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ORIGINAL ARTICLE

Post-traumatic bone and/or joint limb infections due to *Clostridium* spp.

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KEYWORDS

Wound infection;
Bone infection;
Anaerobic;
Clostridium;
Spores

Summary

Background: *Clostridium* spp. are saprophytic Gram-positive bacteria found in soil and capable of generating endospores. Spore germination occurs when environmental conditions are favorable. *Clostridium* spp. can cause infections of compound fractures and deep wounds contaminated from soil micro-organisms.

Hypothesis: *Clostridium* spp. infections of traffic-related injuries are particularly severe events whose outcome is uncertain even with aggressive medical and surgical treatment.

Materials and methods: We retrospectively reviewed 12 patients (median age, 45 years) with *Clostridium* spp. bone and/or joint infections complicating compound limb fractures with soil contamination and extensive soft-tissue damage. Prophylactic amoxicillin-clavulanic acid therapy was administered, followed by emergency surgical wound debridement and lavage. Fracture fixation was performed immediately in nine patients (external in four and internal in five) or at a later time on three patients. The immediate outcome was unfavourable in all 12 cases, requiring early reoperation after a median of 10 days (range, 5–25 days).

Results: Median time to *Clostridium* strain identification was 14.5 days (range, 5–160). All infections were polymicrobial. Surgical wound excision, hardware removal (in four cases), and antibiotic therapy produced a favourable outcome in one patient, with no recurrence after 2 years of follow-up; the outcome was unfavourable in 11 cases, with delayed fracture union,

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septic non-union, impaired healing, and/or chronic sinus tract drainage. Several second-line treatments were used in these 11 patients: intramedullary nailing without bone grafting in four patients, with three failures; decortication and grafting in two patients, with failure in both; nailing with decortication in one patient, who had a good outcome; and the induced membrane procedure described by Masquelet in four patients, all of whom had good outcomes. After a median follow-up of 24 months (range, 18–53 months), the bone infection had subsided in eight patients. The remaining four patients had septic non-union.

Discussion: *Clostridium* spp. infections are particularly severe. The diagnosis is delayed and identification of the organism is challenging. The treatment is difficult and results in unfavorable outcomes in one-third of cases. The identification of *Clostridium* in specimens from an osteoarticular infection indicates a need for extremely extensive and aggressive surgical resection, as spore resistance may impair the in vivo efficacy of antimicrobial agents.

Level of evidence: IV (retrospective cohort study).

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Introduction

Clostridium spp. are Gram-positive rods that are obligate anaerobes found in soil and capable of producing endospores [1]. Some species (e.g., *C. tetanii*, *C. botulinum*, *C. difficile*, and *C. perfringens*) release toxins that cause acute clinical disorders (e.g., tetanus and botulism) [2]. When the environmental conditions are unfavourable, *Clostridium* spp. produce endospores that are highly resistant to physical and chemical factors in the environment (soil or water) [1,3]. In humans, the spores may result in chronic and recurrent infections [4]. Although the spores produce no clinical manifestations, they germinate when the conditions become more favourable, generating a population of actively dividing bacteria [1]. Many trauma-related injuries are at high risk for *Clostridium* spp. infection, most notably severely soiled open fractures or wounds, which may be massively contaminated with environmental micro-organisms.

Nevertheless, although *Clostridium* spp. are ubiquitous in the environment [3] and open trauma is common [5], osteoarticular infections with *Clostridium* spp. are rare. There is a paucity of published data on these infections, their treatment, and their outcomes [2,6–15].

Here, we hypothesized that post-traumatic *Clostridium* spp. infections were particularly severe events whose outcome remained unpredictable despite aggressive medical and surgical treatment delivered in a specialised centre (in France, reference centre for complex osteoarticular infections, CRIOAC). We reviewed cases of post-traumatic osteoarticular limb infections due to *Clostridium* spp. Outcomes were assessed after a follow-up of at least 18 months following identification of the organism. Our goal was to develop suggestions about the optimal medical and surgical management.

Material and methods

We conducted a single-centre retrospective study at the Institut Locomoteur of the Toulouse Teaching Hospital in Toulouse, France. The electronic database of the hospital's bacteriology laboratory was searched (MA, JL) for adult patients with limb trauma and at least one specimen taken in the operating room and positive for *Clostridium*. We identified

23 patients who met these criteria between April 2006 and March 2010. Among them, 11 were excluded (two with superinfected heel pressure sores and no history of trauma, one with impaired healing after treatment for a benign tibial tumour, one with hip arthritis after impaired healing complicating a closed ankle fracture with hematogenous contamination, one with surgical-site infection after a closed fracture, one with infection after finger amputation by a lawnmower, one with a compound pelvic fracture, and four with soft-tissue infections in the absence of osteoarticular involvement). The remaining 12 patients had osteoarticular infections complicating compound fractures of the limbs. There were 10 men and two women with a median age of 45 years (range, 18–77 years). Table 1 reports their main characteristics, including their initial bone and skin injuries according to the classification schemes developed by Cauchoix et al. [16] and Gustillo et al. [17].

Microbiological studies

All specimens were seeded in various enriched culture media than incubated in a CO₂ atmosphere and aerobic conditions for 15 days. *Clostridium* strains were identified using standard criteria, namely, appearance of the colonies, appearance of the Gram-stained organisms, visualisation of spores, and biochemical characteristics documented using ID 32® test strips (BioMérieux SA, Marcy l'Etoile, France). Definitive identification was achieved by 16S RNA sequencing. When the same strain was recovered from several specimens collected on the same day, this strain was studied only once.

Antibiotic susceptibility was assessed using ATB ANA® test strips (BioMérieux SA) and the agar disc-diffusion method (Biorad, Marnes la Coquette, France). Other bacteria recovered in the specimens were recorded (Table 2). All microbiological studies were performed by the same team (MA, JL).

Multidisciplinary medical and surgical management

After collection of the specimens, probabilistic antibiotic therapy was given. Any changes required by the microbiological results were made subsequently. Advice from an

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