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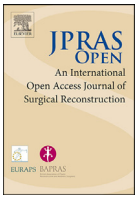

Case Report

First-ever ankle arthrodesis with the Capanna technique in an infected open fracture

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ABSTRACT

Although bone transport by means of distraction osteogenesis has become the standard of care for massive segmental bone defects, the technique faces limitations such as the lengthy period of time during which patients must wear an external fixator. Thus, other techniques may be more appropriate in certain circumstances.

Capanna developed a combination of vascularized fibular grafts and strut allografts in a way that the strut allograft provides with significant initial mechanical stability, which facilitates incorporation of a vascularized fibular graft and promotes long-term survival of the reconstruction.

The case presented in this report is the first in the medical literature where a circular external fixator is used as a stabilization method in a patient with a structural bone deficiency treated by means of the Capanna technique. It is also one of the few reported cases where the underlying condition does not originate in a tumor and where the joint is involved.

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Introduction

Although distraction osteogenesis has become the standard of care for massive segmental bone defects,[1] orthopedic surgeons should also master other techniques which may be more appropriate in certain circumstances.[1]

Capanna[2] developed a method based on a combination of vascularized grafts and strut allografts. Use of a strut allograft is associated with significant initial mechanical stability, which facilitates incorporation of a vascularized fibular graft and promotes long-term survival of the reconstruction, with a low incidence of nonunions or fractures requiring reoperation.[2] Although originally applied to cancer patients,[2–6] the Capanna technique has been successfully implemented in patients with septic bone defects.[7] This report constitutes the first published case where the Capanna technique was applied in combination with a circular external fixator. The patient provided consent for publishing this report, which adheres to the SCARE guidelines.[8]

Case report

We present the case of a 52-year-old male who fall from a height and was treated for multiple trauma, consisting in a Tile type B1 pelvic fracture, burst L3-L5 fractures, and a grade IIIA open right tibial pilon fracture with talar involvement (Figure 1) Table 1.

He immediately underwent a radical debridement and stabilization of the ankle with an external fixator (Hoffmann 3, Stryker Corp, USA), and the hospital's antibiotic therapy protocol for open fractures was implemented. A week later, the wound started to fester. A new debridement was performed, including a distal tibial resection, placement of a vancomycin and gentamicin-impregnated cement spacer (Vancogenx, Tecres, Italy) and application of vacuum-assisted closure to address the soft tissue defect. As cultures revealed a polybacterial infection, treatment with piperacillin-tazobactam and teicoplanin was instituted.

Two weeks later, an even more extensive debridement was carried out, resecting the tibia and the talus to healthy bone and obliterating the resulting space with a new spacer and vancomycin- and gentamicin-impregnated calcium sulphate beads (Stimulan, Biocomposites, UK). The defect was covered using an anterolateral thigh (ALT) flap and the limb was stabilized with an external fixator (Figure 2). Positive cultures for *Clostridium sphenoides* and *Clostridium subterminale* resulted in a modified antibiotic regimen consisting in meropenem and teicoplanin, which were later replaced by oral amoxicillin and ciprofloxacin.

The 12 cm segmental bone defect required limb reconstruction and, since the patient wanted to avoid long treatment times, the Capanna technique was chosen. The second stage was carried out six weeks following the last debridement, once the area was deemed to be free of infection. All the necrotized tissue was removed and the bone surfaces were refreshed. A vascularized fibular graft was obtained from the contralateral leg and inserted through the medullary canal of a tibial allograft, one end inserted into the tibia and the other into the talus. Given the risk of sepsis, the limb was

Table 1
Timeline.

20-03-2022	Injury and admission to the emergency department
20-03-2022	Debridement and fixation of the distal tibia
21-03-2022	Stabilization of the pelvic ring
30-03-2022	Fixation of the pelvic ring
30-03-2022	Resection of the distal tibia and placement of a cement spacer
01-04-2022	Lumbar arthrodesis (L1-S1)
11-04-2022	Tibial and talar resection. Placement of a cement spacer and application of Stimulan
20-06-2022	Second stage of the Capanna procedure
12-08-2023	Beginning of weight-bearing
26-04-2023	Removal of external fixator
12-05-2023	Weight-bearing with a walker boot
11-08-2023	Full weight-bearing with one crutch
06-10-2023	Complete healing. Unaided, pain-free walking

Figure 1. Damage-control surgery with ankle stabilization by means of a bridging frame (Hoffmann 3, Stryker Corp, USA).

stabilized using a circular external fixator (TrueLok, Orthofix Srl, Italy) (Figure 3). To prevent a soft tissue infection, vancomycin- and gentamicin-loaded Stimulan was applied below the flap.

Unfortunately, intraoperative cultures came back positive for *Staphylococcus epidermidis*, which resulted in the initiation of antibiotic therapy with teicoplanin and meropenem, which were later replaced by ceftriaxone and tedizolid. Seven weeks after surgery, it was possible to add footplates to the external fixator to allow him to walk. Follow-up X-rays and CT scans demonstrated satisfactory healing of the grafts, the external fixator being removed at 10 months (external fixation index: 25.8 days/cm). Weight-bearing was initiated two weeks later with a walker boot, which was well-tolerated.

Fourteen months after the second stage of the Capanna procedure, the patient progressed to full weight-bearing with one crutch wearing rocker bottom shoes. His gait was satisfactory, with no pain and a stable arthrodesis. He was able to give up the crutch at fifteen months, with follow-up x-rays showing full healing and signs of tibialization of the fibular graft (Figure 4).

Discussion

This is the first case in the medical literature where a circular external fixator is used in a patient treated by means of the Capanna technique.[2] It is also one of the few reported cases where the un-

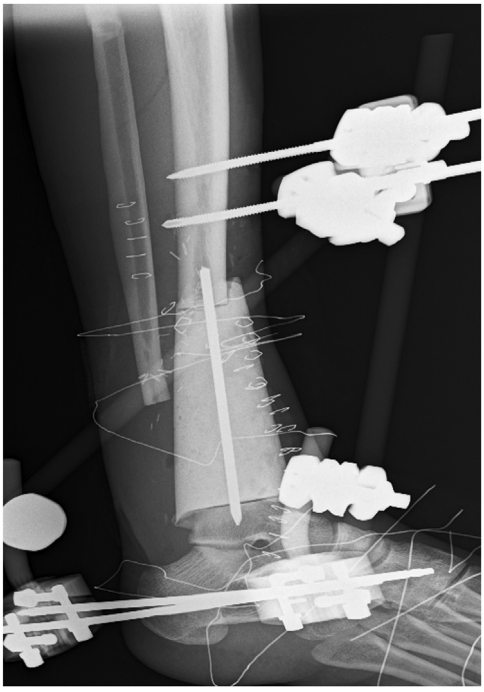

Figure 2. Lateral x-rays of the distal tibia and the ankle following implantation of the second spacer.

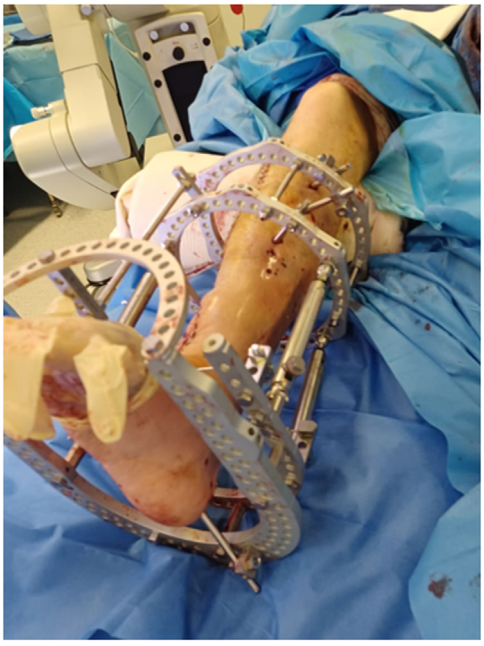

Figure 3. Clinical view of the external fixation system (TrueLok, Orthofix Srl, Italy) stabilizing the leg and the auto-allograft composite.

Figure 4. Radiographic follow-up at 15 months from surgery showing satisfactory incorporation of the strut allograft and hypertrophy of the fibular graft.

derlying condition was not a tumor[2–5] and where the joint is involved. The rationale of our treatment strategy included the treatment time associated with bone transport and the patient's septic status.

Although bone transport is the standard of care in the management of segmental bone defects,[1] the technique faces limitations such as the lengthy period of time during which patients must wear an external fixator. Makhdoom reported external fixation indices of 1.6 months/cm, which is in line with the figures published by Ros (45.6 days/cm), Lavini (45.6 days/cm), De Bastiani (38 days/cm) and Harshwai (1.42 months/cm).[9] Treatment time largely depend on successful healing at the docking site, which tends to be rather unpredictable, with rates ranging between 0 and 83%.[9] Given the size of our patient's bone defect (12 cm) the treatment time was likely to range between 15.2 and 19.2 months, according to the literature.[9]

The patient's septic status was extremely poor, making internal fixation unadvisable. Instead, a circular external fixator was chosen to stabilize both the limb and the grafts. In his original work, Capanna[2] stated that osteosynthesis should be as stable as possible, being the most common approach to fix the ends of the fibula causing as little trauma as possible and bypass the whole construct with angle-stable osteosynthesis plates[2–5] or intramedullary nails.[7] However, current circular external fixator designs have demonstrated excellent mechanical stability without undermining the biological environment. Moreover, the use of an external fixator in the management of foot and ankle infections permits single-stage reconstructions as well as performing the reduction on multiple planes.[10] In our case, circular external fixation resulted in a stable and minimally invasive fixation, facilitating reduction and sparing the graft from damage.

In the reconstruction of large bone defects, the Capanna technique[2] combines the advantages of a vascularized graft with those of struct allografts. It must be considered that the use of isolated strut allografts has typically resulted in high rates of infection, fracture and nonunion[6] and that, according to the literature, the use of vascular fibular grafts must be confined to non-weight-bearing regions or pediatric patients.[3] Capanna took advantage of the allograft's mechanical qualities and the vascularized fibula's biological activity to speed up healing, reduce failure rates and allow early mobilization of the affected limb.[2–5,7] Although it was originally conceived for patients undergoing chemotherapy (in whom vascularized grafts are associated with a higher risk of fracture and nonunion), its usefulness in the management of septic defects has also been documented.[7] In fact, vascularized fibula grafts create a biologically active environment that could potentially offer protection against infection,[4] a highly desirable outcome in our case. And while it is true that the use of donor material in a potentially infected environment has certain risks, our patient's management offered us some assurance that the patient's tissue was free of infection. Although other authors would have used double-barrel fibula transplantation, in our hands we feel that the stability provided by the Capanna technique is superior.

An intramedullary technique was used whereby the vascularized fibular graft was inserted through the allograft's medullary canal. This provided for a closer contact between the graft and the host bone, and offered a mechanically more stable configuration. An extramedullary configuration has also been reported –as well of the use of an ipsilateral vascularized graft-, but those alternatives were not considered appropriated in our case.

The fixator succeeded in stabilizing the limb and the grafts applied, keeping the foot in a plantigrade position. Graft healing was satisfactory, and the external fixator could be removed considerably sooner than would have been possible if bone transport had been applied. The external fixation index was 25.8 days/cm, as compared with 38-48 days/cm for similar cases approached with bone transport procedures.[9]

The latest x-ray follow-up revealed complete healing of the graft as well as hypertrophy of the vascularized fibula. No fractures of the allograft have been observed as yet, but the literature has demonstrated that such fractures – if they do occur - do not usually require to be operated as fibular hypertrophy ensures a sturdy reconstruction.[2]

The combination of a poor septic status, the presence of an articular defect and the use of an external fixator make this a unique case in the medical literature. In spite of the lack of previous evidence, the patient under analysis obtained a satisfactory result over a relatively short period of time.

Conclusions

Use of a circular external fixator combined with the Capanna technique has shown itself to be a valid option to address septic articular bone defects.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Ethical approval

Informed consent given by the patient for publication of the report with the official form of the Sociedad Española de Cirugía Ortopédica y Traumatología (SECOT)

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