinely removed following irrigation and debridement, especially if partially incorporated. However, loose or purulent graft should be considered for removal. Retained allograft may increase the risk for requiring repeat debridement compared to autograft.

LEVEL OF EVIDENCE: Limited

DELEGATE VOTE: Agree: 87%, Disagree: 0%, Abstain: 13% (Super Majority, Strong Consensus)

RATIONALE

No literature could be found that directly stratified patients who had bone graft retained versus removed. Weinstein et al. studied 46 postoperative infections in 2,391 patents [1]. In their regimen, bone graft material that appeared viable was left in place and instrumentation was retained as well. After six weeks of antibiotics, all of the wounds healed. Massie et al. similarly reported that bone graft may be retained and rarely is it necessary to remove all bone graft [2]. Ahmed et al. also showed in their retrospective review that debridement and antibiotics with implant and bone graft retention (allograft and autograft) can result in complete eradication of infection [3].

Nonetheless, bone graft loosened by irrigation may be removed. It seems rational that unincorporated bone graft and loose, dead bone serves as a continued nidus for infection and as such should be removed [4]. Multiple authors thus recommend thorough irrigation and debridement with removal of nonviable, purulent and loose graft material. However, this appears largely based upon intuition and not strict evidence.

There is limited evidence that perhaps autograft is better tolerated in the setting of an infection. Dipola et al. created a predictive model to differentiate patients requiring one versus multiple debridements [5]. The use of bone graft rather than autograft

was shown to be predictive of requiring multiple debridements. Perhaps, therefore, closer attention ought to be given to the viability and infection burden in patients with allograft. However, no specific recommendations can be given and this should be considered on a case-by-case basis, with considerations of host status, infectious organism and infection burden.

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QUESTION 4: What are the indications for implant retention or removal of hardware in spinal infections?

RECOMMENDATION: In early or acute infections, debridement with retention of the implant might be possible and should always be favored, as removal of the implant carries a great risk for non-fusion despite the risk of chronic low-grade infections with possible implant loosening. In late infections, removal is recommended if feasible.

LEVEL OF EVIDENCE: Consensus

DELEGATE VOTE: Agree: 87%, Disagree: 7%, Abstain: 6% (Super Majority, Strong Consensus)

RATIONALE

Similar to periprosthetic joint infections (PJI), several authors recommend that in early spinal implant-associated infections (within one month after surgical treatment or symptom duration less than three weeks), a debridement with retention of the implant constitutes a sufficient treatment strategy [1–5]. However, their recommendation is based on a retrospective, small case series of patients. There

are also reports describing continuous irrigation in early infections [6,7], but no controlled studies with non-continuous irrigation are published.

In chronic infections, which are often caused by low-grade pathogens, such as coagulase-negative staphylococci or *Cutibacterium acnes*, removal of implants is regarded as the treatment of

choice [3,8–10]. Infections with low-grade pathogens often present in a delayed fashion so that the implant-associated biofilm is mature and bacteria in the biofilm cannot be killed by antibiotics only or debridement with retention of the implant. In addition, patients with chronic infections often present with pseudarthrosis [11]. Hedequist et al. retrospectively reported on 26 chronic infections in which curing was only achieved after removal of the implants with prior unsuccessful treatment attempts with implant retention [12]. In six patients, hardware reimplantation was needed due to progression of the underlying deformity (curve progression). Implant removal carries the risk of disc collapse, lack of fusion, loss of normal lordosis and pseudarthrosis [3,13], which have to be considered.

There are no recommendations as to whether only the dorsal instrumentation or the interdiscal cage should be removed as well for successful treatment. In addition, no prospective clinical trials comparing removal versus retention of the implant in chronic infections exist. Lall et al. nicely summarized treatment regimens of deep wound infections after spinal instrumentation [14].

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QUESTION 5: Is there a role for one-stage exchange of hardware in the presence of spinal infections?

RECOMMENDATION: There is insufficient data on one-stage exchange of hardware in the presence of spine infection.

LEVEL OF EVIDENCE: Consensus

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

RATIONALE

Evidence supports debridement and implant retention in early implant-associated infections. In delayed implant-associated spine infections, evidence favors hardware removal followed by a course of antibiotics. Even if solid fusion is present, significant loss of correction can occur, posing the question of whether one-stage exchange of hardware would be adequate [1]. It is established that placing spinal instrumentation into an infected spine is safe when necessary for spinal stability and eradication infection, with low recurrence and reoperation rates [2]. Data on hardware one-stage exchange in deep infections with instrumentation is lacking.

Infection following instrumented spinal fusion can result in significant morbidity to the patient, resulting in prolonged hospitalization, chronic pain and need for revision surgery. In addition to the morbidity, the economic impact of this type of infection to the healthcare system and patient cannot be overstated. Several risk factors associated with the development of surgical site infection (SSI) following instrumented spinal fusion have been identified

[2–4]. Management of superficial infection typically consists of oral or intravenous (IV) antibiotics, with surgical intervention reserved for failure of medical management, symptomatic deep infections or draining wounds with soft tissue compromise. Treatment of deep infections surgically is complicated by the presence of spinal instrumentation. Eradication of infection is the primary goal of surgery, however premature removal of instrumentation can result in pain, pseudoarthrosis and deformity [5–7].

Several series have been published illustrating successful treatment of deep wound infection with irrigation debridement and retention of original instrumentation [8–14]. Picada et al. published on a series of 26 patients with infection following instrumented spinal procedures, with 24 (92.3%) successfully treated with surgical debridement, intravenous antibiotics, nutrition optimization and primary or delayed secondary closure [13].

Kowalski et al. retrospectively reviewed the management of 81 patients with infections following spinal instrumentation. The