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Review article

Operative treatment of early infection after internal fixation of limb fractures (exclusive of severe open fractures)

P. Bonnevialle

Département d'orthopédie traumatologie, CHU de Toulouse, hôpital P.P.-Riquet, place Baylac, 31052 Toulouse cedex, France

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ABSTRACT

Early infection after open reduction and internal fixation (ORIF) of a limb bone is defined as bacteriologically documented, deep and/or superficial surgical-site infection (SSI) diagnosed within 6 months after the surgical procedure. This interval is arbitrarily considered sufficient to obtain fracture healing. The treatment of early infection after ORIF should be decided by a multidisciplinary team. The principles are the same as for revision arthroplasty. Superficial SSIs should be differentiated from deep SSIs, based on the results of bacteriological specimens collected using flawless technique. A turning point in the local microbial ecology occurs around the third or fourth week, when a biofilm develops around metallic implants. This biofilm protects the bacteria. The treatment relies on both non-operative and operative measures, which are selected based on the time to occurrence of the infection, condition of the soft tissues, and stage of bone healing. Both the surgical strategy and the antibiotic regimen should be determined during a multidisciplinary discussion. When treating superficial SSIs after ORIF, soft-tissue management is the main challenge. The treatment differs according to whether the hardware is covered or exposed. Defects in the skin and/or fascia can be managed using reliable reconstructive surgery techniques, either immediately or after a brief period of vacuum-assisted closure. In deep SSIs, deciding whether to leave or to remove the hardware is difficult. If the hardware is removed, the fracture site can be stabilised provisionally using either external fixation or a cement rod. Once infection control is achieved, several measures can be taken to stimulate bone healing before the end of the classical 6-month interval. If the hardware was removed, then internal fixation must be performed once the infection is eradicated.
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1. Introduction

Early infection complicating open reduction and internal fixation (ORIF) of a limb fracture is often a challenge for both the surgeon and the patient. The patient may view the infection as a second unfair blow dealt by a surgeon who cannot be trusted, and the surgeon is legally liable for the outcome [1]. Early infection complicating ORIF is defined as bacteriologically documented surgical-site infection (SSI) that may be either deep or superficial and that develops within 6 months, the interval arbitrarily considered sufficient to achieve bone healing. In practice, this time limit excludes infected non-union and arthroplasty for fracture repair. For purposes of uniformity, severe open fractures, which carry a high risk of infection, are excluded also.

The incidence rate of early SSIs after scheduled arthroplasty has been extensively studied. In contrast, data are scarce for early post-traumatic SSIs, whose incidence rate has been estimated at 1 to 4%, with variations according to the fracture site and circumstances of the injury [2]. Few French-language articles report studies designed specifically to assess post-traumatic infections [3–5]. This situation warrants the review presented herein.

Although revision surgery occupies a place of prominence in the treatment of early SSIs complicating ORIF of long-bone fractures (SSI-ORIF), a multidisciplinary team of specialists must be involved in the treatment decisions. The treatment principles closely resemble those used for revision arthroplasty procedures [6].

This conference is based on a literature review that gave preference to recent work in large patient samples and/or to studies by French authors and medical-surgical teams in university hospitals. The key issues can be addressed via six questions.

2. What are the definition and diagnostic criteria for SSI-ORIF?

2.1. Current opinions

Early fracture-site colonisation by one or several bacteria is the simplest definition. The depth of the infection may be challenging to

E-mail address: ventre.s@chu-toulouse.fr

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determine, however, particularly as the long limb bones (humerus, radius, ulna, femur, and tibia) are covered by layers of skin, fascia, and muscle that vary in thickness. Guidelines about SSIs distinguish superficial SSIs, which affect the incision but do not extend to the fracture site, and deep SSIs, defined as established infection of the bone at the fracture site [7]. The diagnosis of SSI-ORIF may be strongly suggested by systemic clinical manifestations and/or clinical abnormalities confined to the incision or to the involved limb segment. The definitive diagnosis requires a positive bacteriological culture of specimens taken from the surgical site.

2.2. Data from the literature

Two comments are in order regarding the impact of skin breaks over a fracture of a long limb bone:

- everyday practice teaches that local outcomes are often less favourable after ORIF than after elective surgical procedures, particularly when the skin and adjacent soft tissues are damaged during the injury. This fact prompted Oestern and Tscherne to develop a classification for soft tissue injuries adjacent to fractures under intact skin [8];
- disorders in healing of the traumatic and/or surgical wounds may occur during the first few post-operative weeks. Similar healing disorders have been reported after prosthetic surgery. Presentations include wound inflammation, a serous discharge, and partial dehiscence [9]. Healing disorders may resolve completely or progress to infection. They differ from superficial SSIs in that the bacteriological samples are negative. However, the sample results must be subjected to a critical analysis by both the bacteriologist and the surgeon [4,5]. Careful attention must be given to the management of healing disorders. Changes over time should be monitored by regular inspections by the surgeon and/or photographs filed in the patient's medical record.

Superficial SSI is characterised by bacterial colonisation of the skin and subcutaneous tissue that does not extend in depth through the barrier of muscles and fascia overlying the fracture site. Both the anatomic relationships of the fracture site and the fixation technique used play a major role in the course of superficial SSIs. Thus, when the fracture site is located immediately under the subcutaneous tissue and, most importantly, when latero-cortical fixation material is implanted, spread of the infection beyond the superficial plane is virtually unavoidable.

Both the clinical and the bacteriological features of SSI-ORIF deserve attention. There are three main clinical presentations:

- a purulent discharge from the incision and/or surgical site with a fever, although strongly suggestive, is the least common presentation;
- healing disorders and/or unwanted and unusual local symptoms (local or regional pain or joint stiffness) are less obvious signs of infection;
- absence of radiological evidence of bone healing after a few months, with or without incipient fixation failure, may also indicate an infection.

Laboratory abnormalities may contribute to the diagnosis. However, in the early post-operative period, changes in laboratory parameters are non-specific. They may reflect the inflammatory response to the traumatic and surgical insults. For the serum C-reactive protein (CRP) level, the change over time is more helpful than the absolute value [10]. Imaging studies are of limited usefulness during the first few weeks, as they may fail to show changes over time. Nevertheless, ultrasonography and computed tomography (CT) with specific sequences may visualise a deep collection around the bone and guide needle aspiration.

The definitive diagnosis of SSI-ORIF requires identification of a micro-organism within the surgical site. Presence of a micro-organism is the only objective finding that differentiates infections from healing disorders. Consequently, scrupulous technique must be used when collecting the samples. Swabbing is unreliable, because the surgical incisions and traumatic lacerations are usually contaminated by the resident flora [11]. If antibiotics were started before sampling, they must be stopped, to ensure that reliable and informative samples are obtained. Bacteriological sampling is a diagnostic investigation performed by the surgeon after discussion with the bacteriologist. The bacteriologist should be informed of the patient's clinical details and asked to maintain the cultures for prolonged periods if an infection due to a slow-growing organism is suspected.

The sampling technique varies with the condition of the skin [12].

- if the wound is healed, skin preparation is the same as for ORIF: local and regional detersion, rinsing, and painting with an antiseptic agent. The surgical approach and/or fracture site are aspirated using either a large bore needle or a catheter on a metallic guidewire;
- in the event of wound dehiscence or discharge from a fistula, samples are obtained using a semi-rigid catheter that is gradually advanced as deeply as possible into the surgical site down to the bone;
- during early revision surgery for any reason, multiple deep samples should be obtained routinely from the surgical site.

The optimal number of samples depends on the local conditions and amount of abnormal tissue or fluids. Five is the recommended number of samples. However, the collection of three samples from different sites spaced as far apart as possible is acceptable. The surgeon must ensure that the samples are carried promptly to the laboratory and accompanied with a detailed description of the clinical features. Samples are sent in a sterile vial for smears and cultures and in a heparinised vial for cytological testing. If the sample is small or the time to arrival at the laboratory exceeds 2 hours, preference should be given to enriched culture media such as those used for blood cultures.

The results should be interpreted and discussed with the bacteriologist to reach a consensus about whether the patient has SSI-ORIF. Identification of a pathogenic micro-organism (e.g., *Staphylococcus aureus*) in a superficial sample can be considered definitive proof of SSI-ORIF. Presence of a commensal micro-organism in the surgical site is far more challenging to interpret. The number of positive samples, local clinical appearance, constitutional symptoms, and laboratory test results should be taken into account.

2.3. In conclusion

During the early post-operative period after ORIF, a variety of healing disorders may develop. The bacteriological samples are negative. Healing disorders do not indicate an infection but may promote the development of an infection.

An SSI should not be considered superficial when the fractured bone lies immediately under the skin.

The clinical and laboratory manifestations may be more or less suggestive of SSI-ORIF. The definitive diagnosis is established when an organism is recovered from at least three, and optimally five, samples taken from sites in contact with the hardware and/or from the deepest portion of the surgical approach.

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