CASE SERIES

Reverse sural flap: Our clinical experience with car tire injuries in the anterolateral aspect of the foot

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ABSTRACT

BACKGROUND: Defects due to car wheel injury at the anterolateral aspect of the foot are challenging due to the characteristics of the region and the trauma. The aim of this study was to present the results of the patients whose skin defects on the dorsolateral aspect of the foot due to tire injuries were treated with reverse sural artery fasciocutaneous flaps.

METHODS: Fourteen patients with a mean age of 26.9 years (range: 5–46 years) who experienced loss of tissue at the dorsolateral aspect of the foot due to tire injury between the years 2000 and 2014 were evaluated retrospectively. The mean defect size was 27.1 cm2. The patients were followed up for observing the tissue coverage and complications throughout a mean period of 32.4 months.

RESULTS: Despite the development of marginal necrosis in two flaps in the early period, tissues in all cases were successfully covered without requiring additional reconstruction. Primary donor site coverage was achieved in all patients without any donor site problems.

CONCLUSION: In case of tire injuries at the anterolateral aspect of the foot, low complication and high success rates can be achieved with a case-based approach with reverse sural artery fasciocutaneous flap coverage.

Keywords: Car tire; fasciocutaneous flap; foot and ankle; microsurgery; reverse sural artery flap.

INTRODUCTION

Soft-tissue defects in the lower one-third aspect of the leg and in the foot are often a problem due to the thickness and non-elasticity of the skin, relatively weak blood circulation, and the relative scarcity of the soft tissue in the region.[1–4] At the beginning, cross-leg flaps were used as a solution, followed by local cutaneous, proximal, or distal fasciocutaneous flaps, perforator flaps, and free flaps.[5,6] Ideally, the flap should be applied quickly, not require sacrification of a major artery or nerve, create minimal discomfort in the patient, and provide a permanent and reliable coverage.[3,7,8] Reverse-flow sural flaps are used frequently in the defects of this region with low morbidity and high success rates.[3,9,10]

The aim of this study was to present our experience with reverse sural artery fasciocutaneous flaps to cover the complicated soft-tissue defects caused by car tires in the dorsal and dorsolateral aspects of the foot (which are two of the most remote points the flaps can be applied) with a minimum follow-up period of 24 months and to compare the results with the literature data.

MATERIALS AND METHODS

Fourteen patients (12 males, 2 females; mean age: 26.9 years [range: 5–46 years]) who were applied superficial sural artery flaps with distal pedicles for the tissue defects in the anterolateral aspect of the foot between 2000 and 2014 were evaluated retrospectively. All defects were caused by trauma due to the foot being crushed under the wheel (Fig. 1a). Two patients had tibiotalar instability, two patients had cuboid fractures, one patient had a fracture of the fifth metatarsal, and one patient had fractures of the first and fifth metatarsals.

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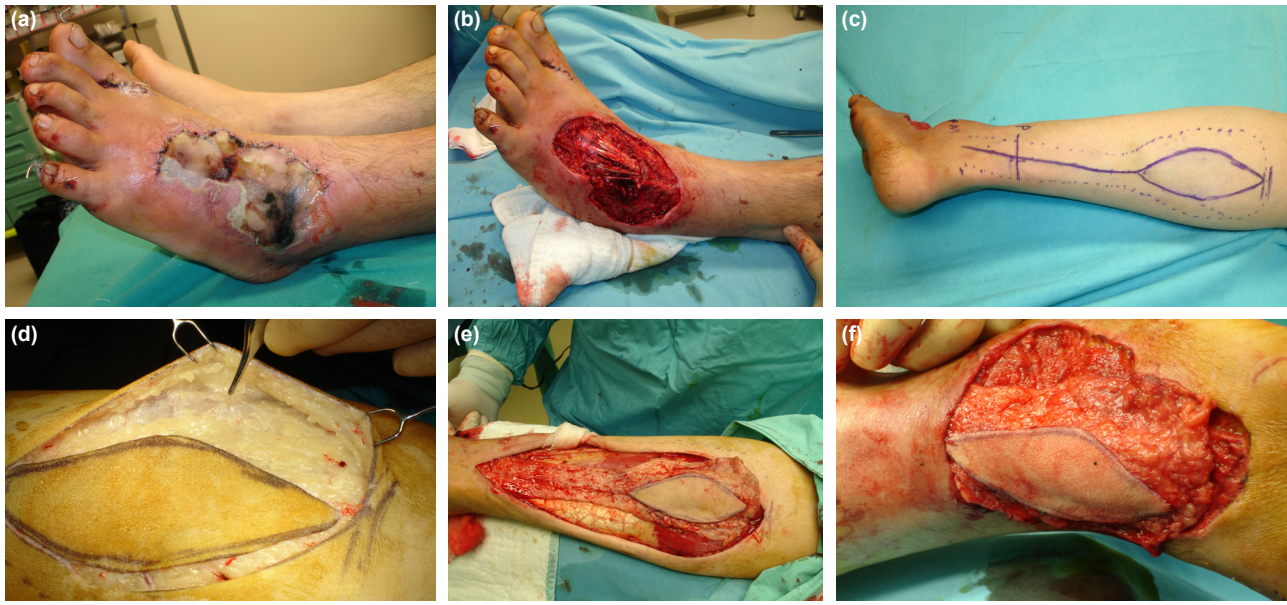

Figure 1. (a) Soft-tissue defect in the dorsolateral aspect of the foot due to car tire injury. **(b)** Post-debridement appearance. **(c)** Drawing the incision line for harvesting the flap from the proximal one-third of the foot. **(d)** Enlargement of the flap with subcutaneous dissection. **(e)** Intraoperative appearance of the reverse sural flap. **(f)** Transferring the flap to the defect site by moving it through the tunnel.

The patients were followed up for a mean period of 32.4 months (range: 24–108 months). The mean defect size was 27.1 cm^2 (range: 16–40 cm^2). One patient was a smoker and one patient had diabetes mellitus (Table 1). The mean length of hospital stay was 5.4 days (range: 4–8 days).

Surgical Technique

Patients were applied a high-thigh tourniquet in the prone position under anesthesia. Following debridement, the anastomosis location of the peroneal artery was determined approximately 5 cm above the lateral malleolus and as the pivot point by Doppler ultrasound. The pedicle length was determined according to the distance between the defect and the pivot point, and the flap size was determined according to the defect size. The skin incision was made through the posterior midline of the leg. The proximal one-third aspect of the leg was used to allow the flap to reach the defect site in the dorsolateral aspect of the foot (Fig. 1b and c). When raising the flap, if the flap size was not small enough to allow for primary closure in the posterior leg, that is, if the defect was larger than the size of the primary closure, the skin was prepared in a way that can be closed with the primary flap and the actual size of the flap was enlarged by mobilizing the skin around the skin island and adding the subcutaneous tissues to the flap (Fig. 1d).

The sural nerve, the superficial sural artery, and the small saphenous vein were reached. While the vessels were ligated and cut, cautery was not used considering the performance of a distal anastomosis, and the tip of the sural nerve was embedded into the muscle in the proximal. The fascial flap was elevated with the fascia under the skin island. A 4–5-cm-wide fascial pedicle was created by a thin and gentle dissection of the skin over the pedicle of the flap (Fig. 1e). Both the tunnel and incision techniques were used to move the pedicle to the defect site (Fig. 1f). If the pedicle was thought to get stuck or create pressure after creation of the tunnel, incision was performed to free the pedicle. For transferring the flap to the defect site, tunnels with an appropriate width were used in five cases, whereas incision was performed in the other nine patients. When necessary, a thin skin graft was applied to the pedicle of the flap.

Throughout the surgical procedure, attention was paid to hemostasis and suction drain was used to prevent a hematoma. In order to prevent pressurizing the pedicle of the flap postoperatively, the patients were instructed to lie in the prone position or on their sides for a week. A plaster splint was applied to the leg for 3 weeks to restrict the movement of the graft over the tunnel and the flap. During the procedure, attention was paid to avoid the splint compressing on the rotation point of the pedicle and the tunnel. Postoperatively, the distal ends of the flap were exposed and the circulation was closely followed up. Post-operative edema developed in two cases and caused circulation impairment by compressing the rotation point of the pedicle. By removing the sutures in this region, the tension in the pedicle was relieved and the flap circulation was improved (Table 1).

The patients were given anticoagulant therapy for 30 days, low-molecular-weight heparin for the first 6 days, and one dose of 100 mg of acetylsalicylic acid daily on the remaining days. After the plaster was removed, active and passive exercises were started. Approval for the study was obtained from the ethical committee of our institution.

Table 1. Descriptive data of the studied patients

Patient no.	Age	Gender	Defect size (cm^2)	Associated problems	Tunnel / Incision	Vein anastomosis	Suture removal	Morbidity	Morbidity
1	32	Male	28		Tunnel	–	+		
2	34	Male	40		Incision	+	–		
3	13	Male	30	Cuboid fracture	Tunnel	–	–	Smoking	Marginal necrosis
4	26	Male	20	Talotibial instability	Incision	–	–		
5	34	Male	30	Cuboid fracture	Tunnel	–	–		
6	45	Female	36	Talotibial instability	Tunnel	–	+		
7	32	Male	36		Incision	–	–	Diabetes mellitus	Marginal necrosis
8	41	Male	20		Tunnel	+	–		
9	25	Male	28	Fracture of the 5th metatarsal	Incision	–	–		
10	10	Male	24		Incision	–	–		Transient infection
11	5	Female	20		Incision	–	–		
12	6	Male	16		Incision	–	–		
13	46	Male	28		Incision	–	–		
14	28	Male	24	Fractures of the 1st and 5th metatarsals	Incision	–	–		

RESULTS

No surgical complications were observed in 11 of the 14 patients, however, marginal necrosis was seen in two cases. One of these patients underwent repair with split-thickness skin graft while the other patient recovered secondarily. Transient superficial infection developed in another case.

Venous congestion and edema observed in the early post-operative period regressed within 7–15 days in 10 of the flaps (Fig. 2a and b). In two cases, saphenous vein anastomosis was performed due to fast capillary refill, thus the suspicion of a venous congestion. The donor area was closed primarily in 14 cases.

Ultimately, no new flap surgery or a debulking procedure was required in any case (Fig. 3). The donor sites healed without any complication. Although sensory loss was detected in the lateral aspect of the foot in all cases, no complaints were detected during the follow-up. All cases returned to their normal activities.

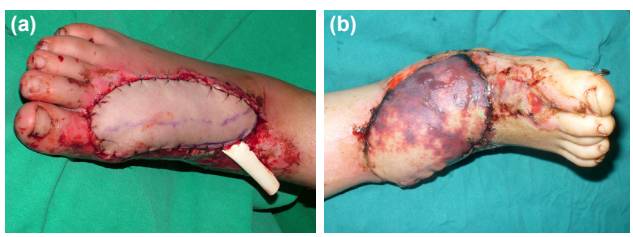

Figure 2. (a) The reverse sural flap in the post-operative early term. **(b)** Appearance of the venous congestion.

DISCUSSION

Car tire injuries have different characteristics than other injuries.[11] Depending on the speed of the vehicle and the position of the foot, the resulting damage may vary from simple abrasion to severe damage accompanied by bone loss.[12,13] During the injury, degloving, shearing, compression, crushing, friction, and burning mechanisms work collectively.[14] The

Figure 3. Appearance of the defect covered with reverse sural flap.

wound is often dirty and has a friction burn on the edges, and the surrounding tissues are affected.

The coverage in the dorsal of the foot should be thin and pliable for a comfortable shoe wear and the protection of the ankle movements.[11] Local adipofascial flaps can be used if the defect is small, while free flaps or cross-leg flaps can be used for larger defects.[12,15] The use of local flaps may be limited due to the surrounding effects of the trauma. Free flaps may be considered successful due to their ability to be applied in single stage, provide reliable blood supply, and cover large defects. However, the long surgical time and microsurgery requirement are the serious disadvantages.[2,16,17] In addition, sacrification of the major vessels and bulkiness are serious problems in free flaps.[8,18] On the other hand, the immobilization for 3 weeks is not well tolerated by adults and a second intervention is required in cross-leg flaps. The difficulties encountered in the repair of these defects began to be solved by the introduction of reverse-flow sural fasciocutaneous flaps.[19,20]

Identification of the flaps in the lower extremities began following anatomical studies. In 1973, Daniel and Willams showed the regular vessels following the leg axis in their research.[21] In 1981, Haertsch examined the circulation of the leg skin and discovered the axial and supplying vessels along with the sural nerve.[22] Masquelet et al.[23] found out the presence of the vascular axis along the sensory cutaneous nerves of the lower extremities and described the distally based sural neurocutaneous flap in 1992. In 1994, Hasegawa et al.[24] used the superficial sural artery flap with a distal pedicle as a new flap to repair the defects in the distal one-third aspect of the leg.

Since this flap has been defined and started to be used, there have been discussions about its vascularization, and its reliability has been questioned due to venous congestion.[7,17,25] The flap receives its arterial blood supply from the neural and venous plexuses. These plexuses are supported by musculocutaneous and septocutaneous perforators from the posterior tibial and peroneal arteries along their pathways.[26,27] The anastomoses between the plexuses and the perforators are below the deep fascia in the proximal one-third and above the fascia in the middle one-third. In the distal aspect, this vascular network makes anastomosis with the septocutaneous perforators from the peroneal artery.[28,29] Arterial blood flows in the opposite direction in the pedicle of these flaps, and the venous drainage of the flap is in the opposite direction of the normal venous flow. Therefore, a flow is generated toward the valves that are responsible for preventing venous reflux. The question of how to bypass these valves initially raised doubts. It is thought that the venous return in reverse-flow flaps is facilitated by the avalvular collateral venules accompanying the small saphenous vein.[30,31] This finding is consistent with the fullness of the veins as a result of the ligation of the proximal end of the reverse-flow forearm flap and the progressive edema seen in the flap.[32] The swelling and venous fullness observed after the proximal ligation of the small saphenous vein during our intervention are consistent with these findings. In two cases where venous congestion was thought to impair the circulation of the flap, the saphenous vein was anastomosed to one of the surrounding veins with appropriate size.

Sural fasciocutaneous flaps with distal pedicles have significant advantages. One of these advantages is that the flap can be transferred easily and quickly in a single step without the need for a microsurgical technique.[1] Other reverse-flow island flaps, such as peroneal artery flap, anterior tibial artery flap, and posterior tibial artery flap, used in lower extremity defects require the sacrifice of a major vessel. The vascular network circulation of the sural region is reliable, and no sacrification is required.[1] This, in turn, allows the flap to be used even in traumatic limbs with vascular damage and arterial circulatory disorders.[1,2,17] However, it would be useful to confirm the circulation in the peroneal artery and the most distal perforator using the Doppler prior to the procedure. This demonstrates the anatomic or traumatic differences and facilitates surgery by choosing the right flap and the pivot point.[1,33] In one of our cases, pre-operative Doppler ultrasound examination showed no circulation due to trauma in the peroneal artery, and flap application was abandoned. This flap can be harvested from anywhere in the sural region, has a wide arc rotation, and can easily be extended to the back of the foot and the heel with its long pedicle.[34,35]

All of our cases had defects in the dorsolateral aspect of the foot, which required a relatively longer flap pedicle and arc rotation. In our cases, we worked near the popliteal fossa to obtain flaps with longer pedicles, as indicated by Herlin et al.[4] Despite the concerns about the proximal extension of the flap in the literature, we were able to successfully reach the defect site.[17]

With the surgical technique we utilized, we were able to perform primary closure on all donor sites thanks to the harvesting of the flap wider than the defect and adding the subcutaneous tissue to the flap. The bulking effect in the defect site was thus minimized, and the adaptation of the flap with the defect area was facilitated.[9,36] In addition, the revision of the length differences that could occur was made easier and a cosmetically superior healing was achieved in the donor site since we did not use a graft.

In their study showing the effect of comorbidity on sural flap surgery, Baumeister et al.[37] reported complication rates of 11% in healthy individuals, with the presence of diabetes, venous insufficiency, or peripheral arterial disease in 60% of the cases.

In their series of 71 cases with a history of traffic accident predominantly, Almeida et al.[38] detected partial necrosis

in 22%, total necrosis in 4.2%, and infection in 8.5% of the cases. The authors demonstrated the reverse flow in the small saphenous vein with the duplex scan performed post-operatively and stated that this current, which was slow especially in the early term, turned into phasic flow over time, and this occurrence explained the recovery from venous congestion that was seen at the beginning in some cases over time.

In their series of 58 cases, Herlin et al.[4] observed venous congestion in 31% (n=18) of the cases in the early period, subsequently performed venous anastomosis or ligation, and decreased the congestion rate to 10% (n=6). Only one of these cases required reconstructive intervention. The superficial necrosis that developed in the remaining five cases (8.6%) was repaired with skin grafting.

Sonmez et al.[39] stated that, in venous congestion problem of the neural island flaps, a more effective venous drainage could be achieved with the elimination of valve mechanisms via vein stripping and they demonstrated the reverse flow in the small saphenous vein, using Doppler US. The authors did not encounter any venous congestion in their series of 19 patients with foot and ankle defects.

Korompilias et al.[3] achieved a successful coverage in nine cases from their series of ten patients who underwent sural flap surgery at the foot and ankle level. However, venous congestion was observed in 40% of the cases, half of these developed partial necrosis, and total necrosis of the flap was seen in only one case. The authors attributed this to the fact that 70% of the defects were below the ankle level and most cases were either smokers or diabetic.[3]

In their series of seven cases, Maffi et al.[2] used interpolation flaps. The only case the authors encountered necrosis was with the smoker.

Although the risk of venous congestion was more toward the proximal, the subcutaneous tissue and venous structure were added to the larger pedicle of the flap and this reduced the possibility of circulation problems. Saphenous vein anastomosis should be added to the treatment in order to prevent the congestion in patients who are likely to encounter venous congestion. In our series, attention was paid to the suture tension in order to eliminate this problem. Sutures were removed in two cases who developed edema, and venous anastomosis was performed in two cases.

In our cases, a case-based approach was followed which maintained the balance between vascular and cosmetic concerns and took the skin elasticity and additional comorbidities into account. Only two patients developed partial necrosis. One of these patients recovered spontaneously and the other patient was performed skin grafting. None of the patients required reconstructive intervention. In addition, the superficial infection developed in one patient healed without any intervention. In our series, the presence of comorbidities (smoking and diabetes) in both cases who developed partial necrosis attracted our attention.

Decreased sensation in the lateral aspect of the foot, graft contracture and cosmetically a bad appearance in the donor site, and excessive tissue in the recipient site may be recounted as the disadvantages of sural flaps.[1,2] Although we detected loss of sensation in the lateral aspect of the foot in the early post-operative period in all our cases, this was not a cause of complaint in the follow-up period, in accordance with the literature.[1,16] In addition, sural nerve-induced neuroma did not develop in any patient. As we performed primary closure, donor site morbidity did not occur. No problem was encountered in shoe wearing due to the thickness of the flap.

Although the defects in all our cases were located in the dorsolateral aspect of the foot, which was a remote point for sural flap application and thus a long pedicle was needed, and had occurred due to car tire injuries, our results were satisfactory.

Limitations of our study include the lack of a retrospective design and control group.

Conclusion

Based on the results of this study, we can assert that superficial sural artery flaps with pedicles are an easy, convenient, and successful method in repairing car tire injuries located on the dorsolateral aspect of the foot and are advantageous in terms of cost–benefit thanks to the short hospitalization period.

The anatomy of this flap, its areas of application, surgical considerations, and complications have been summarized in light of the literature. These flaps cover the exposed tendons, bones, metal implants, or neurovascular structures by creating minimal donor site morbidity and without damaging the main blood supply system of the leg which consists of the peroneal, anterior tibial, and posterior tibial arteries.

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OLGU SERİSİ - *ÖZET*

Reverse sural flep: Ayak anterolateralindeki araba lastiği yaralanmalarında klinik tecrübemiz

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AMAÇ: Ayak anterolateralindeki araba tekeri yaralanmasına bağlı defektlerin örtümü; hem bölgenin özellikleri hemde travma karakteri nedeniyle güçlükler içermektedir. Amacımız lastik yaralanması sonrası ayak dorsolateralindeki cilt defekti gelişen olguların reverse sural arter fasyokütanoz flep ile örtüm sonuçlarını sunmaktır.

GEREÇ VE YÖNTEM: Bu çalışmada, 2000–2014 yılları arasında, ortalama yaşı 26.9 yıl (dağılım, 5–46 yıl) ve ayağın dorsolateralinde araba tekerine bağlı doku kaybı bulunan 14 hasta geriye dönük olarak değerlendirildi. Ortalama defekt büyüklüğü 27.1 cm^2 bulundu. Olgular doku örtümü ve komplikasyonlar açısından ortalama 32.4 ay takip edildi.

BULGULAR: Erken donemde fleplerin ikisinde marjinal nekroz gelişmesine rağmen tüm olgularda ek rekonstrüksiyon gerektirmeden başarıyla doku örtümü sağlandı. Donör saha sorunlarıyla karşılaşılmadan tüm hastalarda donör bölgeler primer olarak örtüldü.

TARTIŞMA: Ayak anterolateral araba tekeri yaralanmalarında, olgu temelli yaklaşımla reverse sural arter fasyokütanoz flepler ile düşük komplikasyon ve yüksek başarı elde edilebilir.

Anahtar sözcükler: Ayak-ayak bileği, fasyokütan flep; microcerrahi; reverse sural arter flep; teker.

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