CASE REPORT

Acute shortening and angulation for limb salvage in a paediatric patient with a high-energy blast injury

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SUMMARY

We present the case of an 8-year-old girl casualty of the Syrian conflict who arrived with open fractures of the right tibia and fibula with extensive bone and soft tissue loss as well as an open fracture of the left calcaneus as the result of a high-energy blast injury. She was successfully treated with repeated debridement procedures, external fixation with acute temporary shortening and angulation of the right leg and skin grafting to both lower limbs.

BACKGROUND

In war, civilian casualties are often afforded only the most basic of care. Owing to severely limited (or even completely absent) medical resources, it is impossible for patients to receive the most up-to-date evidence-based treatment regimen for their injuries. However, in rare cases, the wounded are able to reach a hospital which provides the current standard of care.

This patient was brought from Syria to a regional hospital in northern Israel, where the resources exist to provide her with state-of-the-art treatment for her complex and extensive injuries to both lower limbs. She underwent repeated debridement procedures, external fixation with temporary acute shortening of the right leg and split-thickness skin grafting to both lower limbs. After a 2-month course of the treatment including gradual realignment of the right leg using a hinged Ilizarov circular external fixation frame, the patient was discharged to her home with a plan for further staged care. She returned again to Israel for the next stage of her care, but follow-up remains a challenge.

CASE PRESENTATION

An 8-year-old Syrian girl presented to the emergency department with her mother 5 days after an explosion destroyed their home, injuring them both severely. The child's mother reported that her daughter did not lose consciousness during the explosion or any time thereafter. The patient arrived to the hospital in a relatively stable general condition. Although details of the treatment she received in Syria are unknown, there was evidence of a partial primary closure of the skin wounds on the right lower limb.

In Israel, in the emergency department, physical examination of the head, neck, cardiac, respiratory and abdominal examinations revealed no injury. Neurological examination was normal. The upper

limbs were intact, but the lower limbs, particularly the right leg, were severely injured.

There was an open 4 cm suppurative infected wound on the left leg above the heel. Pedal pulses were palpable, and there was no distal neurovascular deficit.

On the right leg were two longitudinal open wounds over the calf measuring approximately 12 cm each. The medial wound had been closed with sutures (in Syria), and the posterior wound had been left open. These wounds were also infected and malodorous, with large skin, muscle and bone defects, leaving the remaining tibia exposed. The viability of the tendons and nerves could not be assessed on clinical examination outside the operating theatre, but pedal pulses were palpable and the foot was warm.

While the child's mother reported that the explosion also caused a wall to fall on top of the patient, there was no evidence of a crush injury; rather, the patient's injuries appeared to be the result of the explosion itself.

The patient was highly anxious and fearful. She refused to make eye contact with anyone, often hiding under a blanket to avoid any sort of communication. She also refused to eat, which led to a profound weight loss.

INVESTIGATIONS

On admission, initial haematological tests showed a normal leucocyte count, a haemoglobin of 7.5 g/dL and a low reticulocyte index. Blood gases showed a bicarbonate level of 21.5 mEq/L and a base excess of -3.8 mEq/L.

X-rays of the right leg confirmed fractures of the tibia and fibula with bone loss and massive skin and soft tissue defects (figures 1 and 2). X-ray of the left leg showed a comminuted calcaneus fracture and foreign bodies within the soft tissue (figure 3).

Extensive lavage and debridement were performed, and the right leg was stabilised using a unilateral tubular frame (figure 4). After debridement and placement of the tubular external fixation device, the fracture could be seen on gross examination (figure 5).

Repeated debridement procedures were performed, and the wounds were treated with negative pressure wound therapy, prompting good healing with granulation tissue, as seen on gross examination (figure 6).

Right lower limb fixation in a position of acute temporary shortening and angulation (figure 7) provided closure of the fracture site and the bone ends, and after a skin graft, the wound began healing nicely.

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Figure 1 X-ray of the right leg on admission, demonstrating a comminuted fracture of the tibia and fibula with presence of multiple foreign bodies in the tissue.

Figure 3 X-ray of the left foot and ankle, demonstrating calcaneal fracture with presence of small metal foreign bodies.

Figure 2 X-ray of the right ankle, lateral view, demonstrating the fracture of tibia and fibula and massive soft tissue defect on the posterior aspect of the leg.

Figure 4 X-ray of the right leg, after the application of the tubular external fixation device, in the position of shortening.

Figure 5 Clinical picture of the right leg, demonstrating extensive skin and soft tissue defects on the posterior medial aspect of the leg. Exposed bone ends are seen in the fracture site.

Figure 7 X-ray of the right leg with anteroposterior view, with fixation of the left tibia in a position of angulation and shortening, using a tubular frame.

Figure 6 Clinical picture of the right leg, posterior view, demonstrating angulation with external fixation. Granulation tissue is seen.

An Ilizarov frame ([figure 8](#)) was placed on day 56.

TREATMENT

On the day of admission, aggressive skin and soft tissue debridement was performed on each of the patient's legs. The existing sutures were removed from the wound on the right leg, and the wounds were thoroughly washed with 10 L of normal saline. Denuded and comminuted bone fragments with questionable viability were removed. The right posterior tibial artery was ligated.

The open fractures of the tibia and fibula were corrected by external fixation ([figure 4](#)), with shortening of the bones with a tubular external fixation device. The wounds were left open, with paraffin gauze dressings. The patient was managed in the paediatric intensive care unit during the first 3 days for close monitoring, after which she was transferred to the orthopaedic department.

On day 7, distal and proximal ends of the bones were shortened approximately 2 cm. The bones were angulated in a varus position, 50–60° ([figure 7](#)). Angulation allowed more complete coverage of the bone by the soft tissue. During the procedure, peripheral pulse, capillary refill and limb colour were checked to ensure vascular viability. Afterwards, negative pressure wound therapy was applied to the wounds. Wound culture grew *Enterobacter cloacae* and *Pseudomonas aeruginosa*.

On day 10, the fractured edges were shortened a further 1.5 cm, and the varus angulation remained. The technique of shortening plus angulation and negative pressure wound therapy is key. Shortening is performed to salvage the remaining healthy

Figure 8 X-ray of the right leg, lateral view, showing fixation of the tibial fracture using a circular Ilizarov frame, with good alignment.

bone, while angulation and negative pressure therapy then achieve wound closure at a faster rate. Once there is closure, the fracture is reduced to normal alignment, and later, the bone can be lengthened by distraction osteogenesis.

The patient underwent repeated wound debridement and realignment with adjustment of the external fixation device and physiotherapy. On day 27, a split-thickness skin graft was taken from the right thigh and used to cover the granulating wounds on the left and right legs. Another wound culture on day 38 revealed the presence of *E cloacae*. Although the culture came back positive, the wound showed no signs of infection, and the graft was healing as expected.

On day 56, the tubular external fixation device was removed and replaced with an Ilizarov circular external fixation device, placed under X-ray visualisation. The hinged Ilizarov frame allowed the angulated tibia to remain secure. Full weight bearing to both lower limbs was possible immediately, and the patient was able to walk with crutches. The patient received physiotherapy throughout her stay in the hospital. After initial healing of the posteromedial wounds, gradual correction of the malangulation was begun. Over a period of 2 weeks, axial alignment was restored via isolated posteromedial distraction using the hinged circular Ilizarov external fixation frame.

From the time of her arrival, the patient suffered from severe post-traumatic distress. She would not make eye contact with anyone, and frequently hid under a blanket. The patient also

refused to eat, causing her to lose weight. To help manage her pain and mitigate her anxiety, the patient was anaesthetised with ketamine for every dressing change and examination. Throughout her stay, she met with a psychiatrist. The patient was also visited regularly by a medical clown, who was able to form a good bond with her. Over time, as her pain and level of fear decreased, the patient made dramatic improvements. She regained her appetite and her weight slowly increased.

OUTCOME AND FOLLOW-UP

X-rays showed proper tibial alignment, and the patient was discharged on day 70 with crutches and the Ilizarov device in situ, with a request to return for further care in 1 month, when a plan for proximal tibial corticotomy for elongation was to be carried out.

The patient was not able to return the following month, but did return 2 months after her initial discharge. She was to receive a proximal tibial elongation corticotomy, but the operation could not be performed on admission because the patient had a pin tract infection, likely due to lack of proper daily cleaning around the thin wires.

The patient was started on intravenous antibiotics, and two thin wires were extracted and replaced. Corticotomy is planned after resolution of the pin tract infection. The process of limb lengthening via distraction osteogenesis will then begin. The patient's mother will be instructed in the necessary pin care and daily pin adjustments required for limb lengthening, and the patient will again be requested to return for follow-up care. Exactly what type of intervening care is available in Syria is unknown.

DISCUSSION

High-energy injuries cause massive damage to bone and soft tissue and present a great challenge to the surgical team. This challenge is even more pronounced when addressing a paediatric patient, who must grow and develop. Proper realignment of the injured limb and complete fracture union is of the highest importance.

Debridement of wounds must be carried out early and repeatedly to ensure that the wound is free from foreign bodies and necrotic tissue. Radical debridement requires multiple trips to the operating room, which can be psychologically traumatic, particularly for young children. Our patient's wounds were debrided frequently, which helped salvage the limb at risk, but at the same time increased her level of anxiety. All this was on a background of over 2 years of Syrian civil war and unimaginable psychological trauma.

In this case, limb salvage was achieved through a series of several important processes following antibiotic administration and radical debridement. Minimal invasive external fixation of the injured limbs is an essential component of damage control orthopaedics, providing early fracture stabilisation. Temporary acute limb shortening or shortening with angulation are techniques performed in patients where extensive tissue defects (as are seen in war trauma) prevent the reconstruction of the limb to its original length. In addition, negative pressure wound therapy is used to promote faster healing and increase blood flow to the area. Once complete wound closure is achieved, the fracture can be gradually reduced to the proper anatomical alignment.

In cases such as this patient's, possible orthopaedic treatment strategies include massive bone allografting, or free vascularised bone grafting combined with different types of soft tissue flaps.¹⁻⁵ Another option is distraction osteogenesis, achieved using the Ilizarov method.⁶⁻⁸

Patients with delayed presentation after injury are at increased risk for infection and sepsis. Our patient presented 5 days after her

complex injuries were sustained, increasing her risk of sepsis substantially; in addition, her wounds were very dirty without adequate primary cleaning. For this reason, bone autografting and allografting were not considered good options, as the likelihood of infection greatly decreased the chance of transplant survival and fracture union. Moreover, an autografting procedure would have exposed the patient to additional donor site morbidity, and while the risk of a major complication was not high, even a minor complication is relevant when addressing a young patient.^{9 10} Both bone autografting and allografting require adequate coverage by a viable soft tissue flap.

A number of publications have shown that temporary acute shortening and angulation followed by gradual realignment and elongation, performed after successful soft tissue healing, have similar results to bone grafting. In fact, the number of necessary orthopaedic, plastic and vascular operative procedures may be reduced using the technique of acute temporary limb shortening and angulation rather than bone and soft tissue grafting. The rate of deep and chronic infection is also less.^{11–14}

Distraction osteogenesis via Ilizarov or Taylor external fixation frames has been successful in paediatric patients with bone loss,^{15–18} sometimes with even better results than in adult patients; while lengthening via distraction osteogenesis is typically carried out at a rate of 1 mm/day in adults, lengthening can be achieved at a faster rate in children.¹⁹

The use of distraction osteogenesis in paediatric patients is well documented in the literature, as is the use of acute shortening and angulation in adult patients. However, to our knowledge, there is nothing in the literature to describe the use of acute limb shortening and angulation in a paediatric patient with a high-energy blast injury from war.

The patient was discharged to her home in Syria with the Ilizarov circular frame in place. Superficial pin tract infection around inserted thin wires and half-pins must always be considered as a possible complication during long-term treatment with an Ilizarov external fixation frame. Thorough daily skin care around inserted fixation elements (thin wires and half pins) may prevent infection. Facilities for her care postdischarge, in Syria, are of concern.

Learning points

- Severe open fractures must be managed according to the principles of damage control orthopaedics.
- A staged protocol of minimal invasive external fixation combined with radical repeated aggressive debridement procedures seems to be an effective method for treatment of patients with complex high-energy war injuries with extensive tissue damage/tissue loss.
- The technique of temporary acute limb shortening and angulation is successful in paediatric patients.
- Discharging patients when the status of appropriate follow-up care is not known presents a challenge in medical care and is a huge concern for all.

If she is able to receive appropriate wound care, continued physical therapy and eventually, elongation, the patient's outcome should be excellent. However, she was released to her home in Syria, where she may never have the opportunity to complete her planned care, and from where her return to Israel would certainly be precarious.

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