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

Authors: Carles Pigrau, Gregory Schroeder

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)

RATIONALE

Following surgery, wounds are typically closed in a primary fashion. Alternative methods of wound closure include secondary closure and delayed primary closure. Secondary closure is when wounds are left to close naturally on their own. Delayed primary closure (DPC), a combination of secondary and primary closure, is when a wound is cleaned and left open until infection is controlled, followed by surgical closure of the wound. Delayed primary closure is only used on occasion, typically involving contaminated traumatic injuries.

In their prospective randomized study, Singh et al. found that patients undergoing delayed primary closure of contaminated abdominal wounds related to hollow viscus perforation had lower infection rates (17.5%) and shorter hospital stays (18.1 days) when compared to patients undergoing primary closure (42.5% infection and 20.7 days) [1]. Chiang et al. found a similar result for treatment of perforated appendicitis. Patients randomized to primary closure had an infection rate of 38.9% and an 8.4-day length of stay, while patients randomized to delayed primary closure had an infection rate of 2.9% and a 6.3-day length of stay [2].

DPC has also been shown to result in no long-term issues and not be associated with a higher incidence of complications in pediatric liver transplant recipients [3]. Orthopaedic surgeons are familiar with DPC in the context of fasciotomy wounds in patients with compartment syndrome when delayed primary closure is utilized [4,5].

There are, however, no high-level studies related to the role of DPC in spine surgery. In the absence of concrete evidence, and in borrowing from general surgery and other fields of orthopaedics, we feel that primary closure of a wound is the most preferred method of dealing with wound issues in spine patients. 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 and in patients with severe soft tissue loss when primary closure is not possible.

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Author: Wesley Bronson

QUESTION 2: What is the indication for muscle advancement flaps in patients with spinal infections?

RECOMMENDATION: Muscle advancement flaps are useful to help close wounds with exposed hardware as well as those which fail local treatment/vacuum-assisted closure (VAC) therapy and to help improve infection eradication.

LEVEL OF EVIDENCE: Consensus

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

RATIONALE

Multiple risk factors exist for wound complications following spinal surgery, including diabetes, chronic obstructive pulmonary disease, resection of neoplasm with excision of significant soft tissue and prior radiation. Additionally, infection is often complicated by loss of soft tissue and poor tissue viability, which leads to an inability to close the wound overall, resulting in exposed hardware [1,2].

Even if the wound is able to be closed primarily or following VAC therapy, it is important to recognize that the same factors that led to the infection and wound breakdown in the first place still exist [3]. To that end, local or vascularized muscle flaps provide multiple advantages over simple wound closure or delayed primary closure. Muscle flaps have been shown to increase blood flow and oxygen delivery, and decrease bacterial load [4–6].

It seems rational that wounds that are completely unable to be closed due to large soft tissue defects with exposed hardware or wounds that fail to close following VAC therapy are reasonable indications for flap coverage. But, the absolute indication for flap coverage following wound debridement in an otherwise closeable wound remains unclear. Multiple authors argue that it remains a reasonable option versus irrigation and debridement with immediate or delayed primary closure.

Dumanian et al. reviewed their experience with flap coverage for spinal wounds [7]. Fifteen patients in their group had postoperative wound dehiscence or infection, with 12 patients having exposed hardware. They were treated with either immediate local flap coverage or two to three days of dressing changes followed by flap coverage. Of the surviving 14 patients, 13 had healed wounds at final follow-up, and none required hardware removal. One patient on chronic steroids/immunosuppression had persistent infection treated with chronic suppressive antibiotics.

Chieng et al. performed a systematic review on the use of flaps for management of wound complications [8]. While several case reports and retrospective series present supportive data, the authors note that relying on the data is difficult as no level 1 or level