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

cohorts were defined by early and late onset infection [9]. Of the patients with early onset infection, 28 of 30 were treated with irrigated debridement and retention of hardware with predicted probability of treatment success at two years being 71%, while patients with late onset infections required removal of hardware to achieve an 84% probability of treatment success at two years. Maruo et al. retrospectively reviewed a series of 225 consecutive patients with SSIs following spinal surgery [10]. Of those, 126 or 76% were successfully treated with surgical debridement, IV antibiotic therapy and retention of hardware. Failure of this treatment strategy was associated with late infection, long constructs with pelvic fixation, *Propionibacterium acnes* speciation and poly-microbial infection.

Nunez-Pereira et al. published on a series of 43 consecutive patients with SSI treated with surgical debridement and targeted antibiotic therapy with retention of original instrumentation [11]. At a 26-month follow-up, 10 patients (23.3%) failed, requiring removal of hardware, or died. Multivariate analysis found treatment failure associated with sepsis and long constructs (> three levels fused). Tominaga et al. published a retrospective series of 16 consecutive patients who developed SSI following spine instrumentation over an eight-year span [15]. Twelve of the 16 cases (75%) were successfully treated with retention of hardware, with failure associated with long instrumented constructs, previous spinal surgery, low preoperative hemoglobin, high preoperative creatinine and methicillin-resistant *Staphylococcus aureus* (MRSA) speciation. DiPaola et al. developed a predictive model determining the need for single versus multiple irrigation and debridement procedures to successfully eradicate postsurgical spinal infection [8]. The authors identified MRSA-positive cultures, bacteremia, non-autogenous bone graft and diabetics as predictive for requiring multiple debridement procedures. Vacuum-assisted closure (VAC) can be used to help facilitate wound healing following irrigation and debridement with hardware retention for spinal infection [16].

There are several studies illustrating the successful management of SSI following spinal instrumentation with surgical debridement, IV antibiotic therapy and primary or delayed secondary closure. Factors consistently associated with treatment failure included late infection, long constructs with pelvic fixation, *C. acnes*/MRSA speciation and bacteremia. Patients with these characteristics should likely have removal of hardware in addition to surgical debridement. Multiple debridement procedures may be required to successfully treat the infection, which can be assisted by the use of a wound VAC.

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3.4. TREATMENT: WOUND CARE

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QUESTION 1: Should infected wounds undergo primary closure or a two-stage closure?

RECOMMENDATION: The current recommended practice for spine wounds remains primary closure in the majority of postoperative infections. However, there may be circumstances when primary closure of the wound may not be possible or preferred. This may include patients with grossly contaminated traumatic wounds, patients with persistent wound drainage when attempts to address drainage have failed or patients with severe soft tissue loss when primary closure is not possible.

LEVEL OF EVIDENCE: Consensus

DELEGATE VOTE: Agree: 93%, Disagree: 0%, Abstain: 7% (Super Majority, Strong Consensus)