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Original article

Clinical analysis of 54 cases of large area soft tissue avulsion in the lower limb

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ABSTRACT

Objective: To assess the clinical curative effect of different treatment methods for large area avulsion injury in the lower limb.

Methods: Between January 2010 and December 2013, 54 patients with large area avulsion injury in the lower limb were treated in the trauma center of our hospital, including 34 males and 20 females with a mean age of 35.7 years (range, 16–65 years). The injury mechanism was traffic accident in 44 cases, hitting by heavy objects in 8 cases, and fall from height in 2 cases, involving 31 thighs, 19 legs and 4 feet involved. The sizes of the avulsed wounds ranged from 10 cm × 15 cm to 50 cm × 30 cm. There were 16 cases combined with hemorrhagic shock, 5 with femoral fractures, and 7 with tibiofibula fractures. Averagely the patients were sent to our hospital within 3.5 h (range, 1.5–10 h) after injury. For the 54 patients, three different surgical strategies were performed based on the wound area and condition of the avulsed skin: in Group A, 24 patients were treated by debridement and preservation of subcutaneous vascular network + vertical mattress suture of full thickness skin flap + tube drainage; in Group B, 25 patients were treated by split-thickness skin flap meshing and grafting + vacuum sealing drainage (VSD); and in Group C, the other 5 patients were treated by debridement and VSD at stage I + reattachment of autologous reserved frozen split-thickness skin graft at stage II.

Results: All the 54 patients recovered and were discharged eventually, without any deaths or amputees. In each group, there were no statistical differences (all $p > 0.05$) among different injury sites in terms of survival rate and length of hospital stay, except for the infection rate, which was much higher ($p = 0.000$) at the leg area than that at the thigh (32.54% ± 2.97% vs. 2.32% ± 2.34% in Group A and 50.00% ± 0.00% vs. 0 in Group C) or the foot (50.00% ± 0.00% vs. 0 in Group C). Moreover comparison of the three surgical methods showed a significant different (all $p < 0.05$) between each other for all the three assessed parameters, i.e. flap survival rate, length of hospital stay, and infection rate.

Conclusion: Treatment choices for skin avulsion on the lower limb should be based on the viability of the avulsed skin flap and the location of the wound. Proper choice can not only reduce the economic burden caused by using VSD, but also shorten the long hospital stay due to repeated wound dressing change or second stage surgery.

Introduction

With the rapid development of transportation and industry, the incidence of large area skin avulsion injuries combined with severe shock or fractures increased greatly, often caused by traffic accidents, hit by heavy objects, fall from height, twist by large machines, etc. Clinical treatment of these injuries pose a great challenge[1,2] because the surgeons need to face serious complications such as shock, wound coverage and infection, and has to choose a right time to deal with the combined fractures and injuries of the blood vessels, nerves and tendons. Large area skin avulsion injuries, especially those caused by traffic accidents or machine injuries, often couple with secondary skin necrosis (80%–95%), uncovered wound, fracture malunion or nonunion, scar contracture deformity and disfunction, even amputation and death if handled inappropriately.[3–6]

In this study, we compared three different treatment strategies on 54 cases of large area skin avulsion of the lower limb to investigate their therapeutic effects: (1) debridement and preservation

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of subcutaneous vascular network + vertical mattress suture of full thickness skin flap + tube drainage; (2) split-thickness skin meshing and grafting + vacuum sealing drainage (VSD); and (3) debridement and VSD at stage I + autologous frozen split-thickness skin meshing and grafting at stage II.

Materials and methods

General data

Between January 2010 and December 2013, 54 patients with large area soft tissue avulsion of the lower limb were treated in our hospital, including 34 males and 20 females with an average age of 35.7 years (range, 16–65 years). There were 44 cases injured in traffic accidents, 8 hit by heavy objects, and 2 fell from a high place, involving 31 thighs, 19 legs, and 4 feet. The detailed injury locations and injury mechanisms are shown in Fig. 1. The size of the avulsed wound ranged from 10 cm × 15 cm to 50 cm × 30 cm. Comorbidities included hemorrhagic shock in 16 cases, femoral fractures in 5 cases, and tibiofibula fractures in 7 cases. Averagely the patients were sent to our hospital within 3.5 h (range, 1.5–10 h) after injury.

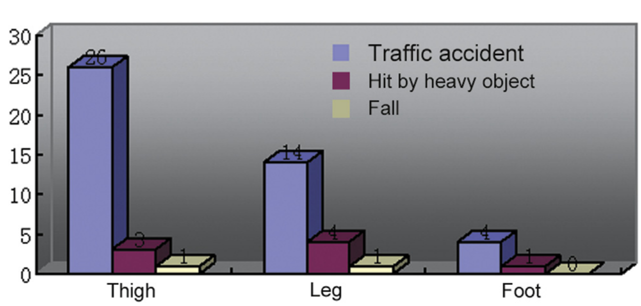

Fig. 1. Distribution of injury locations and causes.

Treatment

Preoperative treatment

For the 16 shock patients, active anti-shock treatment was conducted after admission. Infusion of equilibrium liquid & blood and broad-spectrum antimicrobials to prevent infection was done simultaneously. Patients without shock were infused routine liquid. When patient's blood pressure turned stable, bacterial infection of the wound area was assessed. Patients without infection were prepared for operation.

Anesthesia

All the surgeries were performed under general anesthesia after observation of stable hemodynamics. For patients with active bleeding, tourniquet was used to avoid further ischemia of the avulsed soft tissue. Intraoperatively the temperature was particularly noted, e.g. use of blower to keep the patient warm and heating of flushing liquid to avoid vasospasm due to low temperature.

Surgery

After satisfactory anesthesia, the wound was firstly washed with a large amount of physiological saline. Then the wound edge and surrounding areas were brushed with soap solution, followed by three times of physiological saline washing, during which the wound area was particularly noted to keep away from the washing fluid. Secondly another three times of washing using physiological saline, hydrogen peroxide and Eric was performed to clean the wound area and covert space like cavities and bags. After thorough debridement of the devitalized fascia, muscles, fat, and skin tissue, the broken blood vessels and nerves were repaired. Patients with fractures were fixed with external fixators in advance. According to the observational result of the viability of the skin and soft tissue after debridement, as well as the damage degrees of the subcutaneous vascular network, three different surgical treatments were selected as follows:

(1) Group A (n = 24): preservation of subcutaneous vascular network + vertical mattress suture of full thickness skin flap + tube drainage. The avulsed skin tissue from the back of the thigh/leg was thick and had rich vascular network and perforating branches. When the skin proved to have a good vascular network after capillary test, the subcutaneous soft tissue and vascular network should be reserved directly without thinning. The flap can be directly secured to its original anatomical site with multi-point vertical mattress suture. Thereafter several tubes need to be placed at different directions of the wound area for negative pressure drainage. Finally pressure dressing of the wound was done (Fig. 2).
(2) Group B (n = 25): Split-thickness skin meshing and grafting + VSD. The skin and subcutaneous tissue in the front leg and foot were very thin. If the vascular network of the avulsed skin was damaged seriously, but the wound base had a good blood supply after debridement, this technique can be used. The avulsed skin flap was thinned and subdermal vascular was retained. Thinning must be stopped at 2 cm away from the skin pedicle. Thorough hemostasis was mandatory. By every 2–3 cm, a 1 cm-long hole was punctured on the flap using a small sharp knife. After then, the mesh split-thickness flap was reattached and covered with VSD for drainage.
(3) Group C (n = 5): debridement and VSD in stage I + reattachment of autologous frozen split-thickness mesh graft in stage II. If the wound base, usually the front leg and foot, had a poor blood supply, serious contamination after debridement, or even with partial bone and tendon exposure, the wound should be covered with VSD in stage I. Split-thickness skin flap can be first reserved and frozen, which will be later retransplanted to the wound area in about a week (Fig. 3).

Postoperative treatment

VSD treatment should be dynamically monitored: the pressure should be controlled at 125–450 mmHg and continuous negative pressure aspiration should be guaranteed. Bulge of VSD dressing indicates that negative pressure sucking is invalid and tubes should be checked to see whether there is any blocking or rupture leakage. The sucked liquid should be assessed to rule out bloody drainage or abnormal color. At 5–7 days, surgeons need to remove the VSD to examine the growth of the graft. If the graft did not grow well, re-cutting of the necrotic tissue or even re-debridement should be done.

Statistical analysis

The data of skin survival rate (postoperative survived skin area/avulsed area × 100%), wound infection rate and the average length of hospital stay were collected and analyzed by SPSS 18.0 software. Data were expressed as mean ± standard deviation and ratios. Intra-group comparison of different wound locations was conducted by using single factor variance analysis and inter-group

Fig. 2. A 29 years old male patient in Group A. A: Preoperative picture showing avulsion injury of the right thigh. B: Immediate postoperative picture. The patient received the treatment of preservation of subcutaneous vascular network after debridement + vertical mattress suture of full thickness skin flap + tube drainage. C: Healing picture.

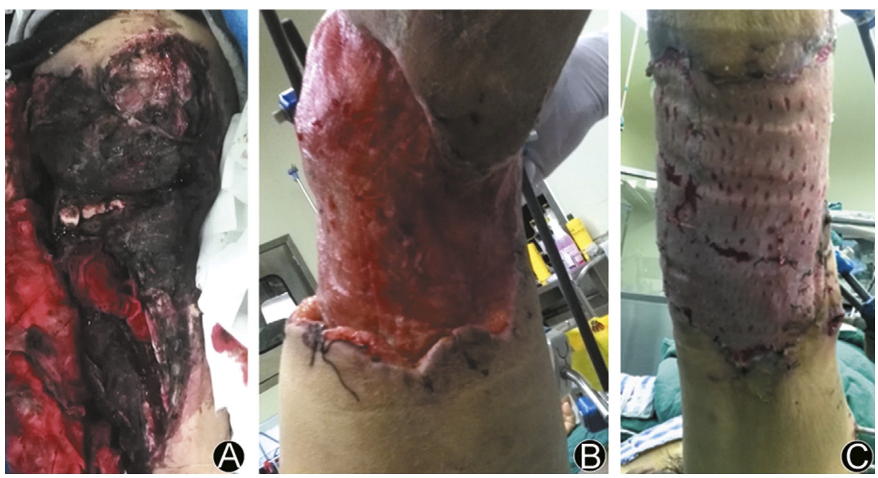

Fig. 3. A 34 years old female patient in Group C. A: Preoperative picture showing wheel crush injury with skin defect. B: Postoperative picture at about one week after surgery. She received the treatment of debridement and VSD in stage I + autologous reserved frozen split-thickness skin meshing and graft in stage II. C: Healing picture.

comparison of different surgical methods was done by SNK test. The significant difference was set at $\alpha = 0.05$.

Results

All the 54 patients achieved wound union and were discharged unevently, with no deaths or amputation. The mean hospitalization time was 19.9 days (range 15–40 days). There were 24 patients received the treatment of full thickness skin flap vertical mattress suture + tube drainage (Group A), including 19 thighs and 5 legs; 25 patients received the treatment of split-thickness skin meshing and grafting + VSD (Group B), including 11 thighs, 12 legs and 2 feet; and 5 patients received the treatment of debridement and VSD in stage I + autologous retransplantation of reserved split-thickness mesh graft in stage II (Group C), including 1 thighs, 2 legs and 2 feet.

Survival rate, length of hospital stay and infection rate for different avulsed areas

In each group, intra-group comparison of different wound locations (thigh, leg and foot) was conducted, which showed no significant difference in term of survival rate and length of hospital stay (all $p > 0.05$). However, the infection rate revealed a great difference in Group A and Group C. The avulsed wound at the leg had a much higher infection rate than that at the thigh or foot (both $p < 0.05$). In Group B, the infection rate showed no significant difference among the involved areas of thigh, leg and foot ($p > 0.05$). Detained data are shown in Table 1.

Survival rate, length of hospital stay and infection rate for different surgical methods

For all the three groups of patients, when infected wound was found, repeat debridement and mesh flap grafting were conducted again. Three patients still developed nonunion of a small size of skin, which healed finally after repeated dressing change. All the patients achieved satisfactory function, although with mild scar hyperplasia. There were statistically significant differences (all $p < 0.05$) regarding skin survival rate, length of hospital stay, and infection rate among the three surgical methods, i.e. Group A > Group C > Group B in skin survival rate, Group B > Group C > Group A in length of hospital stay, and Group B > Group C > Group A in infection rate (Table 2).

Table 1
The comparison and analysis among different wound locations in skin survival rate, length of hospital stay and infection rate.

Surgical group	Wound location	n	Skin survival rate (%)	Statistic data	Days of hospital stay	Statistic data	Infection rate (%)	Statistic data
A	Thigh	19	97.31 ± 0.91	$F = 7.998$	17.34 ± 2.13	$F = 15.386$	2.32 ± 2.34	$F = 56.341$
	Leg	5	92.31 ± 1.11	$p = 0.801$	19.64 ± 1.92	$p = 0.624$	32.54 ± 2.97	$p = 0.000$
B	Thigh	11	41.25 ± 2.34	$F = 19.989$	27.71 ± 3.14	$F = 31.247$	54.21 ± 2.34	$F = 56.098$
	Leg	12	33.22 ± 2.13	$p = 0.552$	31.36 ± 2.09	$p = 0.524$	50.94 ± 1.94	$p = 0.789$
	Foot	2	23.69 ± 1.99		33.14 ± 3.11		51.78 ± 3.31	
C	Thigh	1	90.00 ± 0.00	$F = 35.151$	21.78 ± 2.14	$F = 19.654$	0	$F = 65.187$
	Leg	2	89.21 ± 2.11	$p = 0.724$	25.34 ± 3.09	$p = 0.772$	50.00 ± 0.00	$p = 0.000$
	Foot	2	85.52 ± 2.34		23.14 ± 3.16		0	

Table 2
Comparison among different surgical methods in skin survival rate, length of hospital stay and infection rate.

Surgical group	n	Skin survival rate (%)	Days of hospital stay	Infection rate (%)
A	24	$95.31 \pm 0.81^{*\#}$	$18.24 \pm 2.01^{*\#}$	$6.62 \pm 3.34^{*\#}$
B	25	$39.95 \pm 3.14^{*\wedge}$	$29.61 \pm 3.87^{*\wedge}$	$53.7 \pm 2.84^{*\wedge}$
C	5	$89.91 \pm 2.09^{\#\wedge}$	$25.04 \pm 3.89^{\#\wedge}$	$16.67 \pm 1.8^{\#\wedge}$
Statistic data	54	$F = 32.567$ $p = 0.017$	$F = 12.694$ $p = 0.002$	$F = 7.576$ $p = 0.032$

Compared with Group A, $^{\wedge}p < 0.05$; compared with Group B, $^{\#}p < 0.05$; compared with Group C, $^{*}p < 0.05$.

Discussion

Extensive skin avulsion on the lower extremities has been proved a big challenge due to many factors. Unlike upper limb and face, the lower limb is essential for mobilization and therefore undergoes greater movement causing sheer force on the graft. Moreover most of the patients combined with serious damage and contamination, extensive skin defect and errhysis, as well as a long evacuation time, which may increase the risk of postoperative infection, shock, hypoalbuminemia, vein thrombosis of lower limb, fracture nonunion and chronic osteomyelitis.[7] These problems are very difficult to handle and various techniques have been reported, such as delayed grafting of split-thickness grafts after fenestration and compression dressing on the lower limb.[8–12]

Earlier treatment for skin avulsing and degloving injuries mainly adopt the in situ suture, which has been confirmed inadvisable because of its higher rates of skin necrosis and infection.[13] The technique of quilting full thickness grafts, reported by Harvey et al in 2009,[14] provides a potential solution to these problems faced with lower limb grafts. They thought that the use of full thickness quilted grafts allows firm fixation of the graft to the base, thereby eliminating the shear forces and any potential space to avoid seroma/haematoma formation. This technique is suitable for full thickness skin grafting as full thickness flaps are strong enough to hold the quilting sutures and will not be torn off when shearing forces are applied. Additional benefit of this technique is the low donor site morbidity. Full thickness grafts leave a linear donor scar and require less aftercare than mid-thickness grafts do. They are also subjectively reported as less painful than mid-thickness donor sites. Yan et al's[15] series study revealed that there were no donor site infections, hematomas or sarcomas, with no complication of delayed healing. We adopt the same method in group A (preservation of subcutaneous vascular network after debridement + vertical mattress suture of full thickness skin flap + tube drainage), and obtained the similar result. All the 24 cases had excellent results: more than 95% skin survival rate, as low as 6.62% infection rate and 18.24 days of hospital stay on average.

However, full thickness grafting is not suitable for all patients, especially for those with poor avulsed flaps (seriously destroyed subcutaneous vascular network). We selected the surgical method based on the condition of the subcutaneous vascular network and the fresh degree of the wound bed, which was judged by capillary filling test, flap extrusion or acupuncture test and flap survival prediction by the senior surgeon's experience in our study. McGrouther[16] reported a test method of sodium fluorescein injection, which has not been used widely because it has the side effects of nausea and vomiting.

More and more treatment techniques for skin avulsing injury are reported in recent years,[17] such as closed drainage and compression bandage, split-thickness skin grafting, and autologous skin grafting combined with VSD, which has obtained widespread use. In our research, we thinned and fenestrated the avulsed skin flap into split-thickness skin flap, then reattached them back to the wound bed immediately (Group B) or at the second stage (Group C). VAC evacuates wound secretions and blood, which decreases the risk of abscess, hematoma as well as infection and shortens the required time for reattachment.[18] The combination of cryopreserved split-thickness skin grafts harvested from the avulsed skin, dermal regeneration template and negative pressure drainage provides a good soft condition for knee joint movement. Several reports have emphasized the value of a dermal regeneration template in the reconstruction of large defects,[19] which has a superior functional and cosmetic results to those with skin grafts alone. Indeed split-thickness skin grafts alone offer poor cosmetic and functional outcome, like in our study, some patients developed impaired knee motility, but on the other hand the flaps have good viability since this technique allow drainage thus preventing abscess, hematoma and infection.[20] Furthermore during the harvest of split-thickness skin grafts, surgeons can differentiate viable and nonviable tissue more accurately through dermal bleeding judgment. Immediate or delayed full-thickness skin grafting of the avulsed skin does not have the abovementioned advantages and cannot be applied in the skin defect with poor muscle or wound base and life-threatening patients.[21]

Now it is generally believed that the golden time for avulsing injury treatment is 8 h after injury, because some avulsed skins have blood circulation at the early time, but gradually develop ischemia and necrosis due to circulation disorder as time goes by. This phenomenon is often unpredictable. A possible explanation is the cascade reaction that damaged vascular endothelial cells under stress lead to change in the biological effects, which further changes blood coagulability. While the rough inner wall of the blood vessels is very conducive to thrombosis, which finally causes skin microcirculation dysfunction.[22] In this study, most patients received surgery within 8 h, but some of them delayed in admission and had a high incidence of infection after the first surgery. Therefore we believe that patients' therapeutic effects, including the survival rate of the flap and extremity and the infection rate, are closely related to the operation time, which should be controlled within 8 h after injury.

In addition, this study found that even though we adopt skin thinning and meshing to improve skin graft quality, together with

VSD, the flaps in Group B still had the lowest survival rate compared with the other two groups. This unsatisfactory result may be associated with the skin thinning and meshing technology. Recently this procedure is done manually, which lengthens the operation time and aggravates ischemia. Besides the flap is not thin enough, once with necrosis, has a high risk of infection. That is why Group B has the greatest infection rate, longest hospital stays and highest cost. Moreover the survival rate of the frozen skin from the feet and front leg is lower than that from the high and rear leg due to the lack of tendon and muscle.

In conclusion, skin avulsing injury treatment should be based on the viability of the skin flap and the site of the wound area. Preservation of subcutaneous vascular network and nice drainage can obtain better effect than split-thickness skin meshing and grafting alone. Especially in some patients with seriously wounds, delayed grafting of frozen flap technology can also reduce patient's pain and hospitalization expenses.

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