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QUESTION 5: What is the most appropriate management of early (before complete wound healing) infection after fracture fixation with unstable fixation?

RECOMMENDATION: The most appropriate management of early (prior to complete healing) infection after fracture fixation with unstable fixation consists of surgical debridement with removal of fixation implants, fracture stabilization, antibiotic therapy and soft tissue coverage, if needed.

LEVEL OF EVIDENCE: Consensus

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

RATIONALE

Infection after fracture fixation is a serious complication in orthopaedic trauma surgery, as it may eventually lead to devastating outcomes such as amputation [1]. In contrast with periprosthetic joint infections, literature regarding this condition is still limited considering the number of patients affected [1,2]. Nonetheless, in order to unify the evidence available, major efforts have been made to accurately define "infection after fracture fixation" [3]. The current definition includes a classification according to the onset of symptoms and early infection is considered that which occurs during the first two weeks after the index procedure. [2,4]. For this recommendation, this definition will be maintained.

Several systematic and non-systematic reviews gathered the existing evidence for infection associated with orthopaedic implants. All conclude that antibiotic suppression therapy and surgical debridement with implant retention is a suitable option for the treatment of early infection after fracture fixation when fracture healing has not yet been achieved, but the construct is stable [1,2,4–8]. Therefore, to date, this continues to be the standard of care for early infections. Likewise, the outcomes presented by Trebse et al. [9], Rightmire et al. [10] and Berkes et al. [11] all showed favorable results for this method of management, with success rates ranging from 68% to 92%. However, the quality of evidence of these studies is low.

The question remains whether implant retention is still a viable option for unstable fixation. Metsemakers et al. [2], in their more recent review, suggest that implant exchange or removal should be considered in early infections when intramedullary devices are used, unstable fixation exists or insufficient fracture reduction is present. These recommendations are based on the works by Trampuz et al. [4], Kleber et al. [12] and Rightmare et al. [10]. Moreover, several animal studies have addressed the importance of fracture stability in implant-related infections [13–15]. When fixation is unstable, implant retention is not an option. The existing implants do not provide enough stability at the fracture site, which will impair fracture healing as well as facilitate persistence of infection.

Even though both Rightmire et al. [16] and Berkes et al. [17] performed a multivariate analysis, neither of them reported "unstable fixation" as a predictor of treatment failure [10,11]. The quality of the presented evidence is low and the methodology used might not have been appropriate to conclude that implants must be removed under these conditions.

After performing a systematic search of the literature, no conclusive evidence on the management of early infection with unstable fixation was identified. Therefore, our recommendation is based on clinical experience, established knowledge of implant-related infection [18] and the management of infected non-unions [19,20]. Furthermore, adequate coverage of the fracture site with a well-vascularized soft tissue envelope facilitates both control of infection and fracture healing. Therefore, in the case of soft tissue defects or scarred soft tissues with poor vascularity, a soft tissue reconstructive procedure is usually necessary [21,22].

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QUESTION 6: What is the appropriate timing of conversion to internal fixation (in-fix) following external fixation (ex-fix)? How is this altered by pin site infection?

RECOMMENDATION: Timing of conversion should be based on patient characteristics including concurrent injuries and premorbid health and function, as well as injury features and location. One-stage conversion appears to have similar or even lower infection rates compared to two-stage conversion. In the absence of pin site infection, early conversion is preferred.

LEVEL OF EVIDENCE: Limited

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

RATIONALE

American development of external fixation is credited to Parkhill in 1897 and European development to Lambotte in 1900 [1]. Ex-fix is often used in polytraumatized patients as part of a damage-control orthopaedic approach, in injuries with extensive soft tissue compromise, or when appropriate personnel or resources for in-fix are not readily available [2,3]. It is applicable to periarticular fractures, long bone fractures and articular dislocations, making it an essential component of contemporary orthopaedic traumatology.

Recent literature review using the databases Embase, Scopus, Google Scholar and PubMed was performed with the search terms "internal fixation," "external fixation," "timing" and "conversion" in multiple combinations. Articles were reviewed for relevance and studies were then assessed for quality and assigned a level of evidence.

Following ex-fix, conversion to in-fix can have multiple benefits for patients. A prospective comparison of 39 patients with open lower leg fractures treated with primary ex-fix with randomized conversion to intramedullary nailing (IMN) or to cast immobilization showed significantly shorter mean time to union (26.3 vs. 35.4 weeks), higher overall consolidation rates (94% vs. 64%), and better knee and ankle range of motion (ROM) for IMN [4]. Regarding timing of conversion from external to internal fixation (which includes plate/screw constructs and intramedullary nail constructs), major questions within the field are as follows: (1) Should conversion be performed in one procedure (acute) or in two (staged)? (2) Does time in ex-fix affect outcomes following conversion? (3) Do pin site infections increase the risk of deep infection following in-fix? (4) Does timing of soft tissue coverage affect outcomes following conversion? [2].

Regarding staging, theoretically staged conversion should allow time for pin site granulation and decrease infection rates. Therefore, some authors recommend delayed internal fixation until pin sites heal closed [5]. However, data from level IV studies do not support this. Horst et al. reported on two protocols, one for immediate conversion and one for staged conversion from external to internal fixation. They included local excision of skin-pin interfaces and curettage of soft tissues around pin track sites. For immediate conversion, pin sites were disinfected and covered prior to re-prepping of the surgical field. Pin sites were left covered until all in-fix wounds were closed, and then pin sites were left open with antibacterial dressings. For staged conversion, ex-fix was exchanged for a cast and any required soft tissue coverage was performed prior to in-fix. After institution of this algorithm utilizing the immediate conversion protocol, they observed a decrease in time to conversion (mean 6.8 > 5.0 days), hospital length of stay (mean 25.4 > 16.3 days) and complication rate (21% > 8.3%) [6].

Monni et al. performed a retrospective review of 18 patients (24 limbs) undergoing conversion from external to internal fixation for traumatic bone defects or congenital deformities. Indications for conversion included patient dissatisfaction with ex-fix, pin track sepsis, persistent non-union or refracture. In-fix consisted of IMN or plate and screw constructs. Conversion was performed acutely (19 limbs) or staged (5 limbs). The outcome was considered excellent if patients were full weightbearing, pain free, had a mechanically well-aligned limb and did not need further surgery within the follow-up period. The outcome was considered good if patients required subsequent surgery to achieve union and the outcome was considered poor if an irreversible complication occurred. The acute group had 16 excellent and 1 good outcomes (89.4%), with 2 (10.6%) poor outcomes resulting in amputation, both after acute conversion to IMN for infected tibial nonunion. The delayed group had four (80%) excellent and one (20%) good outcomes. They cautioned against using IMNs in patients with a diagnosis of an actively septic nonunion and reported that conversion to in-fix generally produces good to excellent results [7]. Bandhari et al. found that shorter intervals between ex-fix removal and IMN, for planned or salvage procedures, correlated with reduced infection, but do comment that in level IV studies this may represent confounding [8].

Farrell et al. reported on ex-fix with one-stage conversion to in-fix for nine calcaneus fractures. Ex-fix was applied within 24-48 hours and converted to open reduction and internal fixation (ORIF) through a sinus tarsi approach at an average of 4.8 days from ex-fix. There were no pin tract infections, deep infections or wound healing complications [9]. Natoli et al. reported on 16 complex distal radius fractures, 11 of which were open, and treated with an ex-fix and converted to ORIF at a mean of 8.5 days. One patient developed deep infection, and they did not report a relationship with open fractures, time to conversion of < or > 7 days, or ex-fix pins overlapping the definitive fixation [10]. Shah et al. reported on pilon and tibial plateau fractures treated with ex-fix converted to ORIF excluding cases with evidence of overt pin site infection. They demonstrated a 24% rate of deep