Research Article

Open Soft Tissue Degloving Injuries of Lower Limbs Managed by a Staged Protocol Using Preserved Autologous Skin Graft

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Abstract

Background: Degloving soft tissue injuries (DSTIs) are defined as detachment of skin and its appendages from underlying muscle fascia. The present study aimed to assess the outcome of open circumferential DSTIs of lower limbs using a staged protocol by utilizing the stored skin graft harvested from degloved skin flaps.
Methods: This retrospective study included 12 patients with open circumferential lower limb degloving injuries (Arnez types three and four), with a minimum final follow-up of two years. All the patients were treated using a staged protocol, which included harvesting skin grafts from the degloved skin flaps, followed by refrigerator storage of the graft and stay sutures for the flap. The refrigerator-stored graft was then used to cover the raw areas left after secondary debridement.
Results: The mean wound area per patient that required skin grafting was 1082.9 ± 679.0 cm^2, and mean area of the wound covered by refrigerator-preserved skin graft per patient was 798.7 ± 350.0 cm^2. One patient needed a latissimus dorsi flap, and three patients with whole limb degloving had to undergo skin grafting for the remnant raw area harvested from the contralateral thigh. None of the patients ended up with amputation.
Conclusion: Despite being rare, open DSTIs are very complex injuries with no definitive guidelines for management, especially Arnez type three and four injuries. The staged protocol presented in the present series potentially answers the dilemma. However, larger multi-centric trials are needed to study the outcome of the discussed staged protocol.

Keywords: Degloving Injuries; Free Tissue Flaps; Skin Transplantation

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Background

Degloving soft tissue injuries (DSTIs) are sustained due to shearing forces that arise during high-energy trauma, resulting in the detachment of skin and subcutaneous tissue from underlying fascia and muscles (1, 2). The usual mechanism of injury is a high-velocity traffic accident or an industrial mishap (1), and these injuries commonly involve the lower extremities and torso (1, 3, 4). These injuries have a male predominance (5). The avulsion of skin flaps can be extensive at times damaging the perforating vessel pedicles, hence compromising the microvasculature of avulsed flaps (6). The loss of skin barrier in DSTIs demands a well-planned reconstruction to minimize the potential complications (7). However, there is no consensus on the management protocol for these injuries; therefore, it becomes impossible to follow a set protocol (7, 8).

Among the various attempts to classify DSTIs, the simplest one is to divide these into open and closed types (9, 10). Arnez et al. (7) described four patterns of DSTIs which included limited degloving with abrasion or avulsion (type one), non-circumferential degloving (type two), circumferential single plane degloving (type three), and circumferential multi-plane degloving (type four). They concluded that avulsed flaps re-sutured in situ survived in non-circumferential (type two) cases only. The single-stage procedure with radical excision of devitalized tissue followed by reconstruction of soft tissue defect was successful in all patterns except in circumferential multi-plane degloving (type four). Staged reconstruction was recommended for type four injury. Being self-critical of the aggressiveness in the approach followed, Arnez et al. stated that their approach needed to be modified while dealing with type three and type four injuries.

Some studies have described the re-attachment of detached flaps back to the underlying wound bed of myofascial tissues after debridement (7, 11). However, some authors have discouraged this and favoured early debridement and wound coverage (12). Skin graft harvested from the degloved flap has also been used to cover the defect created post-debridement (7, 11, 12). Cryopreserved skin graft harvested from degloved skin has been replanted successfully over the granulated wound after many days of injury (13).

With such contrasting evidence in literature regarding open DSTIs, especially Arnez types three and four, it is hard to follow a set protocol. Hence, the results of a staged protocol were studied in the present study (Figure 1). The protocol involved primarily limited debridement with the harvesting of split-thickness skin graft (STSG) from the avulsed flap and primary closure of the flap during stage one. The STSG harvested from the skin flaps was stored in a refrigerator. During stage two, serial debridements were done, and the status of the wound was monitored. Once a healthy wound bed was ready, a reconstructive procedure was carried out during stage three.

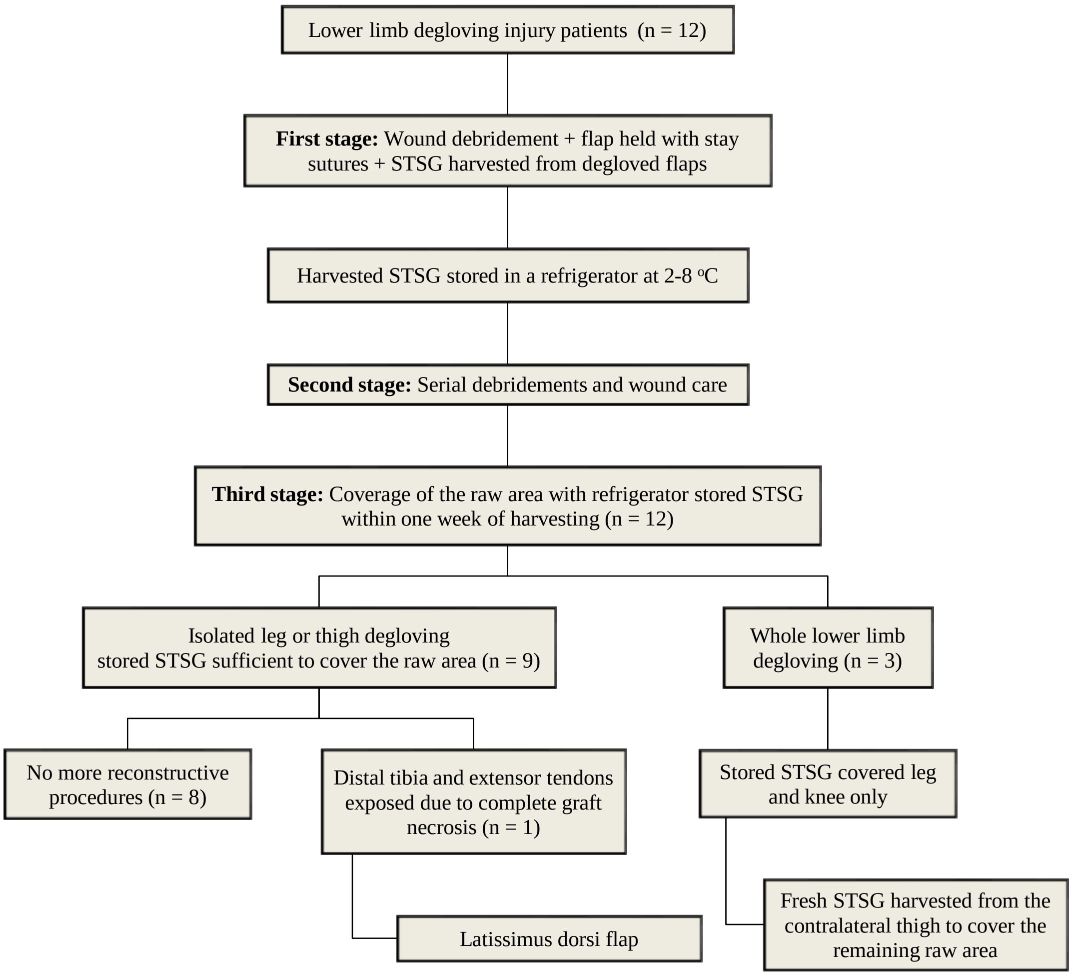

Figure 1. Outline of the study demonstrating various stages of the protocol followed (STSG: Split-thickness skin graft)

Methods

This retrospective study was conducted on a group of patients who had reported to the emergency unit of our institution. Twelve patients with extensive open DSTI of lower extremities, who were admitted from August 2017 to January 2023, were included in this study.

The patient and wound characteristics, including the mechanism of trauma, in addition to management steps, were retrieved. It included age, gender, co-morbidities, pattern and extent of degloving injury, wound size, and associated injuries. Adult patients (aged > 18 years) with Arnez et al. (7) type three (circumferential single-plane) and type four (circumferential multi-plane) open degloving injury of lower limbs who presented to the hospital within 24 hours of the injury were included in the present study. Patients with closed degloving, traumatic amputation, associated bony injuries that required fixation, neurovascular injuries requiring repair, delayed presentation (> 24 hours), and any head injury or thoracoabdominal trauma requiring urgent active surgical intervention were excluded from the study. The procedures performed were by the standards of the institutional ethical committee and with the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards. The institutional ethical committee approved the study (approval No.: GMCA/IEC/2023/15 dated 10-05-2023). Informed consent was obtained from all participants included in the study.

The management protocol followed in the present study was divided into three stages (Figure 1). In the first stage, the boundaries of the wound were marked on the transparent sterile disposable plastic drape after wrapping it over the bare wound area. The area enclosed within the boundaries was taken as the area of the wound. Primary debridement was performed to remove the non-viable and grossly contaminated tissue (Figure 2). The grossly damaged portions of the avulsed flap were trimmed off, and a profuse saline lavage was done to decontaminate the remaining intact flap portions. The avulsed flaps were sutured back to the wound bed without undue tension and were left to act as a 'temporary biological dressing' (Figure 2). A suction drain was placed under the sutured flap. The suturing back of avulsed flaps helped achieve a uniform contour and tension throughout the flap surface sufficient to facilitate the harvesting of STSG using a Humby knife (Figure 2). The harvested skin graft was meshed to increase the surface area, and each piece of skin graft was folded unto itself in a way that the cut surfaces were opposed to each other, and the graft was sandwiched in a saline-moistened gauze.

Figure 2. Circumferential mutiplane degloving of the whole left thigh and leg (A). After gross decontamination and wound debridement and defatting (B), the skin flaps were held with stay sutures (C). A suction drain was placed, and a skin graft was harvested from the degloved flaps (D, E). The harvested skin graft was packed in a saline-soaked gauge (F) and stored in a refrigerator. After serial debridements, almost all the skin flaps were lost (G). The preserved skin graft was sufficient enough to cover the area from knee to ankle in this case (H). The rest of the raw area was covered by a split-thickness skin graft (STSG) harvested from the contralateral thigh (I). Complete take-up of the graft was observed at follow-up (J).

The STSG harvested from the avulsed flap was quantified (cm^2) after meshing in each case. To avoid vaporization during the handling of packed graft and to prolong the retention of the normal saline, providing a physiological environment to living tissue, the saline-moistened gauze was wrapped up in surgical gloves. The gloves were punctured at multiple sites to provide aeration. The skin storage and grafting were carried out in an aseptic way all along the treatment. The STSG was stored at lower (non-freezing) temperatures in a refrigerator at 2-8 ^{o}C.

During stage two, serial debridements were performed as required. The first post-operative bedside examination of the wound was done within 72 hours of injury in all cases. Clinical judgment, including skin flap discoloration, absent capillary refill, loss of skin turgor, sensory loss, bloodless pinprick, non-bleeding flap edges, and viability demarcation line were some parameters utilized to decide regarding the amount of flap that needed excision. Afterward, the wound was watched closely and examined regularly at the bedside to assess its readiness for reconstructive procedure. Any slough noticed on the wound during examination was cleared bedside either by saline dressing or surgical debridement. The intravenous (IV) antibiotic cover was continued from the time of arrival in the emergency. As a result of serial debridements, most of the sutured flap was lost.

During the third stage, refrigerator-stored STSG was used to cover the wound within a week of harvest. Before re-plantation, the refrigerated skin graft was kept in normal saline at room temperature for 15 minutes. The preserved STSG harvested from flaps was utilized to cover the wound bed, and fresh graft from the new donor site was harvested as and when required. The line of management was uniformly the same for all cases except for a small modification in three cases with involvement of both leg and thigh. In these cases, during the third stage, the preserved graft harvested from flaps was primarily used to graft the wound over the leg to preferentially cover the exposed periosteum of the tibial shin, patella, knee joint, and tendons with intact paratenon, if any. The preserved graft in these cases sufficed for the leg and knee, but the area of the wound over the thigh required an additional skin graft, for which we waited another five days before taking the patient to the operating room again to graft the remaining wound (Figure 2). Non-meshed thick portions of graft were used across the mechanically demanding areas like the knee joint to lessen the chance of contracture and scarring around the joint. The first post-operative dressing of the grafted wound and removal of staples was done on the fifth to seventh post-operative day (POD) to avoid shear and traction to the healing graft, and intermittent dressing change for the next two to three weeks was done every two to three days. Paraffin gauze dressing covered with saline-moistened gauze was used for dressing the wounds. Physiotherapy of joints was started three weeks post-operatively in all cases, as the skin grafts were fixed and epithelialized by then. The patients were followed regularly on an outpatient basis for at least two years. SPSS statistics software (version 20, IBM Corporation, Armonk, NY, USA) was used to conduct the statistical analysis of the data.

Results

Master chart depicting parameters of the patients included in the present study are summarized in table 1.

Table 1. Master chart demonstrating demographic details of the patients and complications observed

Age (year)	Sex	MOI	Injury pattern (Arnez type)	Site of injury	Wound area (cm^2)	Preserved graft area (cm^2)	Wound coverage with preserved graft after 1st stage (%)	Graft uptake of preserved graft at 5th POD (%)	Additional procedures (if needed)	Hospital stay (day)	Complications
25	Male	RTA-P	Circumferential single plane (type 3)	Left leg	734	692	94.27	88		14	
30	Male	RTA-P	Subtotal circumferential single plane (type 3)	Right leg	647	632	97.68	82		12	
32	Male	Trapped in concrete mixer	Circumferential multi-plane (type 4)	Left leg	812	786	96.79	68	STSG and latissimus dorsi flap	29	Graft necrosis at distal leg exposing tibia and extensor tendons
27	Male	Railway run over	Circumferential multi-plane (type 4)	Right thigh and leg	1932	1257	65.06	88	STSG	18	Deep serous collection in the proximal thigh after skin grafting
70	Male	RTA-P	Subtotal circumferential single plane (type 3)	Left thigh	342	342	100	100		12	
52	Female	RTA-P	Circumferential multi-plane (type 4)	Right thigh and leg	1848	1152	62.33	86	STSG	20	Knee stiffness
34	Male	Flour roller mill belt	Circumferential multi-plane (type 4)	Right leg	689	560	81.27	84		12	Superficial infection after primary skin grafting
35	Male	RTA-tractor turned turtle	Circumferential multi-plane (type 4)	Left thigh and leg	2248	1348	59.96	93	STSG	15	Partial necrosis of graft over the lateral aspect of the knee after primary grafting
43	Male	Farm roller machine	Circumferential single plane (type 3)	Right leg	750	638	85.06	98		12	
28	Male	RTA-motor cycle	Circumferential multi-plane (type 4)	Right thigh and leg	2041	1294	63.40	78	STSG	16	Hypertrophic scar
62	Female	House collapse	Circumferential multi-plane (type 4)	Left leg	574	506	88.15	96	Exploration of foreign body	11	Missed foreign body (glass)
18	Male	RTA-P	Circumferential single plane (type 3)	Right thigh	378	378	100	100		11	
Mean ± SD: 38.0 ± 15.7					Mean ± SD: 1082.9 ± 679.3	Mean ± SD: 798.7 ± 350.6				Mean ± SD: 15.1 ± 4.9	

MOI: Mechanism of injury; POD: Post-operative day; RTA-P: Road traffic accident-pedestrian; STSG: Split thickness skin graft; SD: Standard deviation

Twelve patients participated in the present study, including ten (83.33%) men and two (16.67%) women. The age of the patients ranged from 18 to 70 years, with a mean of 38.0 ± 15.7 years. The right limb was involved in seven patients (58.33%), while five patients had left-sided lower limb degloving. Four (33.33%) patients had degloving of the whole lower limb (groin to ankle), six (50%) patients had degloving of the leg (knee to ankle), and two (16.67%) patients had degloving of thigh (groin to knee).

The mode of trauma in seven (58.33%) patients was a road traffic accident (RTA). Among these seven patients of RTA, five were pedestrian injuries, one injury occurred due to a motorcycle accident, and one patient was injured during a farm tractor turning turtle while the subject was driving it. Industrial mishaps were the cause of injury in three (25%) patients, among which one patient was injured by a flour roller mill belt, one patient was injured by a farm roller machine, and one patient was injured due to a trapped limb in a large concrete mixer. The mode of injury in one patient (8.3%) was a wall crash due to a house collapse. Seven (58.33%) patients had a circumferential multi-plane (Arnez type four) degloving, while the rest of the five (41.66%) patients' circumferential single plane (Arnez type three) was present.

The mean wound area per patient that required skin grafting in the present study was 1082.9 ± 679.0 cm^2, and the mean area covered by refrigerator-preserved meshed STSG per patient was 798.7 ± 350.0 cm^2. Among all the patients with isolated leg or thigh degloving, wound coverage of ≥80% was achieved with preserved STSG, while the maximum wound coverage achieved in patients with whole lower limb degloving was around 65%. A graft uptake of ≥82% at first post-operative dressing was noted among all the patients with isolated thigh or leg degloving (Figure 3), except one patient in which graft necrosis was encountered exposing the distal portion of the tibia and extensor tendons, for which a latissimus dorsi free flap (Figure 4) was undertaken later. An equally significant graft uptake of the preserved graft was noted in patients with whole limb degloving with a minimum of 78% to a maximum of 93% at the first post-operative dressing.

Among isolated leg or thigh degloving cases, one patient required a latissimus dorsi flap after stage three, given graft necrosis with exposed bone and tendons at the distal aspect of the leg. On the other hand, all four patients with whole limb degloving (groin to ankle) required a second procedure to cover the remnant raw area with STSG. This second procedure was performed five to seven days after the third stage in all cases, and the skin graft was harvested from the contralateral lower limb. The mean hospital stay per patient in the present study was 15.16 ± 4.90 days.

Few complications were encountered during the present study (Table 1). One patient (8.3%) developed a superficial infection after skin grafting, which was managed with regular saline dressings and antibiotics. One patient (8.3%) developed a small, deep, serious collection in the proximal thigh, which settled after bedside wound care. In two patients (16.6%), partial graft necrosis was encountered, among which, one needed a latissimus dorsi flap for the coverage of distal tibia and extensor tendons, while in the other case, the area was covered with secondary STSG later. One patient (8.3%) had a small missed foreign body of leg (4 mm window glass piece), which was detected at three-month follow-up as the patient complained of persistent pain and intermittent serous discharge in the calf region. Ultrasound confirmed the diagnosis of a foreign body, which was removed under regional anaesthesia.

Figure 3. Sub-total circumferential single plane degloving of the thigh in a 70-year-old man (A, B), which was managed by refrigerator-stored autologous skin grafting (C). Complete graft take-up was observed at follow-up (D).

Figure 4. Concrete mixer injury in a 32-year-old man with degloving of left leg (A, B), developed graft necrosis at distal leg (C) exposing tibia and extensor tendons. Latissimus dorsi free flap was needed for coverage in this patient (D, E).

One patient (8.3%) developed a hypertrophic scar, which was managed by a customized compression pressure garment. One patient (8.3%) developed knee stiffness, which was managed with knee physiotherapy and later gained a functional range of motion (ROM) (flexion of 110°) and could perform his routine activities.

At the final follow-up, all the patients had complete graft take-up and healing. None of the patients needed amputation. All the patients were satisfied with the final functional outcome and were able to return to their pre-injury working status.

Discussion

DSTIs of the lower extremity are always attributed to high-energy trauma. The most common mechanisms of injury are RTAs and industrial mishaps. Shear forces, hence produced, cause detachment of skin from the underlying muscle fasia. The skin flaps produced tend to have compromised vascularity. This creates doubt regarding the survival of the avulsed flap. Therefore, there is no consensus regarding the management of these injuries (7, 8). On one hand, some researchers advocate re-attachment of the detached flap to the underlying wound bed after debridement, hoping against flap necrosis (7, 11). On the other hand, other researchers recommend early flap debridement followed by soft tissue coverage (12).

In this context, Arnez et al. (7) propounded a classification system for DSTI and described four patterns of soft tissue degloving. Type one represents a limited degloving with loss of tissue, and most of these injuries tend to occur over bony prominences. Hence, early wound debridement followed by free tissue transfer is recommended for most type one injuries. Type two is described as a non-circumferential degloving in which the majority of the skin is still present as a flap, for which excision of the degloved skin and wound coverage with STSG or a flap gives good results in most cases. Type three represents a circumferential single-plane degloving of the extremity, while type four is described as a circumferential multi-plane degloving. Type three and type four degloving injuries managed with single-stage debridement and reconstruction protocol show the lowest primary healing rate (7). Being self-critical of the aggressiveness in the approach followed, Arnez et al. stated that their approach needed to be modified while dealing with type three and type four injuries.

In the present study, the results of a staged protocol for managing types three and four degloving injuries were evaluated in twelve patients (Figure 1). The protocol involved primarily limited debridement with the harvesting of STSG from the avulsed flap and primary closure of the flap during stage one. The STSG harvested from the skin flaps was stored in a refrigerator. During stage two, serial debridements were done, and the status of the wound was monitored. Once a healthy bed was ready, coverage with refrigerator-stored STSG was carried out during stage three.

Previously, some authors have discouraged suturing of the avulsed flap in situ and favoured the excision of the avulsed flap and immediate wound coverage by STSG (14-16), while some considered a delay of one week for skin grafting after excision of avulsed flaps in cases of extensive injury (17). Few researchers suggest defatting the avulsed flap before its re-attachment to the wound bed for a good prognosis (18, 19). Moreover, the immediate reconstructive procedure of extensive degloving injuries has been discouraged by some researchers for many reasons (20). The interim time gained provides a chance for further resuscitation and build-up of the patient to tolerate further stages of surgery and also improves the wound condition for a better prognosis of the planned reconstructive procedure. The open circumferential degloving injuries cause widespread damage across the tissue planes, which compromises the viability of the avulsed flaps and could threaten the survival of immediate reconstructive procedures (7). Since, there is no accurate clinical distinction between viable and non-viable tissues, especially in the face of systemic hemodynamic instability and direct local disruption of tissues, there is a chance of excising more healthy tissues. In addition, limited availability and patient affordability issues concerning negative pressure wound therapy, which is helpful in primary immediate reconstruction and achieving better outcomes in multiple ways (21), pushed us for staged management.

To counter the development and spread of infection because of potential devascularization of the flap, a close observation was adopted to allow the re-attached flap to develop a demarcation line of its viable extent over time. In addition to an antibiotic cover, a second look debridement was performed within 36 to 72 hours of injury. This way, though compromised yet a biological barrier against infection, was present. Hence, viable flap portions that might have been taken out if radical excision had been done on the presentation day, were saved. Though we ended up excising more than 90% of the re-attached flap within 72 hours of injury, in all cases, we found no gross infection that could be attributed to the re-attached flap. We noted a peculiar injury pattern in two cases with degloving extending to the ankle, having a tongue of flap relatively adherent to the underlying Achilles tendon, and it survived eventually. There could have been a potential risk of exposing the Achilles tendon if we had resorted to primary radical excision.

The skin grafts harvested from the degloved flaps have been previously used successfully to cover the defects created post-debridement (7, 11, 12). Nogueira et al. reported good results with cryopreserved skin graft harvested from the degloved skin, which was re-planted over the healthy granulated wound (13). In the present study, however, due to a lack of advanced cryopreservation equipment, the STSG harvested from avulsed flaps was stored in refrigerators at 2-8 °C.

Processing and preservation of autologous skin grafts harvested from re-attached flaps form a vital part of staged management. STSG was harvested using a Watson's skin graft knife by a free hand technique in the present study. The refrigerated STSG harvested from re-attached flaps was replanted after second look debridement. The outcome of the refrigerated graft was acceptable in terms of take-up, stability, cosmesis, and function in all twelve cases.

There was a need for the excision of some fully damaged flap portions in all cases during primary debridement, especially where both leg and thigh were injured. Hence, a relatively greater mismatch in the area between the preserved skin graft (harvested from flaps) and wound area coverage in these cases was encountered. As a result, all four cases with both leg and thigh involvement required a second reconstructive procedure of skin grafting to cover the left-out wound, which was harvested from the contralateral thigh. Whereas, in the isolated leg or thigh injury, only one out of eight cases ended up with a secondary reconstructive procedure due to the exposed tibia and extensor tendons for which a latissimus dorsi free flap was performed.

The retrospective nature of the study and the small sample size are obvious limitations of the present study. However, the small sample size of the present series is expected due to the rarity of such cases. Hence, multi-centric randomized trials with a larger sample size should be undertaken to dig further into the outcome analysis of this staged protocol.

Conclusion

Despite being rare, open DSTIs are very complex injuries with no definitive guidelines for management, especially Arnez type three and four injuries. The staged protocol presented in the present series potentially answers the dilemma. However, larger multi-centric trials with larger sample sizes are needed to analyze the outcome of this staged protocol.

Conflict of Interest

The authors declare no conflict of interest in this study.

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References

1. Wojcicki P, Wojtkiewicz W, Drozdowski P. Severe lower extremities degloving injuries--medical problems and treatment results. *Pol Przegl Chir*. 2011;83(5):276-82. doi: 10.2478/v10035-011-0043-3. [PubMed: 22166481].
2. Innis CO. Treatment of skin avulsion injures of the extremities. *Br J Plast Surg*. 1957;10(2):122-40. doi: 10.1016/s0007-1226(57)80020-4. [PubMed: 13510571].
3. Antoniou D, Kyriakidis A, Zaharopoulos A, Moskoklaidis S. Degloving injury. *Eur J Trauma*. 2005;31(6):593-6. doi: 10.1007/s00068-005-1059-3.
4. Krishnamoorthy R, Karthikeyan G. Degloving injuries of the hand. *Indian J Plast Surg*. 2011;44(2):227-36. doi: 10.4103/0970-0358.85344. [PubMed: 22022033]. [PubMed Central: PMC3193635].
5. Mello DF, Assef JC, Solda SC, Helene A. Degloving injuries of trunk and limbs: Comparison of outcomes of early versus delayed assessment by the plastic surgery team. *Rev Col Bras Cir*. 2015;42(3):143-8. doi: 10.1590/0100-69912015003003. [PubMed: 26291253].
6. Guo J, Li J, Lu KH. Observation of microvascular casting of avulsion injured skin flap under electron microscope. *Zhongguo Xiu Fu Chong Jian Wai Ke Za Zhi*. 1999;13(2):119-21. [In Chinese]. [PubMed: 12080766].
7. Arnez ZM, Khan U, Tyler MP. Classification of soft-tissue degloving in limb trauma. *J Plast Reconstr Aesthet Surg*. 2010;63(11):1865-9. doi: 10.1016/j.bjps.2009.11.029. [PubMed: 20056504].
8. Hakim S, Ahmed K, El-Menyar A, Jabbour G, Peralta R, Nabir S, et al. Patterns and management of degloving injuries: A single national level 1 trauma center experience. *World J Emerg Surg*. 2016;11:35. doi: 10.1186/s13017-016-0093-2. [PubMed: 27468300]. [PubMed Central: PMC4962500].
9. Powers ML, Hatem SF, Sundaram M. Morel-Lavallee lesion. *Orthopedics*. 2007;30(4):250, 322-250, 323. doi: 10.3928/01477447-20070401-10. [PubMed: 17424683].
10. Latifi R, El-Hennawy H, El-Menyar A, Peralta R, Asim M, Consunji R, et al. The therapeutic challenges of degloving soft-tissue injuries. *J Emerg Trauma Shock*. 2014;7(3):228-32. doi: 10.4103/0974-2700.136870. [PubMed: 25114435]. [PubMed Central: PMC4126125].
11. Cohen SR, LaRossa D, Ross AJ 3rd, Christofersen M, Lau HT. A trilaminar skin coverage technique for treatment of severe degloving injuries of the extremities and torso. *Plast Reconstr Surg*. 1990;86(4):780-4. doi: 10.1097/00006534-199010000-00034. [PubMed: 2217599].
12. Kudsk KA, Sheldon GF, Walton RL. Degloving injuries of the extremities and torso. *J Trauma*. 1981;21(10):835-9. doi: 10.1097/00005373-198110000-00002. [PubMed: 7024564].
13. Nogueira A, Martinez MJ, Arriaga MJ, Perez A, Tevar a. Delayed full-thickness autografting of cryopreserved avulsed skin in degloving injuries of the extremities. *Plast Reconstr Surg*. 2001;107(4):1009-13. doi: 10.1097/00006534-200104010-00017. [PubMed: 11252097].
14. Edlich RF, Rodeheaver GT, Thacker JG, Lin KY, Drake DB, Mason SS, et al. Revolutionary advances in the management of traumatic wounds in the emergency department during the last 40 years: part I. *J Emerg Med*. 2010;38(1):40-50. doi: 10.1016/j.jemermed.2008.09.029. [PubMed: 19264440].
15. Bianchi J. The cleansing of superficial traumatic wounds. *Br J Nurs*. 2000;9(19 Suppl):S28, S30, S32. doi: 10.12968/bjon.2000.9.Sup3.12484. [PubMed: 12271240].
16. Farmer AW. Treatment of avulsed skin flaps. *Ann Surg*. 1939;110(5):951-9. doi: 10.1097/00000658-193911000-00014. [PubMed: 17857505]. [PubMed Central: PMC1391382].
17. Prendiville JB, Lewis E. The pneumatic-tyre torsion avulsion injury. *Br J Surg*. 1955;42(176):582-7. doi: 10.1002/bjs.18004217603. [PubMed: 13240067].
18. Jeng SF, Wei FC. Technical refinement in the management of circumferentially avulsed skin of the leg. *Plast Reconstr Surg*. 1997;100(6):1434-41. doi: 10.1097/00006534-199711000-00009. [PubMed: 9385954].
19. Zwillinger N, Carette S, Lorenceau B. Salvage of a leg avulsion injury by vacuum negative pressure therapy: A case report. *Ann Chir Plast Esthet*. 2008;53(1):74-8. [In French]. doi: 10.1016/j.anplas.2006.08.006. [PubMed: 17030389].
20. Tian L, Ji X, Chen T, Qi F, Tian F, Yao Q, et al. Deep hypothermic preservation of autologous skin in the treatment of large-area circumferential multi-plane degloving trauma: A pilot study of 2 cases. *Cell Tissue Bank*. 2019;20(1):109-15. doi: 10.1007/s10561-018-09745-4. [PubMed: 30637555]. [PubMed Central: PMC6469666].
21. Barendse-Hofmann MG, van Doorn L, Steenvoorde P. Circumferential application of VAC on a large degloving injury on the lower extremity. *J Wound Care*. 2009;18(2):79-82. doi: 10.12968/jowc.2009.18.2.38747. [PubMed: 19418786].