Case Report

Preserving the lower extremity after severe devolving injuries to meet the patient's demand in two cases* (Limb salvage after degloving injury)

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Abstract

Background: Severe injuries of the foot are a life-changing event. They often lead to some form of disability, and are therefore very challenging to manage. Injuries of the extremity, especially the foot and ankle, are distinct predictors of poor outcome in polytrauma patients.

Degloving injuries of the lower extremity involving the heel and foot are a rare and unique subgroup of severe foot injuries.

Treating degloving injuries is challenging. The surgical approach has to take into consideration both osseous and massive soft tissue injuries aiming to preserve the unique architecture of the lower limb and reconstruct the soft tissue.

There are several surgical approaches for treating degloving injuries of the lower limb.

Case presentation: We would like to share our experience with two cases of young very active patients who suffered from a complex injury of the lower limb that included a massive degloving injury. It was of paramount importance to salvage the lower limb and keep it functional.

Both patients were treated while using the degloved skin as a defatted full thickness skin flap that was replanted on the injured limb followed by application of VAC-therapy.

Conclusion: We treated two patients suffering a severe degloving injury of the lower extremity with degloved skin as a full thickness flap in order to preserve both the extremity itself as well as the function of the lower limb according to the individual requirements of the patients. Consequently, we could enable the patient to pursue their professional musical training requiring subtle use of the lower extremity as well as ensuring sufficient function of the lower extremity in everyday use.

Introduction

Severe injuries of the foot are a life-changing event. They often lead to some form of disability and are therefore a real challenge to manage. Injuries of the extremity, especially of the foot and ankle, are distinct predictors of poor outcome in polytrauma patients. Therefore, injuries of the foot and their treatment should be paid similar attention to as injuries of long bones. In complex foot trauma, there is a gray area between those injuries which can and those which cannot be reconstructed.
Degloving injuries of the lower extremity that involve the heel and foot are a rare and unique subgroup of severe foot injuries. Quite often they are result of high impact trauma such as road accidents and crush injuries [1].

Crush injuries are the result of a body part being forcefully compressed between 2 hard surfaces whereupon compression of the muscle mass blocks the flow of blood and oxygen to tissues resulting in ischemia. Following ischemia necrosis occurs within a few hours.

Degloving injuries are characterized by separation of the subcutaneous tissue from its surroundings and thereby depleting its blood supply, thereby increasing the risk of soft tissue dehiscence and necrosis [2].

Treating degloving injuries is challenging. The surgical approach has to take into consideration both osseous and massive soft tissue injuries. Its objective is to preserve the unique architecture of the lower limb and to reconstruct the soft tissue. This should be done as soon as possible after the injury, in order to minimize the risk of future infections and necrosis especially when open fractures are present [2].

When treating a multi-trauma patient suffering from a severe degloving injury, initial treatment protocol is based on the ATLS guidelines, and life threatening injuries should be addressed first. Only after the multi-trauma patient has been stabilized, a thorough orthopedic and plastic evaluation can be conducted. Soft tissue and osseous damage should be classified according to Tscherne and Oestern classification for soft tissue damage in closed fractures (Table 1) and the Gustilo-Anderson classification for open fracture (Table 2). The Gustilo-Anderson classification classifies open injuries according to the size of the wound and neurovascular involvement. Complication rates are associated strongly with the grade of open injury, with complication rates of > 40% in grade 3 open injuries.

The initial or immediate treatment of a complex injury of the foot presents in the emergency department the following two treatment principles should be kept in mind: (1) initial or early treatment and (2) definite treatment.

When treating high energy trauma with severe lower limb damage one can use the MESS scoring system to make clinical decisions whether to save or amputate the injured limb [5] (Table 3)

| Table 1 | Tscherne and Oestern classification of soft tissue injuries in closed fractures. |
|---------|--------------------------------------------------------------------------------|
| C0 | Minimal soft tissue damage. Simple fracture pattern. |
| C1 | Superficial abrasion or contusion caused by pressure from within. Mild to moderate fracture pattern. |
| C2 | Deep contaminated abrasion associated with localized skin or muscle contusion. Impending compartment syndrome. Severe fracture configuration. |
| C3 | Extensive skin contusion and crash. Underlying muscle damage may be severe. Subcutaneous decollement. Decompensated compartment syndrome. Associated nerve and or vascular injury. Severe or comminuted fracture pattern. |

Treatment options should also take into consideration the severity of the injury as well as the patients demands (if he/she is able to communicate them).

When treating a multi-trauma patient suffering from a severe degloving injury, initial treatment protocol is based on the ATLS guidelines, and life threatening injuries should be addressed first. Only after the multi-trauma patient has been stabilized, a thorough orthopedic and plastic evaluation can be conducted. Soft tissue and osseous damage should be classified according to Tscherne and Oestern classification for soft tissue damage in closed fractures (Table 1) and the Gustilo-Anderson classification for open fracture (Table 2). The Gustilo-Anderson classification classifies open injuries according to the size of the wound and neurovascular involvement. Complication rates are associated strongly with the grade of open injury, with complication rates of > 40% in grade 3 open injuries.

Since the inter-observer agreement is weak for the Gustilo-Anderson classification [3], it is advisable to avoid classification of injury in the emergency department, in order to be able to achieve and optimal agreement in the operating room during debridement.

Zwipp et al. proposed a scoring system for foot and ankle injuries to define complex injuries [4] (Fig. 1, here, foot and ankle are divided into 5 major areas: Lisfranc, Chopart, calcaneus, talus, and ankle/pilon). Each injured area (dislocation or fracture) equals 1 point, to which points are added for the severity of the soft tissue injury according to the Tscherne and Oestern grade in the most affected area. When the sum of the Score is 5 points or higher the injury is considered a complex foot trauma.

Whenever a patient with a severe injury of the foot presents in the emergency department the following two treatment principles should be kept in mind: (1) initial or early treatment and (2) definite treatment.

The initial or immediate treatment of a complex injury of the foot has several goals and can be divided into three (overlapping) sub-phases: 1. prevention of progression of ischemia and necrosis, 2. prevention of infection, 3. consideration of salvage or amputation.

Treatment options should also take into consideration the severity of the injury as well as the patients demands (if he/she is able to communicate them).

When treating high energy trauma with severe lower limb damage one can use the MESS scoring system to make clinical decisions whether to save or amputate the injured limb [5] (Table 3)

There are several surgical approaches for treating a degloving injury of the lower limb. In general, one should try and follow the golden rule of reconstructive surgery: “Replace like with like”.

These surgical approaches use local flaps, free flaps or skin grafting [6–8].

Some authors claim that since the degloved skin is avital, a thorough debridement and covering of the underlying tissue with skin grafts or flaps must be performed [7,9]. However, in unique areas like the sole of the foot, transferred skin will not have the same unique architecture and qualities as the injured skin.

In a paper published by Yan [10], they treated patients (children and adults) who sustained severe degloving injury to the lower limb with replantation of the degloved skin as a defatted full thickness skin and put a VAC-therapy on top of it. The results showed good functional and cosmetic results. All patients obtained protective sensation in the transplanted skin.

We would like to share our experience with degloving injuries and replantation of the degloved skin as a defatted full thickness skin flap followed by application of VAC-therapy.

| Table 2 | Gustilo and Anderson classification of open fractures. |
|---------|------------------------------------------------------|
| Type 1 | Wounds < 1 cm, minimal contamination and soft tissue injury, simple fracture pattern. |
| Type 2 | Wounds 1 to 10 cm, moderate contamination and comminution. |
| Type 3A | High energy. Minimal periosteal stripping. |
| Type 3B | High energy. Significant periosteal stripping. Flap required to close the skin. |
| Type 3C | Vascular injury. |
Case 1

A 24-year old woman was overrun by a truck while crossing the road. Hereby, her right foot was crushed under the truck wheels.

On arrival in the emergency room, the patient was awake (GCS = 15), hemodynamically stable and suffered from severe pain in her right foot and displayed some minor wounds and pain in the face. The skin of her right foot appeared to be totally separated from the foot and was taken to the hospital together with the patient. The patient was managed by the trauma team according to the ATLS (Advanced trauma life support) protocol on the arrival in the emergency department. During secondary survey, a massive degloving injury of the right foot was apparent (Picture 1) with the skin of the right foot being completely separated from the foot.

Clinically and radiologically, traumatic amputation in the interphalangeal joint (IPJ) of digitus I and complete deglovement of the skin of the foot caudally of the retinaculum extensorum was diagnosed. All other osseous, muscular, vascular and ligamentous structures were intact.

Further injuries diagnosed were a fracture of the zygomatic bone on the left side and a minor head injury.

The patient was otherwise healthy and had no previous medical conditions. She was studying to become a professional organ player.

After initial stabilization, both an orthopedic and plastic consult were involved. Mutual agreement was to proceed with operative treatment aiming to preserve the function of the foot as much as possible, keeping in mind that the patient’s aspired profession depended on sufficient function of the foot to play the organ.

Primary surgery was aiming for debridement of the contaminated and necrotic tissue with minimal damage to the soft tissue and osseous structure and covering of the large wound using the degloved skin as a defatted full thickness flap. The devolved skin was defatted and prepared for replantation.

During the operation, it appeared that not all toes could be covered with skin again. Thus, we decided for exarticulaton of all toes of the right foot in the metatarso-phalangeal joint (MTPJ) in order to achieve a functional form of the foot with existing traumatic

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**Table 3**

| Type                        | Characteristics | Injuries | Points |
|-----------------------------|-----------------|----------|--------|
| Skeletal/soft-tissue-group  |                 |          |        |
| 1                           | Low energy      |          | 1      |
| 2                           | Medium energy   |          | 2      |
| 3                           | High energy     |          | 3      |
| 4                           | Very high energy|          | 4      |
| Shock group                 |                 |          |        |
| 1                           | Normotensive    |          | 0      |
| 2                           | Transiently hypotensive | | 1      |
| 3                           | Prolong hypotensive |     | 2      |
| Ischemia group              |                 |          |        |
| 1                           | None            |          | 0*     |
| 2                           | Mild            |          | 1*     |
| 3                           | Moderate        |          | 2*     |
| 4                           | Advanced        |          | 3*     |
| Age group                   |                 |          |        |
| 1                           | < 30 years      |          | 0      |
| 2                           | 30-50 years     |          | 1      |
| 3                           | Above 50        |          | 2      |

Score 6 or less – Salvageable limb.
Score 7 or more - Amputation.
* Multiply × 2 if ischemia time exceeds 6 h.

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**Fig. 1.** 5 functional levels of the foot which are important for graduation of complex foot trauma [4].
amputation in the IPJ I.

Afterwards, the full thickness skin graft was adapted on the foot and multiple incisions were placed in the heel in order to allow drainage of secretion (Picture 2). Finally, the foot was wrapped in a vacuum-assisted closure dressing (VAC).

In the course of hospitalization, the patient was taken several times to the operating room for careful debridement of the necrotic and infected tissue and changes of the VAC-system. The VAC was removed 2 weeks after the injury.

The patient was treated prophylactically with co-amoxicillin for 17 days from the first operation onwards.

25 days after the initial surgery, wet gangrene occurred on the dorsal foot and parts of the heel, so that further debridement of the infected areas and vacuum-assisted closure system was performed again. Microbiology samples taken during this surgery revealed growth of aspergillus fumigata, serratia fonticola and Staphylococcus aureus. Consequently, antibiotic therapy was adapted to Sulfamethoxazol und Trimethoprim based on the bacteriogram and sensitivity.

Combination of surgical debridement and the targeted antibiotic treatment prevented further dissemination of infection from...
happening. During the hospitalization period the full thickness skin graft was partially absorbed and islands of autologous skin have been formed. In the space between the skin island mash skin grafts were attached.

The patient was discharged from hospital after 3 weeks. Further regular controls took place in our outpatient clinic.

Today, the patient has dry and pink skin on the foot. The patient can sense light touch and pressure on her foot. The ankle and subtalar motion are intact. Patient can walk using an orthopedic shoes adjusted for the amputated forefoot and is playing the organ professionally again while using her right foot (Picture 3).

**Case 2**

A 57-year-old, otherwise healthy woman was hit by a truck as a pedestrian. During this accident, the right lower limb was overrun by the wheels of the truck.

The Patient was admitted into the emergency room and evaluated according to the ATLS guidelines by the trauma team. On arrival, the patient was alert and conscious, GCS 15. She was generally healthy and had no previous medical conditions.

After initial stabilization, the patient was taken to the operation room for further exploration of the wounds. Injuries of this patient appeared to be more extended than in the first case with a large Morrel-Lavallee lesion ranging from the right inguinal region up to the lower costal arch and an extensive degloving injury beginning in the right groin down to her foot. The muscles of the right thigh and leg were exposed. The right foot displayed partial traumatic amputation of the forefoot with complex open fractures of the metatarsal bones. Other injuries included traumatic open osteochondral lesion of the medial femoral condyle of the right knee (Picture 4).

Prior to this first surgery, we decided to try and salvage the limb. The Patient was taken to the operating room on the day of arrival to the hospital. During this first surgery, a thorough but careful irrigation and debridement of the soft tissue of the degloved lower limb was performed, paying attention to not cause further damage to the soft tissues. The partial amputation of the forefoot, displaying Gustilo grade IIIb open fractures, was converted into a Lisfranc amputation. A formal open arthrotomy of the right knee was conducted with irrigation of the open joint followed by application of an ex-fix bridging the knee joint. Degloved skin was defatted and partially stored for future use and partially replanted as a full thickness skin graft. By the end of the surgery, a VAC-therapy was applied on the whole right lower limb.

During the second look operation 3 days after, debridement of infected-looking and necrotic tissue was performed and samples for
microbiological examination were taken. The VAC was reattached to the whole lower limb. Microbiological samples that were taken during this second surgery were sterile.

A third look followed a few days later in which additional debridement of infected and necrotic tissue was conducted. Moreover, the trans-knee ex-fix was converted to a trans-ankle ex-fix. The stored degloved skin was defatted and reattached to the right lower limb as a full thickness graft (Picture 5). Afterwards, VAC was reattached to the whole lower limb.

A fourth surgery included further debridement of infected and necrotic tissue. Mesh grafts from the contralateral thigh were harvested and placed on the right thigh. Again, a VAC was installed over the whole lower limb.

Co-Amoxicilline intravenously was started as prophylactic antibiotic therapy and stopped 14 days after, since no signs of infection were diagnosed clinically.

Four days after antibiotic therapy was finished, the patient started to complain about pain in the right lower limb especially in the groin and ankle. Physical examination, revealed signs of superficial skin infection in the right groin. Hence, patient was taken to the operation room again for debridement in the right groin. Following the debridement, mesh grafts from the contralateral thigh were harvested again and placed on the right thigh which was not covered by split thickness skin grafts yet. VAC was reattached covering the whole lower limb. However, the patient continued to complain about increasing pain in the right lower limb radiating from the right groin to the foot with maximal pain in the groin and ankle joint.

The microbiology samples that were taken revealed growth of *Enterobacter cloacae* resistant to Ampicilline, Co-Ampicilline and Cefuroxim. Antibiotic treatment with Cefepime iv. was started according to the recommendations of the infectious diseases physicians.

Patient continued to complain about pain in the right groin and ankle. After the establishment of soft tissue infection in the right groin, patient was taken again to the operating room for further debridement. This time the microbiology samples showed growth of *Enterobacter cloacae*, *Stenotrophomonas Maltophilia* and *Citrobacter Koseri*. Antibiotic therapy was adapted to Sulfamethoxazol und Trimethoprim based on bactriogram.

After adjusting the antibiotic therapy, patient was debrided two more times in the operating room. Since no more progression was seen with the use of the VAC, it was decided not to reconnect the VAC and to use wet bandage on the wounds on the right lower limb.

In the course of the events, patient improved clinically but still complained about pain in the right ankle. The wound in the right groin was closed, the trans-ankle ex-fix was removed and patient was released to a rehabilitation clinic. Antibiotic therapy was continued according to the infectious diseases physician's recommendation.

During the stay in the rehabilitation center pain in right ankle increased and an MRI was initiated which showed osteomyelitis of the right ankle, the medial malleolus and the distal fibula.

Patient was taken once more to the operating room where Boyd amputation was performed. The tibial plafond, medial malleolus, distal fibula, talus and mid foot were resected. The calcaneus was flipped 90° and secured to the tibia with 3 cancellous 7.3 mm screws. The soft tissue and skin of the mid foot were debrided and closed without tension.

The bactriogram now showed growth of gram negative flora and MSSA (Meticillin-sensitive-staphylococcus-areus). Rimacatan was added to the sulfa-trimethoprim.
The antibiotic treatment was continued for 4 months after the last surgery according to the infectious diseases physician's recommendations.

Following the last surgery patient improved dramatically.

Today the patient is fully ambulating with a special orthopedic shoe. The stump of the right foot which was covered by defatted degloved skin as a full thickness flap, has today pain sensation, light touch sensation and temperature sensation (Picture 6).

Discussion

Degloving injury of the foot continues to be a challenging condition to treat. Despite current advancements in reconstructive options, most of these injuries can end up in amputations, causing physical and emotional impairment. Since the majority of patient who sustain such an injury are young and active, the aim to save the limb is of outmost importance. Few reports have been published on the management of these complex traumatic injuries. There is no consensus on the treatment algorithm in such cases. The treating physician has to tailor a specific and unique treatment protocol for every single case. The surgical approach should treat both osseous and massive soft tissue injuries. The aim of treatment is to preserve the unique architecture of lower limb and reconstruct the soft tissue.

The typical reconstruction options have included skin grafting, flaps and reattachment of the avulsed skin. Good results were achieved while using the degloved skin as defatted full-thickness skin grafts combined with a VAC machine. Jostey et al. were among the first to report good clinical results after replantation of degloved skin of the foot and the use of VAC afterwards.

This technique provides a full thickness skin graft with almost all the characteristic of the native degloved skin, plus a constant negative pressure on the transplanted skin.

The constant use of the VAC machine decreases the edema and the amount of fluids in the transplanted skin bed, thus helping it to incorporate.

The use of VAC has decreased the risk of grafts failure and improved the recovery time of the tissue after the operation.

Our experience with using the foot degloved skin as defatted full thickness graft on the degloved foot and then applying the VAC machine has showed good results. The patients that were treated with this method have regained functionality. Patients are mobile without walking aids and resume their daily activities. The defatted degloved foot skin retains most of its special characteristics. The foot remains sensate with good light touch, pain and temperature sensations.

We believe that although degloved injuries pose a challenge to the surgeon, the patients benefit is huge. Keeping the degloved limb functional with the special characteristic of the skin of the foot is a true limb salvage procedure. The patients remain functional and lack the physical and emotional impairment caused by an amputation.

However, the success of such therapeutic approach depends on various factors. Guo the al. [8] have shown that comorbidities such as diabetes, PVD and malnutrition should be taken into consideration because of adverse effect on the results. Yan et al. described that age itself did not have any influence on the final outcome.

A multi-disciplinary approach is essential when treating such patients. A collaboration between the trauma team, orthopedic and plastic surgeons, infectious diseases doctors and the physiotherapists is of the outmost important.

Our experience with degloving injuries of the lower extremity where degloved skin was used as a full thickness skin graft followed by VAC showed promising results. Since such injuries are rare, and every injury has its own characteristics it is difficult to attach to a one single protocol telling what to do in such cases. The approach to such injuries changes from case to case but it is always important to keep in mind that reconstructive surgery has better functional and cognitive outcomes.

Picture 6. 6 months after the initial trauma.
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List of abbreviations

MESS: Mangled Extremity Severity Score
VAC: vacuum assisted closure
GCS: Glasgow Coma Scale
ATLS: advanced trauma life support
IPJ: interphalangeal joint
MTPJ: metatarso-phalangeal joint
Ex-fix: external fixator
MSSA: Methicillin-sensitive-staphylococcus-aureus