The use of negative pressure therapy and hyaluronic acid for the management of post-traumatic lower limb injury

Emanuele Cigna, Michele Maruccia, Valentina Sorvillo, Paola Parisi, Francesca Palumbo & Maria Giuseppina Onesti

Department of Plastic and Reconstructive Surgery, Sapienza University, Rome, Italy

Key words
Advanced dressings; Conservative treatment; Degloving injuries; Dermal substitute; Negative pressure therapy

Correspondence to
M Maruccia, MD, Department of Plastic and Reconstructive Surgery, ‘Sapienza’ University of Rome, Via Mongiana, 28, 00126 Rome, Italy
E-mail: marucciam@gmail.com
doi: 10.1111/j.1742-481X.2012.01011.x


Abstract
Management of severe limb trauma continues to challenge surgeons. Suitable treatment should be individualised for each patient, taking into consideration not only the wound extremity but also the associated injuries, age and socioeconomic status of the patient with the goal to recover function and to improve patient quality of life. The aim of this report is to present a severe degloving multiplane lower limb injury case in which a conservative treatment of the wound was performed with negative pressure therapy and dermal substitute, avoiding amputation and restoring limb function.

Introduction
Large post-traumatic soft-tissue defects with bone exposure usually resulting from high energy trauma, such as car, motorcycle and work accidents, may represent a challenge for the surgeon. A wide spectrum of lesions can occur, ranging from isolated soft-tissue injuries (avulsion, degloving and crushing) with or without bone exposure. Furthermore, the framework of these lesions is often complicated by the presence of other injuries that have to be treated with priority (1). Management of bone exposure occurring after severe trauma of lower extremity is usually treated with an initial wide debridement of necrotic tissues, reduction of contamination and subsequent coverage of the defect (1,2). A case of wide and complex multiplane crushing and degloving injury of the lower limb with tibial bone exposure treated with dermal substitute is presented.

Key Messages
- management of bone exposure occurring after severe trauma of lower extremity is usually treated with an initial wide debridement of necrotic tissues, reduction of contamination and subsequent coverage of the defect
- a case of wide and complex multiplane crushing and degloving injury of the lower limb with tibial bone exposure treated with dermal substitute is presented

- an 83-year-old man presented to the Emergency Department of Policlinico Umberto Hospital of Rome, with a traumatic degloving injury of the lower limb caused by a rotavator
- a wide surgical debridement with the resection of devitalised tissue, bone reduction and fixation with Kirschner wires, repositioning of bleeding flaps and placement of negative pressure therapy (NPT) (continuous pressure of −125 mmHg) to cover the residual defect were performed
- multiple dressings and specific antibiotic therapy led to resolution of the infection 10 days after the trauma
- twenty-one days after hyaluronic acid (HA) application, we observed the presence of granulating tissue on the wound bed, except in the area of the tibial bone exposure, and small area of granulating tissue formation could be appreciated at the level of tibial periosteum
- at 6 months after trauma, the patient could ambulate independently and after appropriate physiotherapy he could practice his usual daily activities
- anterior tibial muscle flap is ideal to cover the exposed middle one third of the tibia
- total transfer of this muscle is not suitable because of disturbance of its function in dorsiflexion and inversion of the foot and possible damage of its segmental blood supply from the anterior tibial or anterior recurrent vessels

© 2012 The Authors
International Wound Journal © 2012 John Wiley & Sons Ltd and Medicalhelplines.com Inc
the choice for wound coverage is determined by the size of the defect, the tissue exposure, state of the wound, location of injury and length of vascular pedicle required
additional factors, such as general health status, aesthetic results and donor site morbidity, have also to be taken into consideration
in order to decide whether to save or amputate the limb, it is necessary to differentiate the neuropraxia from a partially severed or completely severed nerve, which cannot regenerate spontaneously
in our case, the plantar sensation was maintained, therefore, the limb salvage was chosen as the most appropriate treatment
in this patient, NPT was used to reduce bacterial load and to remove excess fluid and debris from the wound, increase tissue perfusion and improve local tissue oxygenation
in conclusion, this new therapeutic strategy could be considered a valid option for the treatment of lower limb trauma
the use of a dermal substitute allowed the filling of a large defect that subsequently could be covered with skin grafts and substitutes
also, reapplication of the dermal substitute is effective in cases with bone exposure when there is not enough granulation tissue, always monitoring local condition of the wound and making sure that there are no clinical signs of infection
at 6 month after trauma, the aesthetic and functional results were excellent
the 83-year-old patient returned to his normal life and was able to walk alone and promised to use the rotavator more carefully

Case report
An 83-year-old man presented to the Emergency Department of Policlinico Umberto I Hospital of Rome, with a traumatic degloving injury of the lower limb caused by a rotavator. The patient had a highly contaminated, knee-to-ankle-wide right leg defect with tibial bone exposure and posterior tibial vessel laceration, exposure of the extensor tendon of the foot and the cuboid bone with a V metatarsal bone fracture (Figure 1).

The patient had a previous history of ischaemic heart disease and was in ASA (American Association Anesthetists) class III (patient with severe systemic disease). A wide surgical debridement with the resection of devitalised tissue, bone reduction and fixation with Kirschner wires, repositioning of bleeding flaps and placement of negative pressure therapy (NPT) (continuous pressure of $-125$ mmHg) to cover the residual defect were performed. The dressing was changed every 3 days. After swabbing, a systemic antibiotic therapy was administered because of *Staphylococcus aureus* and *Achromobacter denitrificans* infection at the wound. Multiple dressings and specific antibiotic therapy led to resolution of the infection 10 days after the trauma. After 2 weeks, the patient underwent a second surgery, in which after a new debridement, HyalomatrixPA® (Fidia Advanced biopolymers, Abano Terme, Italy), was applied. Twenty-one days after hyaluronic acid (HA) application, we observed the presence of granulating tissue on the wound bed, except in the area

Figure 1  [A] Pre-operative appearance of the severe soft-tissue injuries with black necrosis due to complete degloving of the skin and soft tissue on the right lower limb at the Emergency Department.  [B] Large wound after surgical debridement and negative therapy pressure. [C] Dermal substitute application.  [D] At 3 months post injury after conservative treatment the wound of the lower leg is completely closed.
of the tibial bone exposure, and small area of granulating tissue formation could be appreciated at the level of tibial periosteum. A 3:1 meshed split thickness skin graft was applied to cover the granulating tissue areas and HA was used again to cover the exposed bone surface (Figure 1). After 3 weeks, the skin graft covered the soft-tissue defects while HA allowed the presence of granulation tissue that covered the exposed tibial bone area. In the areas where skin grafts did not attach, Jaloskin® (Anika Therapeutics Inc., Bedford, MA) was applied. The patient was treated once a week in the outpatient clinic with dressings. Complete reepithelialisation of the extensive defect was achieved 3 months after the injury. At 6 months, the patient could ambulate independently (Figure 2) and after an appropriate physiotherapy he could practice his usual daily activities.

Discussion

Severe, complex limb trauma management continues to challenge surgeons (1–3). Degloving injury has been defined as avulsion of the skin from the underlying structure such as nerves, blood vessels, muscles and bones. Soft-tissue injury could fall into four distinct patterns as follows: limited degloving, non-circumferential degloving, circumferential single plane degloving and circumferential multiplane (Table 1) (4). This case can be classified as a multiplane degloving injury, even if not circumferential, observing a large defect of the anterior region of the right leg and foot with avulsion of the skin from the underlying tissue and tibial bone exposure. Surgical treatment is always the first choice in lower limb trauma; it may be based on local flap, wherever peripheral tissues permit it. Sural artery flap could be performed for lower-third leg reconstruction (5–7), but its effectiveness is often limited by the nature and the infection of the bed, as in this case (8). Gastrocnemius muscle flap is a safe and relatively simple flap. It is usually used for knee and upper-third of the lower leg reconstruction (9,10). The main problems using this kind of flap are as follows: the presence of a short pedicle; the impossibility of covering extensive defects and the ones which are outside its arc of rotation, because of the small volume of the muscle distal part; and its lack of pliability. While several modifications have been made to solve these problems, the Gastrocnemius flap is indicated for moderate size lower extremity defects (11).

Anterior tibial muscle flap is ideal for covering the exposed middle one-third of the tibia. However, total transfer of this muscle is not suitable because of disturbance of its function in dorsiflexion and inversion of the foot and possible damage of its segmental blood supply from the anterior tibial or anterior recurrent vessels (12).

We did not use these types of flap because they could not afford full coverage of the area, particularly the lower-third of the tibia.

Graft application has selected indications and its use is not recommended in severely infected areas (13,14). Traditionally, soft-tissue coverage is delayed to allow for oedema to settle, as well as to facilitate a second look procedure that can reassess tissue viability (15). Nowadays radical debridement and early (within 72 hours) wound closure with vascularised tissue is preferred due to its several advantages (16). However, immediate reconstruction is not the answer for all patients under all circumstances. Lastly, certain wounds, such as electrical burns and highly contaminated wounds, would benefit more from multiple debridements and delayed reconstruction.

The choice for wound coverage is determined by the size of the defect, the tissue exposure, state of the wound,
location of injury and length of vascular pedicle required. Additional factors, such as general health status, aesthetic results and donor site morbidity, have also to be taken into consideration.

The gold standard reconstruction for defects larger than 25 cm² or those on distal third of the leg, ankle and foot is the use of free muscle flaps or free perforator flaps (17,18). Free tissue transfer can provide more tissue, have long pedicles (greater flexibility in insetting) and are not dependent on blood vessels within the recipient injured area. The decision between limb amputation and salvage is still unclear (19). There are different severity scores designed to assist the surgeon in making the decision on whether to amputate a wide injured lower extremity (19–23). But, these systems have limited utility and cannot be used as the sole criteria by which amputation decisions are made. Another important prognostic factor is thought to be preservation of plantar sensation. But, more than half of the patients who presented with an insensitive foot usually regain sensation after 2 years, presumably due to neuropraxia of the posterior tibial nerve (24). Neuropraxia is characterised by temporary interruption of impulse transmission, the loss of nerve continuity and absence of a complete recovery over a variable time period. Hence, plantar sensation should not be used as part of limb salvage decision algorithm (25). In order to decide whether to save or amputate the limb, it is necessary to differentiate neuropraxia from a partially severed or completely severed nerve, which cannot regenerate spontaneously. In this case, the plantar sensation was maintained. Therefore, limb salvage was chosen as the most appropriate treatment. Ultimately, the decision of whether to amputate or salvage must be individualised for each patient, taking into consideration not only the wound extremity but also the associated injuries, age and socioeconomic status of the patient and should be based on the patient’s needs and desires, direct and indirect costs of surgery, the patient’s motivation, compliance and the family’s support during the rehabilitative phase. In this case, leg amputation was a valid option due to the patient’s age and size of the wound and general health status. However, alternative strategies were also tried in order to avoid amputation. In this case, flap reconstruction could not be performed due to patient’s clinical status and extent of the loss of substance. Therefore, a staged reconstruction based on staged surgical debridement with debridement of the devitalised tissue, NPT and advanced dressing was performed. NPT is usually used in the granulation phase of healing in large wounds that are free of infection and necrosis, to achieve a rapid reduction in size. In large skin defects, other benefits associated with the therapy are a reduction in the number of dressing changes required. Its mechanical force also attracts the wound edges centripetally (26,27). In this patient, NPT was used to reduce bacterial load and to remove excess fluid and debris from the wound, increase tissue perfusion and improve local tissue oxygenation. Two weeks after the trauma, a reduction of clinical contamination and a clean wound bed were obtained with local surgical and medical systemic therapy, and an ester of HA was applied (28).

HA is one of the main extracellular matrix (ECM) components; the main role of HA in tissue repair process consists in promoting the entry of a large number of cells into the injured area and in orientating the deposition of ECM fibrous components (28–32), facilitating granulation tissue formation and the wound healing process. This dermal substitute provides a three-dimensional scaffold useful for the ordered colonization of fibroblast, endothelial cells and the deposition of ECM components, favouring a correct and anatomic three-dimensional reconstruction of the dermal tissue (33,34) through spontaneous degradation and prolonged release of HA up to 3 weeks (35). In this patient, HA also allowed coverage of the large tibial bone exposure. The particularity of this case is the formation of granulation tissue at the level of tibial bone, even in the areas with periostal stripping. After evaluating the possible complications of applying dermal substitute on the bone surface, we decided to proceed with this method which eventually produced a positive result. The remaining area was treated with an epithelial substitute, an ester of HA that helps prevent the need for further surgical procedures, and has been proven to be a valid and effective topical advanced dressing to promote skin epithelialisation (36,37). This conservative approach appeared to be effective in this case. A staged treatment with delayed reconstruction increases the time of wound healing and the number of hospitalisations and is useful especially in elderly patients.

In conclusion, this new therapeutic strategy could be considered a valid option for the treatment of lower limb trauma. The use of a dermal substitute allowed the filling of a large defect that subsequently could be covered with skin grafts and other substitutes. Also, reapplication of the dermal substitute is effective in cases with bone exposure when there is not enough granulation tissue, always monitoring local condition of the wound and making sure that there are no clinical signs of infection.

At 6 months after trauma, the aesthetic and functional results were excellent. The 83-year-old patient returned to his
normal life and was able to walk alone and promised to use the rotator more carefully.

Acknowledgements

All authors hereby declare not to have any potential conflict of interests and not to have received funding for this work from any of the following organisations: National Institutes of Health (NIH); Wellcome Trust; Howard Hughes Medical Institute (HHMI) and other(s). Each author participated sufficiently in the work to take public responsibility for the content.

References