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Treatment of a case of septic tibial nonunion by the Capanna technique

Kilian Fraga Lavía *, Óscar Izquierdo, Hernan Santiago Boccolini, Rafael Hernández, Gonzalo Pérez, Manuel Andrés, Manel Panadero

Egarsat Hospital, Barcelona, Spain

A R T I C L E I N F O

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A B S T R A C T

This report presents the case of a 25-year-old male with an infected tibial diaphyseal nonunion caused by a bone transport procedure carried out to treat an open fracture the patient had sustained 10 years before referral to our hospital. After an initial radical debridement, a bone defect was created, which was subsequently obliterated by placement of an antibiotic-impregnated cement spacer and Stimulan beads and covered by an anterolateral thigh flap. As the patient refused to wear an external fixator and his osseous biology was not amenable to a Masquelet procedure, a decision was made to apply the Capanna technique as soon as the infection healed.

The second debridement resulted in a 12-cm-long bone defect that was filled with a tibial allograft and a vascularized fibular graft. At six months, the patient had regained full knee function and was able to bear his full weight, without pain or the need of support equipment. At one year, the bone had healed completely, the infection had subsided and the patient was able to resume his everyday activities.

Although the Capanna technique was initially developed to reinforce reconstructions at risk of fracture or nonunion as a result of chemotherapy, its use in post-traumatic cases has been shown to be successful in a selected group of patents. Our study demonstrated that increasing the stability of a reconstruction with an allograft can accelerate the time to heal, and that using a vascularized fibular graft can enhance incorporation of the whole construct.

It can be concluded that the Capanna technique is a valid treatment option for managing infected segmental bone defects in selected patients.

Introduction

Myriad techniques have been described for the management of segmental defects, each with its own indications and limitations [1]. While smaller defects may be addressed by shortening and distraction or bone grafting, larger defects are not amenable to such methods. Indeed, an excessive shortening in the acute setting could result in vascular problems in the first case while the bone resorption and revascularization resulting from the creeping substitution of the graft could give rise to weak and fracture-prone reconstructions in the second. Consequently, the gold standard for the management of defects larger than 5 cm is distraction osteogenesis, with more advanced techniques such as vascularized bone grafting being reserved for selected cases [2]. Bone transport,

* Corresponding author.
E-mail addresses: kiliangondar@hotmail.com (K.F. Lavía), oizquierdo@egarsat.es (Ó. Izquierdo), hsboccolini@egarsat.es (H.S. Boccolini), gperez@egarsat.es (G. Pérez), mandres@egarsat.es (M. Andrés), mpanadero@egarsat.es (M. Panadero).

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however, has its limitations; and the small diameter of vascularized grafts make them suitable only for areas of the body subject to low mechanical demands, such as the upper limb, or for pediatric patients [1]. Cappana developed an alternative technique for cancer patients [3], which combines the biological advantages of a vascularized graft with the mechanical strength of a strut allograft. Although this technique is more commonly used in individuals undergoing chemotherapy, this report presents a case that shows that it can also be useful in the context of sepsis, provided that patients are carefully selected.

Case report

This paper reports on the case of a 25-year-old male who in 2009 sustained a Gustilo & Anderson type II [4] open distal tibia fracture following a motorcycle accident. After an initial diagnosis of bone infection at a different hospital, the patient was subjected to 10 surgical procedures before being referred to us with a well-fused tibiotalar arthrodesis and a diaphyseal tibial nonunion resulting from a bone transport procedure carried out three years before using a monolateral external fixator (LRS ADV, Orthofix Srl, Italy) (Fig. 1). The soft tissues of the anteromedial tibial region were in very poor condition. Table I presents the timeline of the case.

As this was a patient with an unclear clinical presentation where sepsis had been developing for a long time, a single-photon emission computed tomography/computed tomography (SPECT-CT) scan was performed, which showed signs of infection at various pin sites but not at the nonunion site (Fig. 2).

The patient was subjected to a two-stage procedure. The first surgical stage consisted in removal of the external fixator and a radical bone debridement to well-vascularized tissue (paprika sign). This created a 10-cm-long bone defect, which was obliterated by a combination of a vancomycin-impregnated cement spacer and Stimulan beads (Biocomposites Ltd., United Kingdom) with the same antibiotic load (Fig. 3) [5]. To provide adequate soft tissue coverage, an anterolateral thigh (ALT) flap was raised, under which antibiotic-impregnated Stimulan beads were delivered [6]. Intraoperative cultures revealed a *Staphylococcus aureus* infection, which was treated with an 8-week course of ciprofloxacin and clindamycin. One month after completion of antibiotic treatment (Fig. 4), polymerase chain reaction (PCR) and erythrocyte sedimentation rate (ESR) values were within normal ranges and the appearance of soft tissues was also normal.

Treatment options for a multi-operated patient with a 10-cm-long bone defect are basically limited to bone transport with external fixation, a Masquelet procedure with intramedullary nailing [7], a Capanna procedure [3] (a vascularized fibular graft reinforced by an allograft), and amputation. The patient rejected having to wear an external fixator again as well as an amputation, and the surgical team considered that the quality of his bone stock was incompatible with a Masquelet procedure, which meant that the only alternative

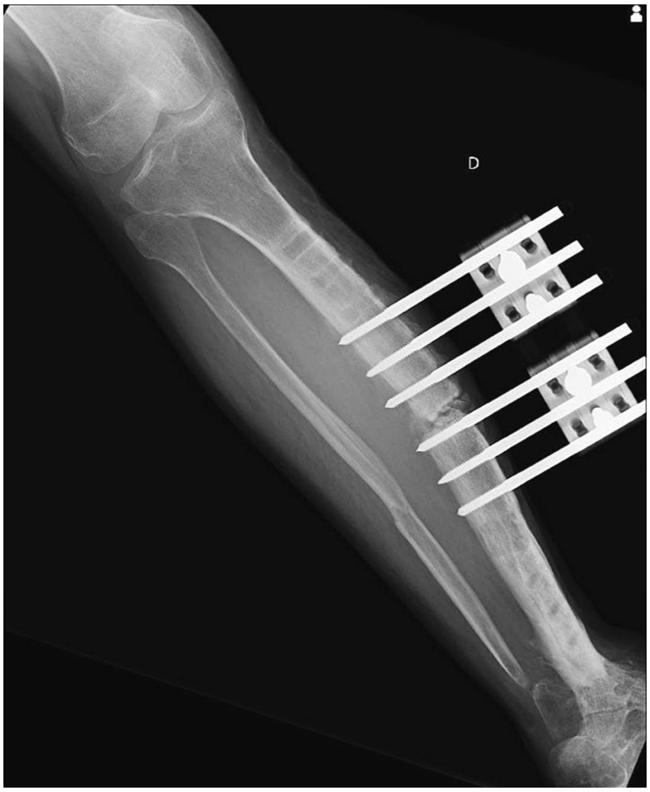

Fig. 1. X-ray taken on admission to our hospital showing a tibial diaphyseal nonunion and solid ankle fusion. The configuration of the monolateral external fixator is clearly unstable.

Table I
Timeline.

Timeline	Intervention or event
2009	Patient sustains fracture
2009–2018	Nine surgical procedures performed
2018	Tibial bone transport and tibiotalar arthrodesis
30 March 2021	Patient referred to our hospital
Day 0	First surgery (washout and spacer implantation)
Day 30	Clinical assessment
Day 208	Second surgery (Capanna)
Day 218	Discontinuation of antibiotics
Day 250	Start of range-of-motion exercises
Day 271	Start of partial weight-bearing
Day 388	Unassisted walking, with no support and no pain. Compensatory 5-cm shoe lift.
Day 573	Final assessment

possible was performance of a Capanna technique.

During the second surgery, removal of the spacer was followed by radical debridement until the paprika sign became visible. This created in a 12-cem-long bone defect. After taking samples for microbiological analysis, a profuse lavage was carried out with nine liters of chlorhexidine solution. The defect was obliterated with a 12-cm-long intercalary tibial allograft (Spanish blood and tissue bank), which was fixated with a vancogenx-coated (Tecres Spa, Italy) T2 intramedullary nail (Stryker Corporation, USA) inserted through a suprapatellar incision (Fig. 5). Subsequently, a vascularized fibular graft 5 cm longer than the defect [8] was placed laterally to the nail and secured into the tibial cortex, cutting a trench both in the host bone and in the allograft. Fixation was obtained using two VariAx plates (Stryker Corporation, USA). Vancomycin and gentamycin-impregnated Stimulan beads were also delivered under the ALT flap (Figs. 6 & 7).

Postoperatively, vancomycin and ceftazidime were administered for ten days, until absence of infection was ascertained. The patient's immediate evolution was excellent, with satisfactory pain control and good graft survival. Splinting was indicated for a two-month period [9–11], but the patient was allowed to start range-of-motion exercises at two weeks a partial weight-bearing at two months.

At six months post-op, (Fig. 8) the patient recovered full knee function and was able to walk bearing 100 % of his weight, with no pain and without any support equipment. He did however present with a 5-cm leg length discrepancy that he compensated for with a shoe lift. The discrepancy, which had been identified prior to surgery, had been caused by a shortening of the soft tissues that could not be corrected acutely (and the patient had rejected the use of an external fixator).

At one year (Fig. 9), the patient reached a U1-I2-F1 score on the Cattaneo scale [12] (complete healing, remission of infection and ability to perform activities of daily living). The result obtained was considered to be good.

Discussion

The case presented here is one of the few in the literature where the Capanna technique was used in a non-oncologic indication [1,3,9–11,13–18]. The technique consists in the use of an allograft strut to reinforce cases where vascularized grafts are at a higher risk of fracture or nonunion as a result of chemotherapy [11,15].

The choice of the most appropriate reconstruction method should be governed by the individual patient's characteristics [1]. In this case, the subject rejected the use of an external fixator, which precluded the use of distraction osteogenesis to allow progressive correction of the existing leg length discrepancy. Moreover, as the defect was intercalary, the surgical team thought it best to preserve the joint as no (prosthetic or interpositional graft) arthroplasty can do a better job that the patient's own native joint [17]. The surgical team considered using a strut allograft, which usually allows an anatomical and biological reconstruction of large defects thanks to its osteoinductive and even osteoconductive properties [19]. However, isolated use of struts is often associated with high rates of nonunion (17 %–50 %), fracture (17 %–30 %) and infection (10 %–15 %) [11,14,20–22]. A valid alternative is to supplement the strut with a fibular graft. Such grafts may be vascularized or otherwise. Although some authors believe that non-vascularized grafts are able to reduce OR time with similar long-term results [10,28], others have found vascularized grafts to be preferable in cases where blood supply is compromised [1] (given that the graft's biological activity permits faster healing rates [33]) or in the lower limbs, which are subject to higher mechanical demands [1]. Based on this reasoning, a vascularized fibular graft [23,24] was selected as the treatment of choice for our patient. Nevertheless, despite the undeniable osteogenic potential, resorption resistance and antibiotic-penetration and immune-response enhancing properties of vascularized grafts [14], their diameter and physical characteristics have circumscribed their use to areas of the body subject to low mechanical stresses such as the upper limb, or to pediatric patients [1]. The location and severity of the defect in our patient, compounded by the fact that the bone remnant present was not eligible for an induced-membrane technique [25], led us to consider that the vascularized fibular graft could be reinforced by a strut allograft [10]. Capanna et al. [3] described a technique for reconstructing large diaphyseal defects which combined a vascularized fibular graft with a conventional allograft. The idea was to enhance the mechanical properties of the strut allograft with the biological activity of the vascularized fibular graft, thus accelerating the healing process, minimizing the incidence of failure and allowing early use of the limb [8,11,14,17]. The advantages and limitations of the treatment proposed are described in Table II.

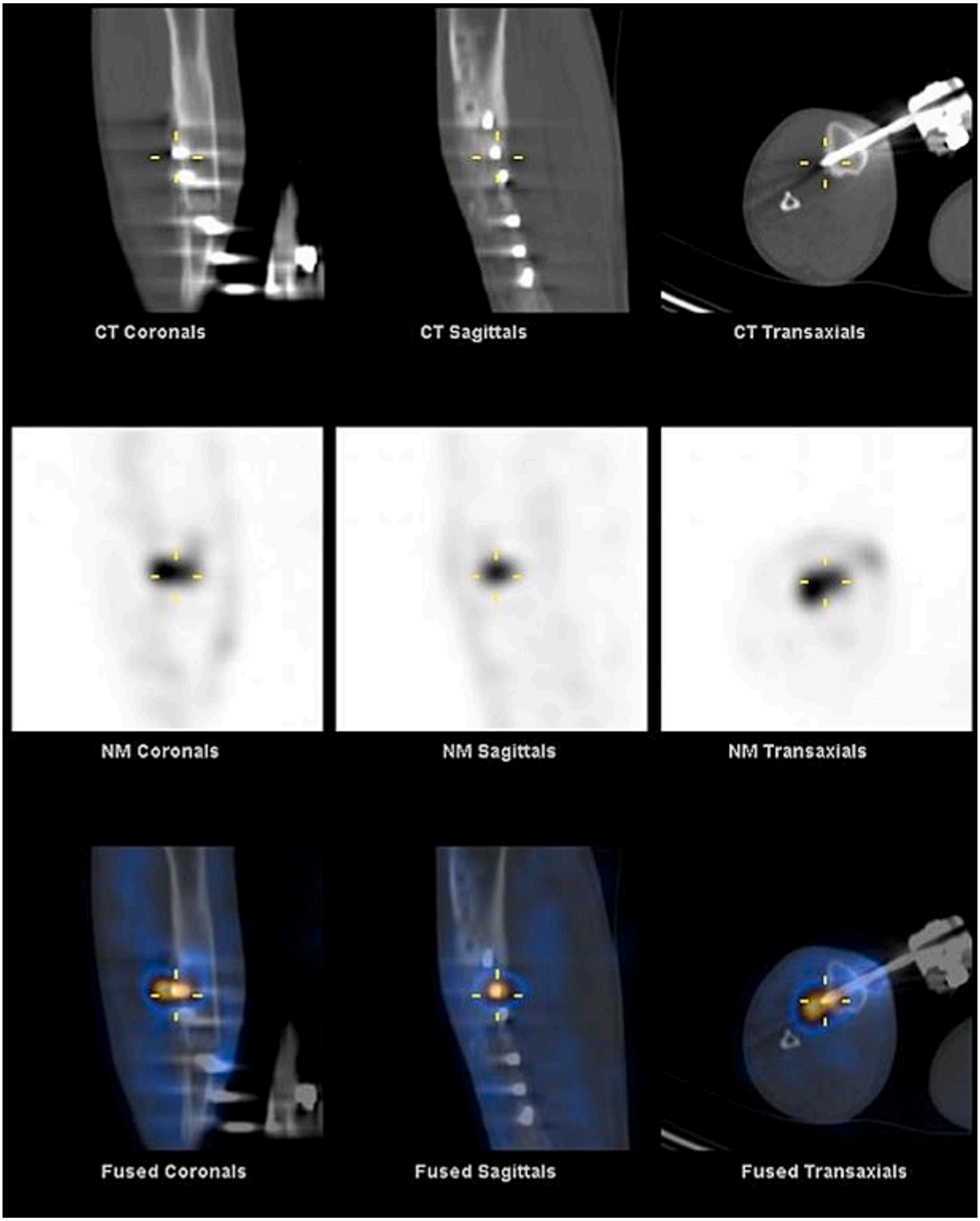

Fig. 2. SPECT-CT scan showing signs of pin tract infection but no sepsis at the nonunion site.

Fig. 3. Image of the operated site following the first surgery showing obliteration of the bone defect by a cement spacer and Stimulan beads.

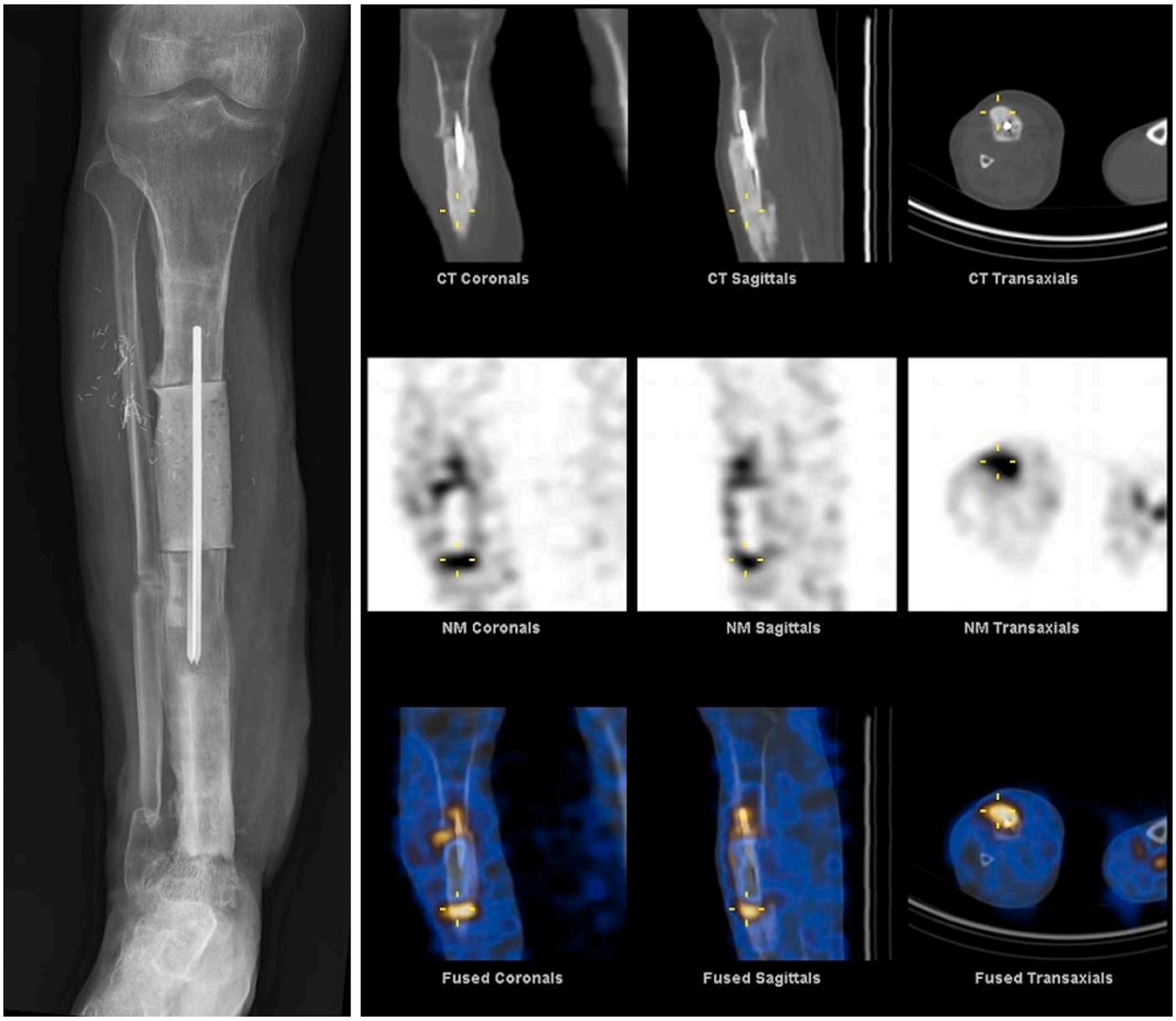

Fig. 4. SPECT-CT scan at 6 weeks from the first surgery showing signs of normality.

Increasing the stability of a reconstruction with an allograft shortens the time to heal. The vascularized fibula graft for its part induces revascularization of the strut's diaphyseal segment, facilitating its incorporation [11,26]. Moreover, although the allograft provides the fibula with a certain measure of protection against mechanical stresses in the initial stages of healing, it cannot protect the bone from becoming hypertrophied as it takes over the function of the allograft as the latter resorbs [3,8,11].

The Capanna technique can be executed in one of two ways. The most usual one consists in placing the fibular graft in the strut's medullary canal [11,26], which permits close contact between the graft and the host bone. Alternatively, the technique may be performed extramedullarly (onlay technique) to revise nonunions associated with isolated allografts [14] or in the femur to avoid undermining the integrity of the allograft [11]. As in this case the priority was to speed up range of motion recovery and weight-bearing, we decided to go for an intermediate solution consisting in the use of an interlocking nail. This prevented us from applying the intramedullary technique, which requires placing the fibular graft at the center of the medullary canal. However, a trench was cut into both the allograft and the host bone, where the vascularized fibula was fitted ensuring that it remained lateral to the nail and centered with respect to the lateral cortex of the patient's tibial remnant.

Ozaki et al. [9] modified Capanna's original procedure by using an ipsilateral vascularized graft. Although their goal was to reduce the incidence of complications, shorten the OR time and improve graft survival, their results were inconsistent. Other authors [16], however, did report satisfactory results using ipsilateral grafts in longer series. Such authors claim that Ozaki et al.'s technique is simpler and less time-consuming than Capanna's, making a microvascular anastomosis and a procedure in the contralateral leg unnecessary. In our case, a contralateral free graft was selected because the patient's underlying condition was non-oncologic but rather traumatic and septic, and he presented with an ankle arthrodesis. These factors raised doubts about the geometry and vascularization of the ipsilateral fibula.

As regards fixation of the grafts, the procedure to be followed was established by Capanna [27] himself, who stated that the osteosynthesis had to be as stable as possible. Although it is generally recommended that the ends of the fibula should be fixed using as

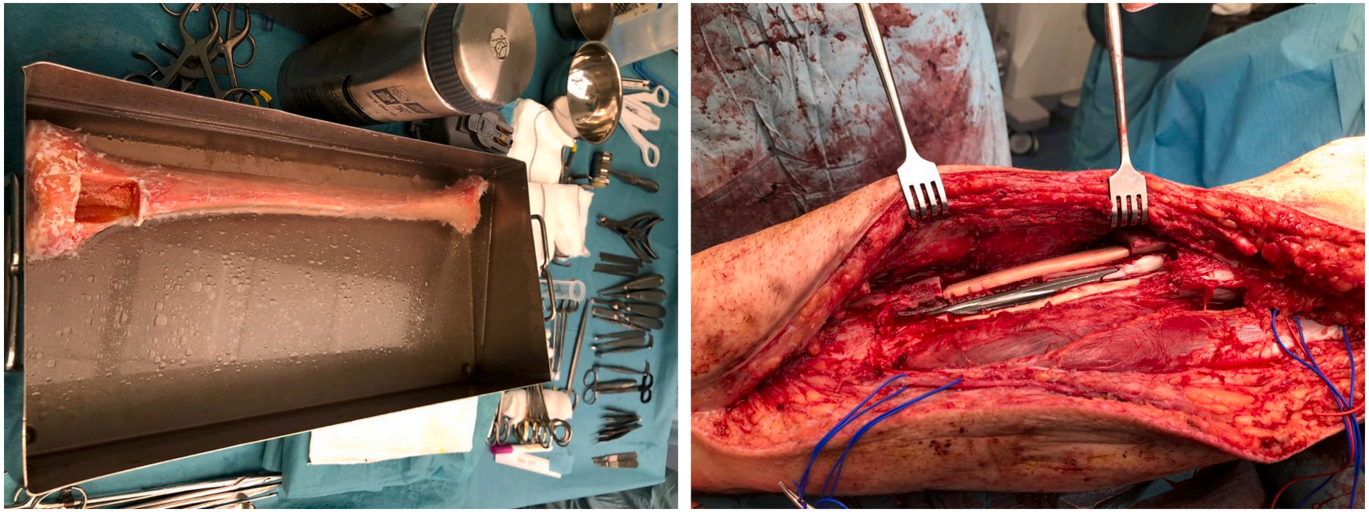

Fig. 5. (a) Tibial allograft before preparation; (b) Positioning of the allograft and the intramedullary nail before insertion of the vascularized fibular graft.

Fig. 6. Clinical image following the second surgery showing the fibular graft's skin island flap.

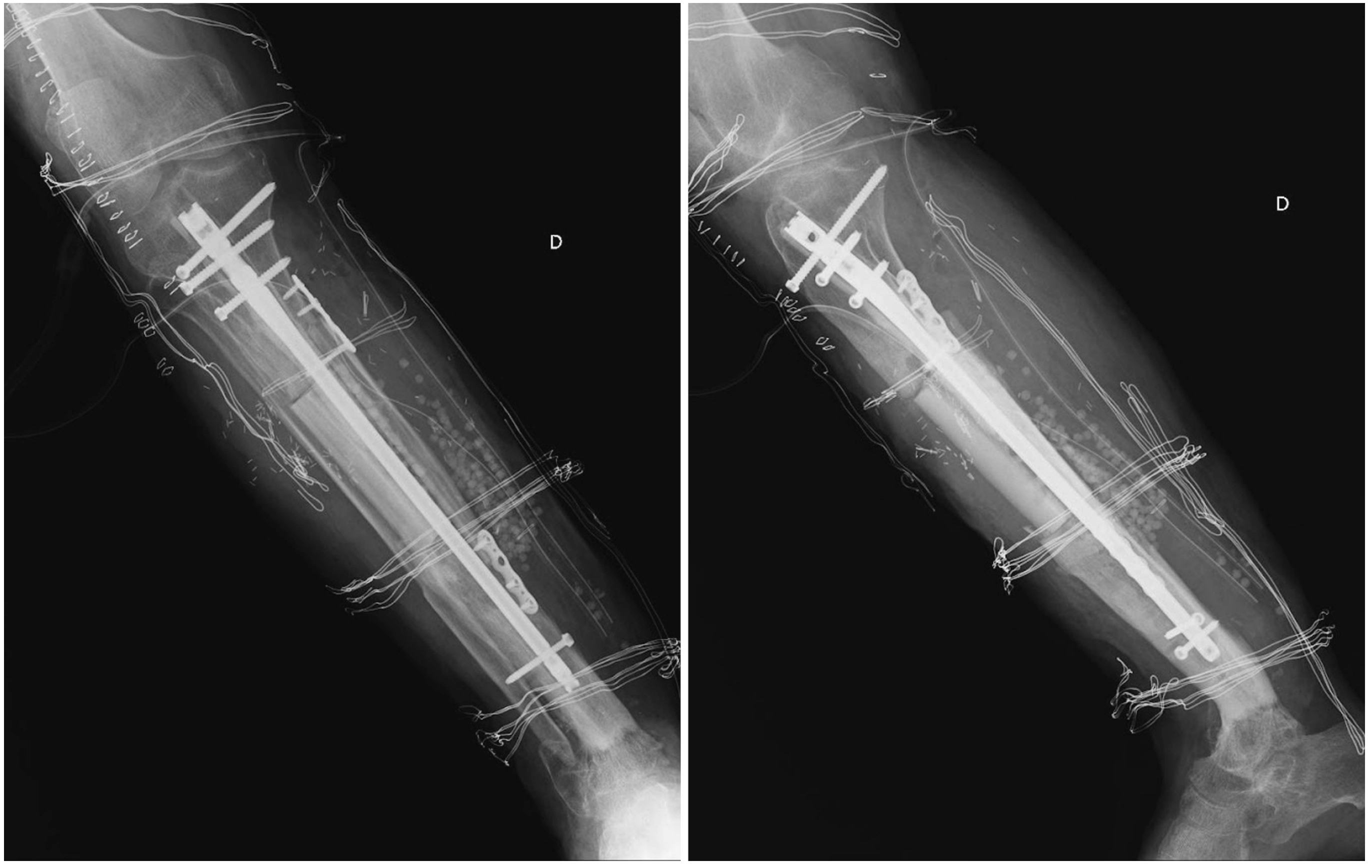

Fig. 7. X-rays after the second surgery showing the allograft and the vascularized fibula autograft. The construct was stabilized by means of an intramedullary nail and two plates.

Fig. 8. (a,b) Anteroposterior and lateral x-rays at 3 months from surgery; (c,d) Anteroposterior and lateral x-rays at 6 months from surgery.

Fig. 9. CT scans showing complete incorporation of the vascularized fibular graft and partial incorporation of the tibial allograft.

Table II
Advantages and limitations of the capanna procedure [3].

Advantages
Initial stability provided by the allograft
Long-term biological stability provided by the vascularized fibula
Osteogenic response induced by the vascularized fibula
The graft's length does not constitute a limiting factor
Allograft availability
Possibility to add a skin island flap to the fibular graft
Low incidence of nonunion or fractures requiring reoperation
Minimal need of internal fixation

Limitations
Prolonged OR time
Excessive non-weight-bearing time
Potential transmission of allograft-related diseases
Potential donor site complications

gentle a technique as possible and that the whole construct should be bridged using angle-stable bone plates [1,10,11,15,27], we used an intramedullary nail as we wished to enhance the construct's stability and accelerate weight-bearing and functional recovery. This made it necessary to ream both the allograft and the host's tibial bone to ensure that the nail was positioned laterally but in alignment with the patient's bone. This provided enough stability to allow the patient to start progressive weight-bearing at two months from the procedure and to achieve nearly full functional recovery six months post-op.

Excepting the leg length discrepancy, which could not be avoided given the patient's refusal to wear an external fixator, the results of this case were extremely encouraging, not least given that they were achieved over a relatively reduced period of time. Graft survival with the Capanna technique tends to be good and in any case better than with isolated allografts [8–10,17,27]. The earlier healing of vascularized grafts provides adequate stability and a biologically active environment that offers protection against other problems [8,10]. Consequently, although fractures of the allograft are relatively common, they seldom affect the integrity of the reconstruction, which is reinforced by the hypertrophy of the vascularized fibula [3,8,11]. Although our patient did not develop any significant complications or fractures of the allograft, given that the internal repair of the strut occurs through creeping substitution, a slow and often incomplete process [20], allograft fractures may take quite a long time to occur, with 16 % of them arising within 3 from surgery and 20 % between 6 and 12 years post-op [27].

Despite the lack of references in the literature to the use of the Capanna technique in septic indications, our patient regained leg function (with no complications) at 6 months from surgery, which is sooner than reported in the literature for oncologic indications (between 6 and 13.7 months) [11,14,15]. This could be due to the fact that, although our patient's bone quality was far from optimal, cancer patients are typically characterized by worse systemic conditions and are exposed to external insults such as chemotherapy.

In a nutshell, it could be argued that using a vascularized fibular graft reinforced with a strut allograft is a valid option for the management of segmental bone defects of septic origin in selected patients.

Declaration of competing interest

None.

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