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Case report

Septic femoral shaft non-union treated by one-step surgery using a custom-made intramedullary antibiotic cement-coated carbon nail: case report and focus on surgical technique

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Summary. *Background and aim of the work:* In the orthopaedic and traumatological fields septic non-unions represent a severe complication, hard to manage and treat. Traditionally, the surgical technique consists in to two sequential steps: debridement with administration of local and systemic antibiotics associated with temporary stabilization of the fracture and subsequent reconstruction of bone and soft tissues. Recently, the use of some devices to treat septic non-union by one-step surgery have been introduced with encouraging results. *Methods:* We reported our experience with a case treated by one-step procedure using a custom-made intramedullary antibiotic cement-coated carbon nail. We reviewed the literature and described the surgical technique employed in this case. *Results:* At 6 months from surgery the patient was able to perform full weight-bearing and carry out the normal activities of daily living. Serum inflammatory markers normalized and radiographic controls showed the presence of a mechanically good bone callus at the non-union site. The bone resection carried out determined a limb length discrepancy of 3 cm, that was corrected through a temporary shoe lift, currently well tolerated. The patient regained full ROM of the right knee. *Conclusion:* Intramedullary antibiotic cement-coated nail associated with systemic antibiotic therapy proved to be an effective treatment to control the infection and provide immediate stability at the septic non-union/fracture site, allowing a rapid functional recovery. It represents a valid option especially in patients who refuse external devices or surgical additional procedures, as in our case. (www.actabiomedica.it)

Key words: septic non-union, coated nail, infection, one-step surgery, osteomyelitis, femoral fracture, intramedullary nail, carbon nail

Background and aim of the work

Septic events are caused and maintained by pathogen bacteria, toxins, inflammatory cytokines and immune cells. When these events occur at bone fracture sites, the healing process slows down and a septic non-union can take place: this complication is one of the most difficult to manage and treat in the traumatological field. Septic non-union is traditionally defined as clinical and/or radiological evidence of cessation of fracture healing after 6-8 months of treatment associated to persistent clinical, laboratoristic and radiological signs of infection (1).

The treatment of infected non-union has two main objectives: control of infection and recovery of stability.

Traditionally, the surgical technique consists in two sequential steps. The first step consists in a local debridement with administration of local and systemic antibiotics associated with temporary stabilization of the fracture. Once the infection is resolved, reconstruction of bone and soft tissues can be performed as sec-

ond step. Many more or less complex sur- gical strategies can be performed to reach this goal (e.g. external fixators, antibiotic-loaded cement spacers, tissue flaps, etc.), but in any case the patient and the orthopaedic surgeon have to face a long and demanding path.

Recently, the use of some devices to treat septic non-union by one-step surgery have been introduced with encouraging results. This strategy allows to resolve the infection and, at the same time, to provide fracture stability by using a single surgical step.

This gives considerable advantages in terms of septic non-union healing time and saving of economical and psychological resources (2-6).

We report our experience with a complex clinical case successfully treated by one-step procedure using a custom-made intramedullary antibiotic cement-coated carbon nail.

Methods

This case report has been performed in accordance with the ethical standards laid down in the 1964

Declaration of Helsinki and its later amendments. The patient gave written consent.

A 17 years old man was admitted for the first time to our institution on May 2017, with the diagnosis of right femoral shaft septic non-union. The patient reported an open femoral fracture Gustilo I following a motorcycle accident on July 2016. The fracture was treated with an intramedullary nail at another institution, but a few days after treatment the patient presented clinical and laboratoristic signs of infection. At the site of fracture the patient presented a secreting cutaneous fistula from which St. Aureus and Epidermidis multi-resistant (MR) were isolated. Targeted systemic antibiotic therapy was administered to the patient until January 2017, when clinical signs of infection disappeared although serum inflammatory markers (i.e. ESR and CRP) remained high, with a delay of fracture healing. Therefore the intramedullary nail was removed and an external fixator (EF) was applied, going on with specific systemic antibiotic therapy. After 4 more months, a purulent secretion appeared from external fixator screws and a deep collection was detected.

So EF was removed and a rigid cast was positioned until the patient arrived at our institution.

We performed lower limbs magnetic resonance (MRI), TC scans and total body PET to confirm osteomyelitis diagnosis and to assess its extension. We found out a septic non-union type III in a host class A according to Cierny and Mader classification (1) (Fig. 1).

The patient presented a severe right knee flexion limitation with a Range Of Movement (ROM) of 0-15° at the time of admission, and he didn't agree with the use of EF systems anymore. Because of these problems, we looked for another one-step procedure as the one reported below in the text.

So after a period of antibiotic wash-out on June 2017 we decided to perform an extensive surgical debridement of right thighbone septic non-union by the resection of the affected bone section and the implantation of a custom-made antibiotic cement-coated intramedullary carbon nail (Piccolo Composite® CarboFix Orthopaedics, Unimedical, Torino, Italy)

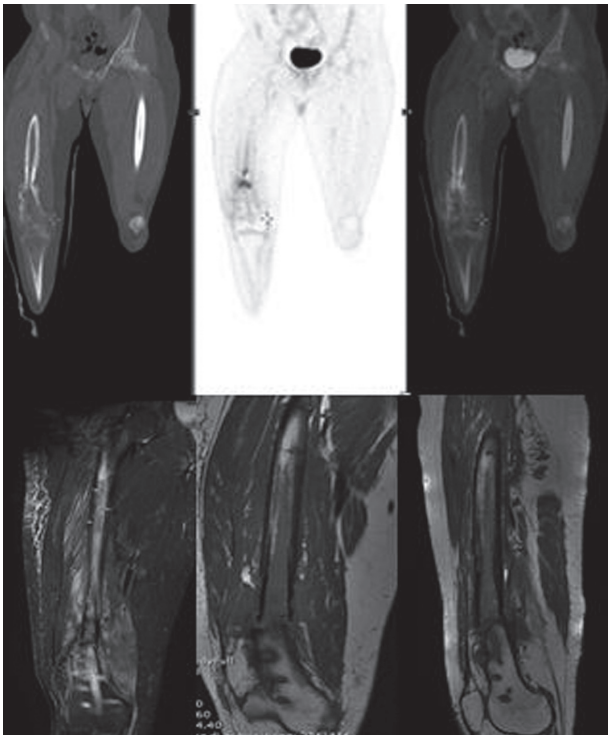

Figure 1. At the top from the right: TC, PET, PET-TC of the patient's femoral septic non-union. The same patient's MRI sequences at the bottom

as fracture fixation system. In our case the antibiotic cement used (Antibiotic Symplex Bone Cement with Erythromicyn and Colistin, Stryker, Kalamazoo, MI, USA) as nail coating was added up with 1g of Vancomycin every 40g of cement powder targeted against isolated pathogens.

Surgical procedure: The Patient was positioned on a radiolucent surgical table with the right lower limb in traction and the contralateral lower limb suspended to allow the intraoperative use of c-arm x-rays system. With the aid of intraoperative x-rays to detect the septic non-union level, a skin incision was performed in the lateral area of the thigh. The bone tissue was reached preserving as much as possible the soft tissues and then a femoral bone resection of 3 cm was performed to remove the osteomyelitis site as previously detected with imaging scans (MRI, PET, TC and PET-TC matched together). At that point it was very important to remove all nonviable or infected tissues and perform a plentiful irrigation with antiseptic and saline solution in order to avoid non-viable bone seizures that represent a good breeding ground for pathogens with the risk of infection recurrence.

Before performing the osteotomy stabilization the cemented coated intramedullary nail was made separately on an instrument table in the same operative room: a sterilized rubber tube 3 mm larger than carbon nail was use as scaffold. It was greased inside with sterile surgical lubricant to avoid cement adhesion to the tube and then filled with poly-methyl-methacrylate bone cement added up with specific antibiotics targeted against isolated pathogens as indicated above in the text. So the selected carbon nail was inserted into the rubber scaffold and placed into a basin full of physiological solution to cool the system during the cement exothermic reaction to avoid as far as possible antibiotics denaturation or alteration of the materials in use (i.e rubber tube).

The rubber scaffold was cut and removed obtaining a cement coated custom-made carbon nail. The proximal and distal screw holes were freed from excess cement with a drill, the coated-nail surface was inspected in search of gaps that were not found and the edges were smoothed to facilitate its insertion into the femur. The femoral canal was then prepared and reamed 1 mm more than the coated-nail diameter to avoid cement-nail detachment and finally, under intraoperative radiographic control, the nail was positioned inside the femoral canal in an antegrade way using its own guidewire (the coating technique employed allows not to fill with cement the cannulated portion of the nail). The fracture/osteotomy was then compressed and the nail was fixed with 2 titanium blocking screws: the proximal one inserted with the use of its own guide and the distal one with a freehand technique (Fig. 2). Surgical access was sutured and post-operative xrays in two projections were performed.

After surgery a systemic targeted antibiotic therapy was administered to the patient and a rehabilitation program was started. Thrombosis prophylaxis was administered until the patient was able to achieve full weight-bearing. Patient was allowed to perform partial weight-bearing for 1 month after surgery and full weight-bearing from 2 months after surgery.

During standard periodic follow-up a delay of fracture healing was found with x-rays, despite normalization of serum inflammatory markers and clinical functional improvement. So on January 2018 the intramedullary nail was dynamized (removing the proximal screw) to allow compression and micromovements at the fracture site. Systemic antibiotic therapy was continued until scintigraphy imaging negativity on February 2018 (Fig. 3).

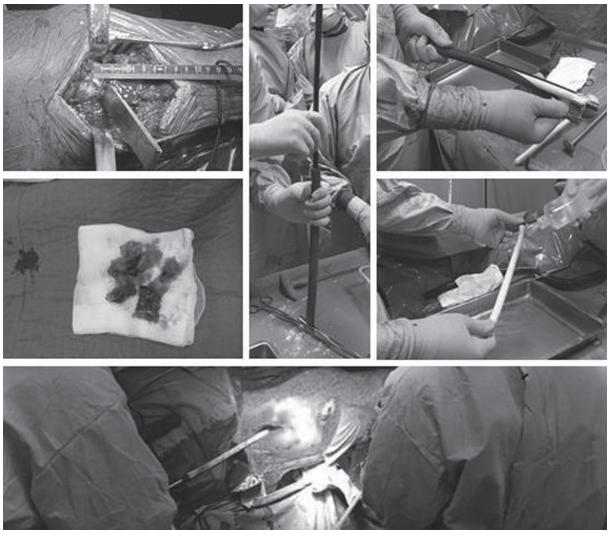

Figure 2. Surgical steps from septic non-union bone resection to coated-nail manufacturing and its introduction in to the femur

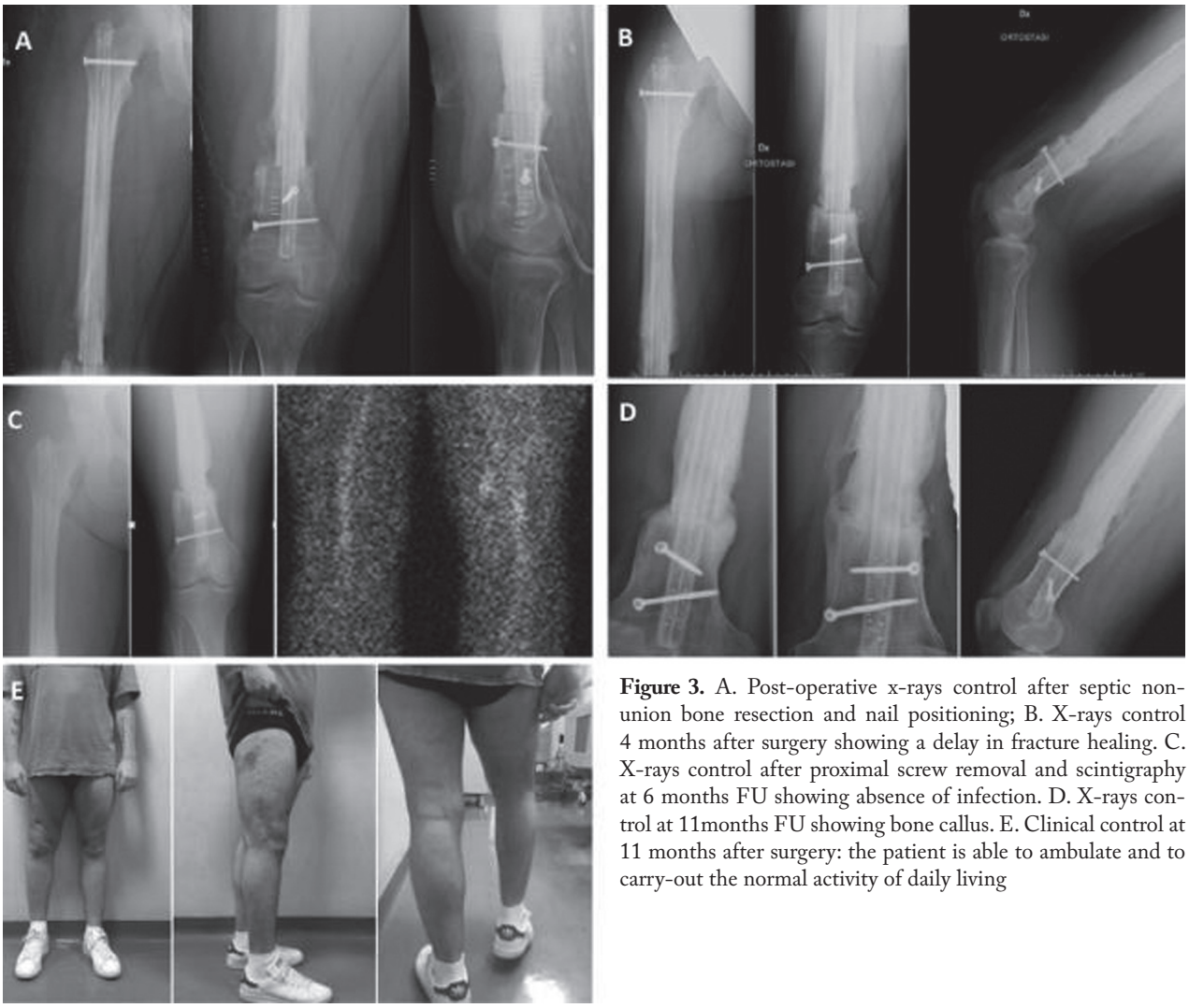

Figure 3. A. Post-operative x-rays control after septic non-union bone resection and nail positioning; B. X-rays control 4 months after surgery showing a delay in fracture healing. C. X-rays control after proximal screw removal and scintigraphy at 6 months FU showing absence of infection. D. X-rays control at 11months FU showing bone callus. E. Clinical control at 11 months after surgery: the patient is able to ambulate and to carry-out the normal activity of daily living

Results

On May 2018, about 3 months after nail dynamization and antibiotic therapy suspension, the patient was able to perform full weight-bearing without pain and carry out the normal activities of daily living. Serum inflammatory markers normalized and radiographic controls showed the presence of a mechanically good bone callus at the non-union site.

The bone resection carried out determined a limb discrepancy of 3 cm, that was corrected through a temporary shoe lift, currently well tolerated (Fig. 3). At the last FU the patient regained full ROM of the right kee (active ROM: 0-110°).

Discussion

In the orthopaedic and traumatological fields, infections represent a severe complication hard to manage and treat. Internal devices such as prosthesis, intramedullary nails, plates and screws represent a good substrate for bacterial pathogen growth. They are able to produce a biofilm on the surface of inter-

nal devices making difficult to resolve infection without their removal (7, 8). Moreover, the infection can involve bone tissue too, making challenging to avoid infection diffusion and obtain patient recovery. In order to avoid these complications, in many cases a two steps procedure represents a safer and more successful approach also in orthopaedic field and it has been the gold standard in the last years (2-4, 9, 10). Internal device removal as first step allows an easier treatment of infection and, once resolved, another device can be implanted as second step. On the other hand, a two steps approach requires much time and several surgical procedures making this way more expensive in terms of costs and psycho-physical resources for both the patient and the surgeon.

When an infected non-union occurs it is important to provide stability in order to achieve good results and often the use of a cast is insufficient especially if femoral shaft is involved. Intramedullary nailing represents the conventional tool to treat recent or non-united femoral shaft fractures, while in the osteomyelitis management, the use of external fixators represents the gold standard to provide stability (6, 11). Unfortunately its use is related with a high incidence of pin site infections as well as poor tolerance of the patient (12).

In some cases a single step procedure can prove effective specially in case of infected non-union with the dual problem of infection control and stability recovery. Local delivery of high concentrations of antibiotics is well described with various methods (antibiotic-loaded cement beads and spacers, calcium sulphate delivery vehicles and synthetic polymers) and it isn't related with the systemic complications of antibiotic use. Local drug-delivery systems allow a quick release of high local antibiotic concentrations for a prolonged time. So they increase the bactericidal effect, reducing at the same time the risk of bacterial resistance. In this scenario, the introduction of antibiotic coated intramedullary nails (ACINs) offers the advantage of fighting infection and providing stability for definitive fixation of fractures and septic non-unions (4).

Staphylococcus Aureus represents the most common bacterium responsible for bone infections and it is often associated with other bacteria as in our case. We decided to use Simplex bone cement added with Vancomicyn because of its antibiotic properties. In fact, Aminoglycosides and Vancomycin are the most common antibiotics employed for local delivery because of their spectrum of activity, heat stability, low allergy rate and good elution properties from bone cement (2, 13-14).

Our surgical technique is very similar to the one described by Thonse and Conway. In their series 20 patients were treated for septic bone non-union at different anatomic sites with the use of an antibiotic cement- coated nail with good results. Infection control was achieved in 19 of the 20 patients (95%) while bony union was achieved in 17 of the 17 patients where the final goal for the patient was to achieve bony union (100%). The 50% of their patients needed additional procedures to control infection and achieve bony union (2).

In another study Shyam et al. treated 23 femoral septic non-unions and 2 shinbone septic non-unions by the use of antibiotic-coated Kirschner wires after previous implant removal and wide debridement. They reported infection control and fracture healing without re-intervention in 20 patients. In 4 cases an additional procedure was necessary to achieve fracture healing and in 1 one case the infection became quiescent (5). Also Sancineto et al. reported their experience in 19 cases of long bones septic non-unions successfully treated with a cement antibiotic coated Ender nail with excellent results (3).

Concerning the use of an antibiotic cement coated carbon fibres intramedullary nail to manage septic non-unions we found only one case report of a distal femur arthritis described by Mauffrey et al. In their work the authors described a surgical technique using a thoracic drainage tube as scaffold to coat a carbon fibres humeral nail that was introduced into the distal femur in a retrograde way. The use of a humeral nail allows the surgeons to have thicker coating (15).

The use of this material presents some advantages. Carbon nails and titanium screws are radiolucent devices allowing radiological FU without CT and MRI interferences. This property is very useful specially in the osteomyelitis and bone tumors management. Moreover carbon fibres nails present an elastic modulus more similar to cortical bone and a fatigue resistance higher than titanium and steel (16, 17).

In our experience the use of an intramedullary cemented-coated carbon nail associated with systemic antibiotic therapy has proven to be an effective treatment to control the infection and to provide immediate stability at the septic non-union/fracture site, allowing a rapid functional recovery. The use of a custom made coating system, although initially it seemed to be a disadvantage, has allowed us to use targeted antibiotics that have been released locally at high concentrations reducing the risk of biofilm formation on the internal device. Moreover, the use of carbon fibres nail allowed to provide high resistance and mechanical elasticity to the fracture stimulating the bone callus formation and, at the same time, to perform the subsequent radiological FU avoiding ferromagnetic artefacts. Some complications have been described with the use of this system, such as cement/nail detachment or infection recurrence, but in our experience they didn't occur.

Moreover, in our case the patient refused an additional surgical procedure to remove the nail and possibly perform a femoral elongation. This event is related to the long medical and surgical history of our patient and this is to highlight how some treatments can physically and psychologically bend a patient making impossible to adopt some approaches.

Conclusions

The best septic non-unions treatment is challenging for the orthopaedic surgeons and one stage approaches present prominent advantages in terms of saving hospitalization time and economic resources with a positive impact on the patient's quality of life. Published works reported encouraging results, but further studies with a wider sample of patients and a standard protocol are needed in order to validate this treatment.

Conflict of interest: Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article

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