The management of degloving injury of lower extremities: Technical refinement and classification

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BACKGROUND: Degloving injuries are severe and frequently underestimated lesions. Lower extremities are the most commonly affected limbs. This injury is associated with a high morbidity and mortality if mismanaged. The treatment of such patients still varies, clinical indicators for its prognosis are scarce, and some technical protocols are also controversial.

METHODS: Between August 2002 and July 2011, 102 patients with skin avulsion of 129 lower extremities were treated with immediate full-thickness skin graft following a protocol of radical debridement. The full-thickness skin grafts were processed with sharp scalpels in situ. They were further secured with multiple sutures after repositioning to improve skin graft take. Outcomes were evaluated based on different patterns and age groups.

RESULTS: Three patterns of injury, that is, a purely degloving injury (Pattern 1), a degloving injury with the involvement of deep soft tissues (Pattern 2), and a degloving injury with long-bone fractures (Pattern 3), were revealed. Among the three patterns, much higher primary healing rates were observed in Patterns 1 and 2. Younger patients in Pattern 3 achieved a higher primary healing rate than the old ones, whereas no differences of primary healing rate regarding different age groups were noted in Patterns 1 and 2.

CONCLUSION: The degloving injuries of the lower extremities can be generally divided into three patterns. The preparation of full-thickness skin graft with scalpels is very simple and prompt. The management of degloving injury of the lower extremity with immediate full-thickness skin grafting following the protocol of radical debridement is feasible. Age has little impact on the skin graft take except for severe cases (Pattern 3) in which old age is an indicator of unfavorable prognosis and special attention is required. (*J Trauma Acute Care Surg*. 2013;74: 604–610. Copyright © 2013 by Lippincott Williams & Wilkins)

LEVELS OF EVIDENCE: Prognostic study, level IV; therapeutic study, level V.

KEY WORDS: Degloving injury; lower extremity; full-thickness skin graft; classification.

Degloving injuries are severe and frequently underestimated lesions.[1] It has been defined as avulsion of the skin off the underlying muscle and bone.[2] In such injuries, the skin and subcutaneous tissue are forcibly detached from the underlying fascia by a sudden severe shearing force, usually as a result of friction from rubber tires in run-over accidents. Mismanagement of such injuries results in delayed full-thickness necrosis of the avulsed skin flap and even loss of the limb or, even worse, loss of life.[3] There have been publications describing novel ways to use the devitalized degloved skin.[1,4] Some have advocated the use of a dermal equivalent in purely degloved skin and negative pressure dressing.[5,6] So far, the concept of resurfacing the denuded bed of a large degloved limb with either a split-skin graft or a full-thickness skin graft taken from an avulsed flap has been widely accepted.[7–9] However, the associated specific techniques in dealing with such patients still vary with the discrepancy of outcomes in literature.[4,10] In this retrospective study, 129 lower limbs treated with immediate full-thickness skin grafting in situ between 2002 and 2011 were reviewed. Detailed techniques were presented, and a classification of such injuries based on this series was also discussed in an attempt to provide a better means of assessing this injury in the lower extremity.

PATIENTS AND METHODS

From August 2002 until July 2011, 102 patients with a total of 129 injured limbs were treated with extensive degloving injuries of the lower extremities. Those patients who had diabetes mellitus requiring special attention have been excluded. The mean age was 32.5 years (range, 6–75 years), with 87 males and 15 females. Among them, 94 patients were run over by rubber tires during car accidents; the remaining 8 patients were victims of industrial accidents by roller devices.

The patterns of soft tissue injury with the following criteria were included: (1) all patients with a degloved skin greater than one fourth of the circumference of the affected parts (ankle, calf, or thigh) of the lower extremities; (2) adequate photo-documentation of the initial injury to allow accurate classification before reconstruction; (3) injuries proximal to the metatarsals.

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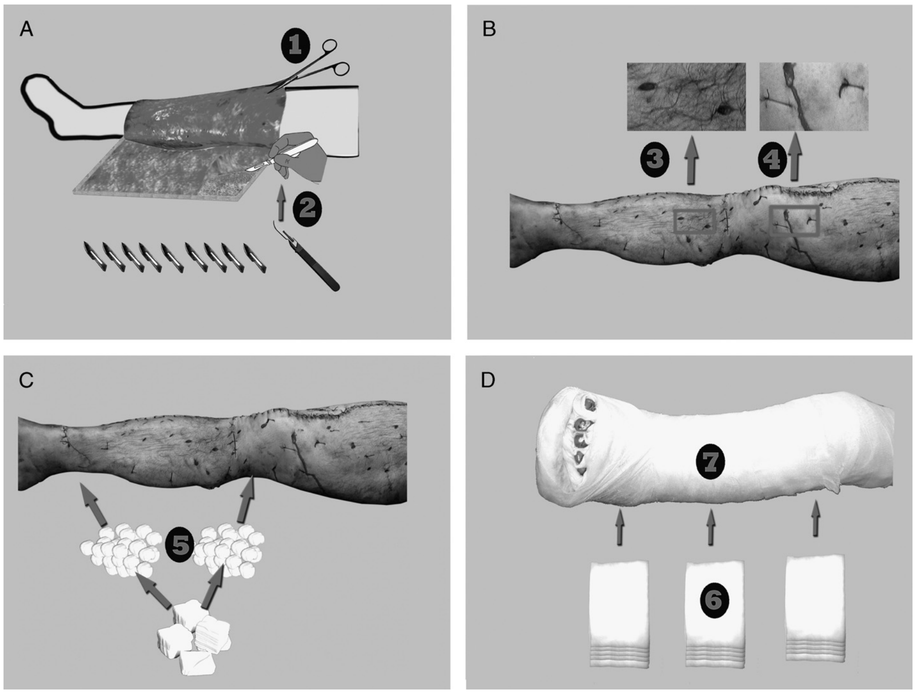

Figure 1. Technical illustration. (*A*), Wound debridement: Radical excision of nonviable tissues and even tissues doubtful in viability; muscle or fascia flap transfer to cover bone exposure when necessary. Skin defatting: Skin is defatted toward the leg using scalpels (replaced frequently); be sure to keep the skin in tension during the process for the ease of defatting. (*B*), Skin graft reprocessing: Multiple small incisions (~1 cm) are made to drain seroma or hematoma from the recipient bed. The inset demonstrates the stabs. ''Internal fixation'' of the skin graft: Skin graft is further stabilized with interrupted sutures around the limb, especially around the ankle and knee joints, after repositioning. The inset demonstrates the securing sutures. (*C*), Bolus dressing: Gauze is processed into a small bolus and stuffed around the ankle and knee joint to secure the skin graft. (*D*), Padding dressing: Cotton pads are applied around the limb to facilitate a bulky dressing. External fixation of the skin graft: The limb is immobilized with a posterior plaster for 7 to 10 postoperative days.

Surgical Techniques

Following initial resuscitation, the patients were taken to surgery. We followed the basic rules of making routine surgical approaches to incise the degloved skin, leaving the proximal attached part intact. Similar techniques reported by Jeng et al.[9,10] were adopted. Instead of using curved scissors, we preferred to use sharp scalpels to defat the degloved skin. Multiple stab wounds were also made to drain seroma or hematoma from the recipient bed. The resultant full-thickness skin graft was secured to the wound edges and underlying recipient beds with sutures instead of skin staples. The grafts were first dressed by bolus dressings around irregular topographic regions, such as the ankle and knee joints, and then by bulky dressings and bandages. Limbs were immobilized with a posterior plaster for 7 to 10 postoperative days. If the thick graft did not take completely, the superficial portion of the graft was excised tangentially while preserving the viable part of the deep dermis to allow split-thickness skin overgrafting in 2 to 3 weeks postoperatively. Detailed technical procedures were illustrated in Figure 1.

Outcome Assessment

A "healed wound" was defined as one which was free of any dressings. Whether the wound healed by "primary healing," defined as a healed wound within 2 weeks of reconstruction, or by "secondary healing," defined as a healed wound after 2 weeks of reconstruction, was used as an outcome measure of our surgical strategy.[11] The rate of primary healing was statistically compared among different patterns and age groups using a χ^2 analysis.

RESULTS

In this series, the defatting procedure of a circumferentially degloved leg (from knee to the ankle joint) with scalpels was completed in about 30 minutes on average. Five patients in this series experienced relatively small skin defects after debridement, which were covered primarily with Vaseline gauze (Zhende Medical Dressing Corp., Shaoxing, Zhejiang, China) and resurfaced secondarily with split-thickness skin grafts 2 weeks after first management. The degloving injuries fell into distinct patterns as a result of the magnitude of the energy as follows:

Pattern 1: Purely Degloving Injury

According to the clinical findings, this pattern consists of two subpatterns based on the extent of the injury: noncircumferential (Fig. 2*A*, *B*) and circumferential degloving (Fig. 2C, D). In this pattern, the plane of avulsions is confined between the deep fascia and the subcutaneous fat and skin, and no obvious damage to the deep soft tissues (deep

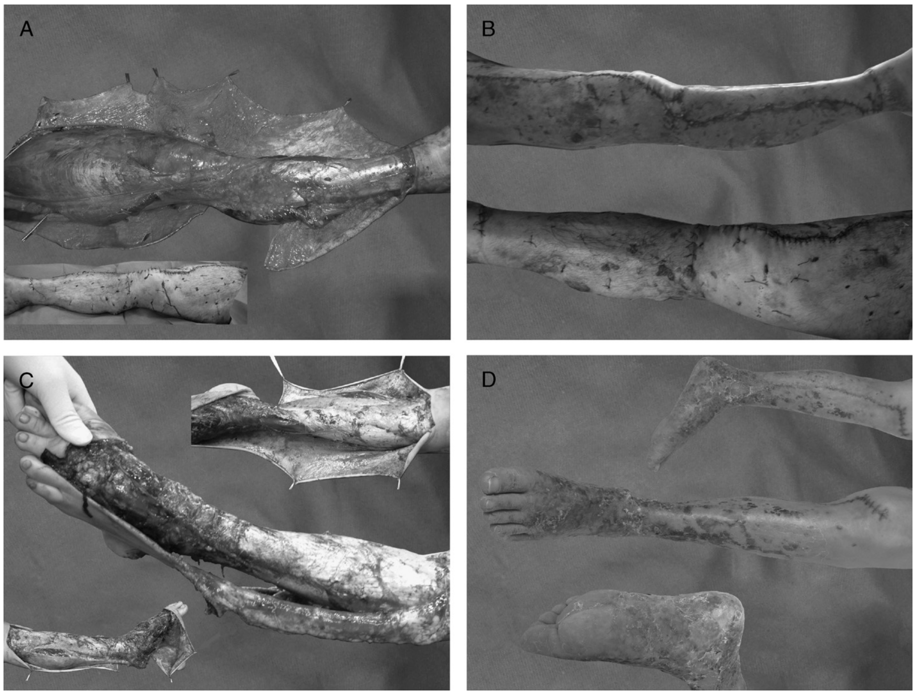

Figure 2. Pattern 1, purely degloving injury. (*A*), This shows a typical subpattern degloving injury of Pattern 1 (noncircumferential). A 32-year-old man was run over by a truck, which resulted in extensive degloving of the skin from the thigh down to the ankle at the deep fascia plane, with only about one fifth of the posterior skin attached to the deep fascia. The avulsed flap was defatted as full-thickness skin graft and applied to its original anatomic location (the inset picture, bottom). (*B*), Three weeks after the operation, primary healing was achieved. (*C*), This shows a typical subpattern degloving injury of Pattern 1 (circumferential). A 52-year-old woman was run over by a car, which resulted in a circumferential degloving of skin from the knee to the metatarsal joint. After adequate debridement, the degloved skin flap was defatted in attachment and repositioned as a full-thickness skin graft. The inset picture shows the defatted skin of the calf (top) and the foot (bottom). (*D*), Recovery was uneventful, and no further management was needed. At a follow-up at 3 months, the appearance was good. The pictures show the lateral view (top) and front view (middle) of the leg and the lateral view of the foot (bottom).

fascias, muscles, and bones) is present. It is either an open or closed injury, in which loss of skin is seldom encountered.

Pattern 2: Degloving Injury With the Involvement of Deep Soft Tissues

In this pattern, a higher degree of energy transfer to the limb than in Pattern 1 is indicated. Deep soft tissues, such as deep fascia and muscles, are involved, but no long-bone fractures (tibia, fibula, or femur) occur. It is also divided into two subpatterns: noncircumferential degloving (Fig. 3*A*, *B*) and circumferential degloving (Fig. 3*C*, *D*). It is usually an open injury, and there may be friction burning on the part of the degloved skin, but loss of skin is also rare.

Pattern 3: Degloving Injury With Long-Bone Fractures

In this pattern, the highest degree of energy transfer to the lower extremity occurs. This high-energy injury first causes the degloving injury to the superficial skin and then continuously transfers to the deep soft tissues and even the long bones, resulting in varying damage of soft tissue and different types of fractures. Mostly, it is a circumferential degloving, and friction burning on the part of the degloved skin is often present. However, a direct skin defect is not common, and secondary skin loss is often a result of surgical debridement because of severe skin contusion (Fig. 4*A*–*D*).

Table 1 shows the healing outcomes (primary or secondary) for the three patterns. Primary healing rate ranges from 55.2% in Pattern 3 to 96.3% in Pattern 1, and the overall primary healing rate is 81.4%. No significant differences regarding the primary healing rate were noted between the subpatterns in Pattern 1 and Pattern 2, respectively (all $p > 0.05$). Among the three patterns, much higher primary healing rates were revealed in Patterns 1 and 2, and the differences were statistically significant ($p < 0.05$); however, no significant difference was observed between Pattern 1 and Pattern 2 ($p > 0.05$). In this series, 14.7% of patients who required secondary intervention, including 11 patients in Patterns 1 and 2 and 8 patients in Pattern 3, were treated with split-skin grafts harvested from the normal extremities. The remaining patients in Pattern 3 were reconstructed with flaps.

Table 2 shows the healing according to patterns and different age groups. In Patterns 1 and 2, no significant differences were observed among the different age groups (all $p > 0.05$); whereas in Pattern 3, younger patients achieved a higher primary healing rate than the old ones, and the difference was significant ($p < 0.01$).

Figure 3. Pattern 2, degloving injury with the involvement of deep soft tissues. (*A*), This shows a typical subpattern degloving injury of Pattern 2 (noncircumferential). A 7-year-old boy sustained avulsion injury to both of his legs by a car. Physical examination revealed partial closed avulsion injuries of his legs, with obvious damage of gastrocnemius in his left leg. The degloved flaps were defatted as full-thickness skin graft and applied to its original anatomic location. The inset pictures show the intraoperative view of both legs: left (top), right leg around the front knee joint; left (bottom), right leg of popliteal fossa; right (bottom), lateral view of the calf showing the tissue disruption of the gastrocnemius muscle. (*B*), At follow-up after 7 years, both functional and cosmetic results were satisfactory. (*C*), This shows a typical subpattern degloving injury of Pattern 2 (circumferential). A 63-year-old woman sustained a roadside accident, which resulted in circumferential degloving injury of both legs. The skin of her legs was degloved from the knee joint down to the ankle area, with deep fascia and gastrocnemius muscle disruption. The avulsed flap was defatted as full-thickness skin graft and resutured anatomically. (*D*), The primary skin grafting take was 95%. At follow-up after 8 years, she showed no limitation of ambulation, with excellent leg appearance.

Ninety-seven patients were available for follow-up at an average of 3.1 years (1–8 years). Most of the patients in Patterns 1 and 2 were satisfied with the cosmetic appearance of their legs; whereas in Pattern 3, seven patients had a deformed contour of their legs because of flap and muscle transfers. Stable wounds in most of the patients were achieved. A mild flexion contracture at the ankle and knee areas, with minimal limitation of range of motion, was reported in six patients. Eight patients experienced an occasional breakdown of skin grafts on the popliteal fossa, which was treated conservatively. Most of the patients in Patterns 1 and 2 were ambulatory within 4 to 6 weeks postoperatively.

DISCUSSION

Degloving injuries of the lower extremities are common, occasionally benign in appearance, and may be associated with a high morbidity and mortality if mismanaged.[10,12,13] Extensive degloving injuries can be problematic for reconstructive surgeons in regard to treatment and closure because of the complexity of the injury. These wounds used to be treated with repeated serial debridements and painful dressing changes, with eventual placement of split-thickness skin grafts on compromised tissues. Grafting these chronic fibrotic wound beds often results in only partial graft take and/or graft contractures.[3,12,14,15] Studies have shown that immediate use of the degloved skin as a skin graft gives the most satisfactory coverage to the denuded areas, especially using the full-thickness skin graft, and the approach with primary reattachment of the degloved flap by suture or use of compression dressings without defatting has been proved unsuccessful and been abandoned.[7–10,12,16] However, the grafting methods used in clinical practice vary.[4,7,17] Jeng et al.[9] and Jeng and Wei[10] refined the techniques in the primary treatment of such patients, with satisfactory results. In their practice, multiple stabbing over the skin graft was performed, allowing fluid drainage when the defatted skin was repositioned. The fixation of the skin graft to the underlying bed with multiple staples was advocated to provide enough stability. The full-thickness skin graft with such a pattern of perforation heals well and produces a satisfactory cosmetic appearance.

In our experience, similar techniques were performed. Skin graft preparation is a tedious but crucial step in the treatment of degloving injury and is commonly processed with scissors in literature.[10,18,19] However, if defatting procedure is

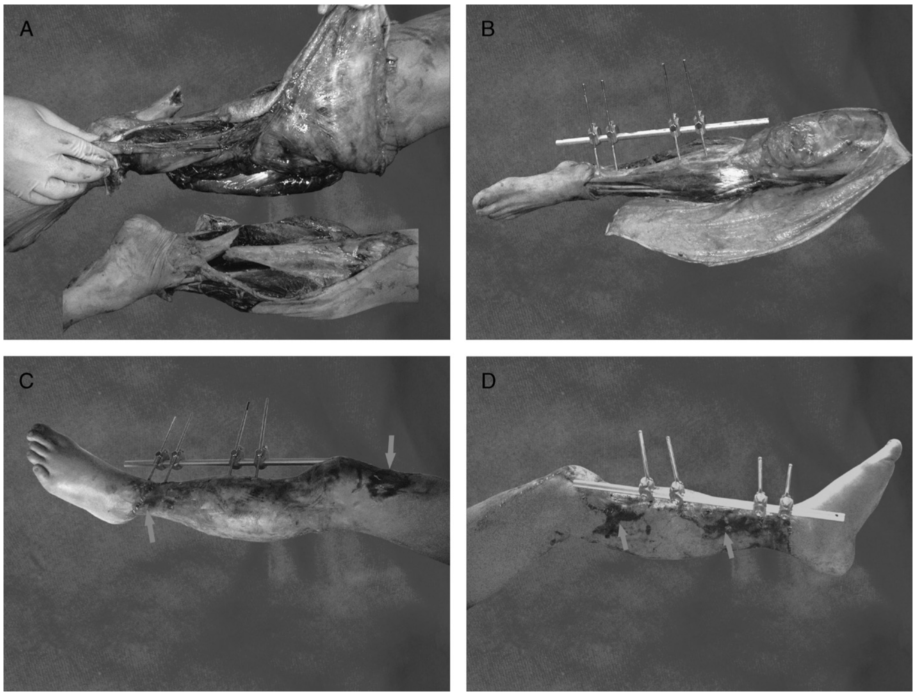

Figure 4. Pattern 3, degloving injury with long-bone fractures. (*A*), This shows a typical Pattern 3 degloving injury. A 44-year-old man had his left leg injured in a car accident. This was a Type IIIB open tibial fracture and a circumferential degloving of skin from the middle thigh to the ankle area. (*B*), External fixation of the tibial fracture was performed, soleus and gastrocnemius muscle flaps were transposed, and full-thickness skin grafts were made from the avulsed flap for coverage. (*C, D*) Primary graft take was estimated at 80%. The *arrows* show the areas of graft loss. Dermal overgrafting was performed 2 weeks after the initial operation with success.

performed with scissors, it is usually difficult to obtain a satisfactory full-thickness skin graft with redundant fat tissues remaining and also is very time consuming. Using sharp scalpels, the procedure is greatly simplified, and high-quality full-thickness skin grafts are easily achieved (Fig. 1), which in turn contributes to the skin graft take. In our practice, it takes about 30 minutes to complete the flap defatting of a whole degloved leg using about 15 to 20 scalpels. We prefer to use simple sutures to stabilize the repositioned skin with the underlying tissues instead of staples,[10] which may aid a more flexible and secure fixation of degloved skin and produce less irritation on the affected region (Fig. 1). The secured attachment of the grafts with the subcutaneous tissues is of great importance on the graft take; however, the irregular topography around ankle and knee areas often results in insufficient stabilization of the skin grafts using traditional dressings, and consequently, grafts loss is frequently encountered.[11,17,20] A bolus dressing of gauze was applied around these areas in our series, and no difference in graft take in comparison with other areas was obtained (Fig. 1). This stabilization technique is effective, especially for the area around the ankle and knee joints. The above techniques reduce the operating time because they are all simple to execute.

Viability of the avulsed skin flap is difficult to determine clinically. Various methods, both clinical and experimental, have been described for ascertaining viability of flaps;[3,21] however, their efficacy in extensive degloving injuries remains unclear. Although direct observation is a subjective method, it is still feasible on its merits of convenience and efficiency. Skin with bleeding edges, good color, and rapid capillary refill will most

TABLE 1. Outcomes of the Three Patterns

	Pattern 1, n (%)		Pattern 2, n (%)		Pattern 3, n (%)	Total, n (%)
	Noncircumferential	Circumferential	Noncircumferential	Circumferential		
Primary healing	26 (96.3)	19 (86.4)	17 (89.5)	27 (84.4)	16 (55.2)	105 (81.4)
Secondary healing	1 (3.7)	3 (13.6)	2 (10.5)	5 (15.6)	13 (44.8)	24 (18.6)
Total	27 (20.9)	22 (17.1)	19 (14.7)	32 (24.8)	29 (22.5)	129 (100)

Pattern 1, purely degloving injury; Pattern 2, accompanied by deep soft tissue injuries; Pattern 3, accompanied by long-bone fractures. Fisher's exact test showed that no significant differences were observed either among different subgroups or between Patterns 1 and 2 (all $p > 0.05$); significant differences were revealed between Pattern 3 and Patterns 1 and 2 ($p < 0.05$).

TABLE 2. Outcomes of Different Age Groups

	Pattern 1			Pattern 2			Pattern 3			
	<15	15–50	>50	<15	15–50	>50	<15	15–50	>50	Total
Primary healing	11	25	9	10	27	7	6	9	1	105
Secondary healing	0	2	2	1	4	2	1	4	8	24
Total	11	27	11	11	31	9	7	13	9	129

Fisher's exact test showed t no significant differences among different age groups in Patterns 1 and 2 patients (Pattern 1, $p = 0.496$; Pattern 2, $p = 0.720$); whereas in pattern 3, significant differences were noted among different age groups ($p < 0.05$).

likely survive.[3] In our patients, the assessment of flap viability was performed using direct observation. We basically follow the protocol of radical excision, by which excision of all those confirmed devitalized tissues and even those that are highly suggestive of having the least viability is encouraged, in determining the extent of debridement and defatting areas, especially in Pattern 3 and senior patients. This technique is open to criticism because the radical nature of excision may have removed healthy tissue. However, the fact that a relatively lower rate of graft take observed in the early cases in our series implies a potential hazard for a conservative protocol, which may trigger a series of reactions if doubtful tissues remained necrose, eventually resulting in a bigger graft loss. The sacrifice of the potential healthy tissue turns out to be worthwhile in salvaging the skin graft in such patients in the long run.[11]

The vacuum-assisted closure or vacuum sealing drainage (VSD) system, which applies even pressure to the entire wound and configures precisely to the intrinsic three-dimensional structure of the wound, reducing or eliminating movement or tenting,[17] has been reported to be useful in challenging wounds to accelerate wound healing.[22] This system is able to remove excessive tissue edema, increase tissue blood flow, and decrease the amount of localized bacteria. It also has the ability to remove third-space fluid effectively.[22] Historically, defatted full-thickness degloved skin has been difficult to hold in position because edema and bleeding in the underlying tissue are associated with a poor take, despite fastidious time-consuming suturing, dressing, and splinting of such injuries.[13] The VSD system seems to meet the needs of the treatment of degloving injuries and has been used in dealing with such patients with success.[6,13,17,23,24] However, a large area of skin graft loss was experienced in several circumferentially degloved patients in our center (unpublished data) using VSD (Wuhan VSD Medical Science and Technology Co., Ltd) system. We postulated that failure might be caused by blockage of the drainage system or vacuum system, but the fact that the VSD foam will dry out and become rigid after 24 hours after application, which may weaken its function of stabilizing the grafts, was considered to be the main cause of graft loss. Therefore, the VSD system, a much higher expense for patients, is not the first choice in the management of such patients in our hospital.

According to the classification recently proposed by Arnez et al.,[11] soft tissue degloving can be distinguished by four patterns: abrasion/avulsion, noncircumferential degloving, circumferential single-plane degloving, and circumferential multiplane degloving. It is valuable in the management of certain patients; however, in our series, we found that there was no correlation between the patients and the abrasion/avulsion pattern because these patients are usually diagnosed as having soft tissue defects, which occur when the limb is dragged along an abrasive surface with force,[11] while a degloving injury is commonly a result of a run-over accident by a shearing force. In addition, the other patterns can coexist in the same limb, for example, noncircumferential degloving may involve a multiplane injury, and sometimes it may be difficult to estimate the prognosis of the affected limb. Based on the extent of injury (i.e., the magnitude of shearing force), we proposed three patterns, including two subpatterns in Patterns 1 and 2, in this series. The accident energy increases from Pattern 1 to Pattern 3, and damage to the limbs is accordingly more extensive, indicating a tendency for unfavorable prognosis with increasing pattern number.

In this series, the subpatterns of noncircumferential degloving in Patterns 1 and 2 both achieved relatively higher primary healing rates than those of the circumferential subpatterns, respectively; however, no statistical differences were revealed. Moreover, as a whole, there was no significant difference in primary healing rate between Pattern 1 and Pattern 2, although patients in Pattern 2 sustained a more severe tissue damage, but patients in Pattern 3 had a much lower primary healing rate than those in Patterns 1 and 2. These results indicate that the skin grafts demonstrate a strong take under certain circumstances provided that the subcutaneous bed can be "reconstructed healthy" enough; while in pattern 3, it is sometimes difficult to build up a "healthy" bed for graft take in some patients if too extensive injury occurs, undoubtedly resulting in a lower primary healing rate. We also analyzed the influence of age on the primary healing rate; surprisingly, only in Pattern 3 did we observe a better graft take in younger patients. This result may also be attributed to the strong vitality of the skin grafts within a certain magnitude of injury.

From the analysis of this series of patients and based on our proposed categorization into the three basic patterns, we suggest the following protocols in an effort to improve the rate of primary healing and provide guidance for prognosis.

In Pattern 1, either in noncircumferential or in circumferential degloving injuries, the extent of defatting area should be carefully determined, and special attention must be paid to find out the closed degloving injuries.[25–27] Most patients can achieve primary healing by immediate full-thickness skin grafting. For the remaining very few patients, secondary healing can always be obtained by split thickness skin grafting, and no flap transfers are needed.

In Pattern 2, determination of the extent of excision of deep soft tissues is as important as confirmation of the extent of the defatting area. Radical excision of the nonviable tissues and even those tissues doubtful in viability is vital for graft take. With meticulous management, most patients can also achieve primary healing either in noncircumferential or in circumferential degloving subpatterns. For the remaining patients, secondary healing can mostly be obtained by split-thickness skin grafting, and flap transfers are seldom needed.

In Pattern 3, patients sustaining these injuries had experienced the greatest degree of tissue disruption. The key point differing from the other two patterns is the management of bone exposure, especially in old patients. These patients had the lowest rate of primary healing. A staged reconstruction in these patients is recommended, and free tissue transfer is also indicated in some patients.

In this study, we mainly attempted to summarize the injury patterns of the degloving injury of the lower extremity. Nonetheless, the number of patients seems to be relatively limited to fully cover the different injury patterns. In addition, this is a retrospective study and the demographic data were not presented in detail. Further investigations are needed regarding these concerns.

CONCLUSION

In this retrospectively study, the degloving injuries of the lower extremities can be generally divided into three patterns. The preparation of full-thickness skin graft with scalpels is very simple and prompt. The management of the degloving injury of the lower extremity with immediate full-thickness skin grafting following the protocol of radical debridement is feasible. Age has little impact on the skin graft take except for severe cases (Pattern 3) in which old age is an indicator of unfavorable prognosis and special attention is required.

AUTHORSHIP

H.Y. conceptualized and designed the study, wrote the article, and took overall responsibility. W.G. analyzed and interpreted the data. Z.L. and S.L. collected the data. F.Z. performed critical revision of the article. C.F. gave the final approval of the article. CW performed the statistical analysis.

DISCLOSURE

The authors declare no conflicts of interest.

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