approaches. In 9 out of 10 cases, solid bone fusion was achieved via an anterior procedure consisting of cage removal and the use of autogenous iliac bone graft to fill the interbody space [16]. An anterior approach for removal of a posteriorly-placed interbody cage prevents complications associated with epidural scar tissue and fibrosis due to the inflammatory response to the original surgery and infection process [16].

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QUESTION 2: Is there a length of time of infection beyond which instrumentation should be removed?

RECOMMENDATION: **The data suggests that early infection can commonly be treated with implant retention and debridement followed by intravenous (IV) antibiotics and common oral antibiotic treatment. If the patient has achieved spinal fusion, the implants can be safely removed. In the setting of pseudarthrosis, thought should be given to removal of implants to eradicate infection followed by re-instrumentation.**

LEVEL OF EVIDENCE: Limited

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

RATIONALE

The primary goals of treating postoperative spinal surgical site infections (SSIs) are to eradicate the infection, maintain stability and achieve fusion (when warranted). While the decision to retain existing instrumentation in the setting of an acute infection may be necessary for maintaining stability or promoting fusion, this may jeopardize the surgeon's ability to completely eradicate the SSI. The preponderance of available evidence suggests the ability to both retain hardware and successfully eradicate the infection depends on the acuity of the presentation, with early diagnoses of SSI (within 30 to 90 days after index procedure) having higher rates of successful retention after debridement and IV antibiotics, while deep infections over one year commonly require removal.

Several studies have demonstrated successful eradication of infection with debridement and hardware retention for early-onset SSI. Patel et al. reviewed surgical debridement and retention of instrumentation in 17 patients with SSI after spinal arthrodesis ranging from 1 to 6 weeks after the index procedure, noting eradication of infection in all patients and successful fusion in 15 of 17 (88.2%) [1]. Sierra-Hoffman et al. reported successful instrumentation retention with early onset (< 30 days) SSIs with debridement and long-term antibiotics alone, noting eradication of infection in 17 out of 19 (89.5%) patients. However, six of the seven late infections (> 30 days) ultimately required instrumentation removal for eradication of the infection [2].

Pull ter Gunne et al. noted that their management of SSI involved aggressive debridement (89.3%) with hardware retention (if stable) and revision of hardware (if unstable), followed by an average of 40 days of antibiotics. With this protocol, 76% of their deep infections were eradicated with a single debridement, although no comment was made about the chronicity of the SSI prior to reoperation [3]. Kowalski et al. reported on 30 acute SSIs (< 30 days) with 80% successfully retaining implants with surgical debridement and IV antibiotics followed by oral suppressive antibiotics [4]. Tominaga et al. reviewed risk factors for unavoidable removal of instrumentation after SSI < 90 days, finding that 12 of 16 cases successfully retained implants after debridement and IV antibiotics, but noted that 3 of 4 failures grew methicillin-resistant *Staphylococcus aureus* (MRSA) on operative cultures, compared with only 1 of 12 successfully-treated cases diagnosed with MRSA [5]. Nunez-Pereira et al. reported 43 patients with acute SSI after posterior spinal fusion requiring debridement and IV antibiotics for at least 8 weeks, finding 90.7% survival (survival to follow-up timepoint with avoidance of implant removal) at 6 months, 85.4% at 12 months, and 73.2% out to 4 years [6]. Multivariate analysis revealed a significant risk of treatment failure in patients who developed sepsis (hazard ratio 12.5 [95% confidence interval 2.6 to 59.9]; $p < 0.001$) or who had more than three fused segments (hazard ratio 4.5 [95% confidence interval 1.25 to 24.05]; $p = 0.03$) [1].

Accurately predicting the number of required debridements to eradicate the SSI can be challenging. Thalgott et al. identified that initial debridement culture results and the patient's comorbidities, including systemic disease, immunocompromise and malnourishment, are prognostic for the number of debridements required. Healthy patients with less virulent bacteria commonly required a single debridement, while immunocompromised hosts, multiple and/or more virulent organisms, and polymicrobial infections often require multiple debridements [7]. DiPaola et al. evaluated risk factors predicting multiple debridements, identifying MRSA and distant site infection as the strongest predictors, and diabetes mellitis, the presence of instrumentation, use of allograft and posterior lumbar spine location also displaying significant associations [8].

Conversely, delayed diagnoses of SSI commonly require implant removal for successful infection eradication. Hedequist et al. found all 26 cases with SSIs presenting greater than 3 months postoperatively required implant removal to definitively clear the infection [9]. Similarly, Kowalski et al. reported 7 out of 13 late diagnoses of SSI (> 30 days) failed debridement and initial implant retention, requiring secondary surgery for implant removal [4]. Tsubouchi et al. noted that although 29 out of 43 patients successfully retained spinal implants for SSI < 30 days postoperatively, only 4 of 12 patients diagnosed later than 30 days and 0 of 4 patients diagnosed later than 90 days successfully retained implants [10]. Garg et al. reported on 42 patients with deep infection more than 1 year postoperatively after spinal fusion, noting that 41 required implant removal and retention attempted in 1 patient failed. Additionally, 27 of the 42 patients showed *C. acnes* on intraoperative cultures [11].

Ho et al. reviewed their experience with pediatric SSI after instrumented fusion for scoliosis, noting that 43 out of 53 (81%) patients had retained implants at their first irrigation and debridement. They found a significant increase in secondary debridement required with implant retention (47%) in comparison to implant removal at the first irrigation and debridement (20%). However, implant removal was associated with a 10-degree or greater curve progression in 60% of patients [12]. Balancing the need for spinal stability and prevention of deformity progression or pseudarthrosis against a more complete eradication of infection remains a case-by-case decision guided by surgeon experience.

Mok et al. reviewed the functional impact of infection after posterior spinal fusion with 12 early (< 90 days) and 4 late (> 90 days) SSIs undergoing debridement with retention of instrumentation, and reported no significant difference in long-term SF-36 outcomes compared with non-infected controls at an average follow-up of 56.7 months [13]. Kuhns et al. similarly compared quality of life (QOL) scores between infected posterior cervical fusions requiring reoperation to noninfected matched controls. While the total projected costs were increased ($21,778 vs. $9,159) and 6-month QOLs were significantly lower for the infected cohort, no significant differences were found in QOL outcomes at the 12-month follow-up [14].

Recent literature has questioned the significance of time-based decision-making for implant removal following SSI and instead has turned to advanced imaging to understand the causes of implant retention failures. Kanavama et al. evaluated preoperative magnetic resonance imaging (MRIs) in SSIs, noting that once vertebral osteomyelitis and/or intervertebral abscess were evident in MR images, all the hardware should be removed [15]. Six of seven patients without osteomyelitis or intervertebral abscess successfully retained implants, while 9 of 13 patients with osteomyelitis or intervertebral abscess ultimately required implant removal and three of four patients who retained implants resulted in loss of fixation stability [15].

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