Venous Arterialization for the Treatment of Large-area Foot Skin Retrograde Avulsion

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abstract

Between 2009 and 2011, three patients with large-area foot skin retrograde avulsion (more than 1% of the body surface area) underwent venous arterialization. Anastomosis of the artery in the wound surface with the vein in the skin flap and an appropriate number of venous end-to-end anastomoses were performed. The skin flaps survived in all 3 patients. Six months postoperatively, the flap elasticity and appearance were close to that of normal skin, and foot function was better without scar contracture.

When venous arterialization is used to treat foot avulsion, the following points should be noted. Surgical indications include no fresh bleeding from the wound edge of the avulsed skin after debridement, more complete avulsed skin, and superficial veins that do not completely separate from the avulsed skin. Venous arterialization is not suitable to avulsion with fresh bleeding, avulsed skin in small fragments, and avulsion with a subcutaneous venous network embolism. During debridement, the subcutaneous venous network should be protected to avoid exposing the vein stems outside the fat layer. If the avulsion is less than 1% of the body surface area, arterial-venous anastomosis can provide adequate blood supply. Venous-venous anastomosis is performed as much as possible to enhance venous return and decrease microcirculatory pressure, which is conducive to the establishment of effective blood circulation.

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Figure: Photograph of the foot sole showing an avulsion in the left foot that accounts for approximately 2% of the body surface area. The tendon and bone are exposed and the avulsed skin is pale without blood supply (A). Photograph of the lateral position of the foot 6 months postoperatively showing that the flap elasticity and appearance were close to that of normal skin. Foot function was better without scar contracture (B).
Large-area skin retrograde avulsion is one of the more intractable traumas. This is especially true for the feet because the incidence of necrosis is higher and it is difficult to replace necrotic heel skin with skin from other sites, which affects foot function. Between 2009 and 2011, the authors successfully treated 3 patients with large-area foot skin retrograde avulsion (more than 1% of the body surface area) with venous arterIALIZation. All study methods were approved by the authors’ ethics committee, and the 3 patients gave written formal consent to participate in the study.

The 3 patients had large-area foot skin retrograde avulsion that was more than 1% of the body surface area. Of the 3 patients, 2 sustained a mangled injury and 1 sustained a rotary avulsion. The wounds had serious contamination, and the avulsed skin was pale without blood supply. One patient also had a lateral malleolus fracture.

**Surgical Technique**

All operations began 45 to 120 minutes after injury. First, end-to-end anastomosis of the vein in the flap and the vein in the wound surface was performed. In general, the establishment of venous circulation can decrease the venous pressure and improve the arterial blood supply. However, in the 3 patients, the flaps were still pale without blood supply after the successful venous end-to-end anastomosis. Based on venous skin flap and severed finger reunion of venous arterIALIZation, arterial-venous anastomosis of the artery in the wound surface with the undamaged vein in the avulsed skin was performed to build arterial blood supply. Then, an appropriate number of venous end-to-end anastomoses were performed to build a backflow path. Postoperatively, the blood supply of the flaps was adequate, with good blood circulation. The statuses of the 3 patients are shown in the Table.

The 3 patients were on absolute bed rest for 10 days postoperatively, and the injured feet were in a 25°C environment adjusted with a side lamp. Patients received 30 mg of intramuscular papaverine 3 times daily and 500 mL of intravenous low-molecular dextran once daily (or twice daily when blood circulation was poor). Antibiotics were given for 1 week. An analgesic drug was given to avoid vasospasm. Regular dressing changes were performed, and blisters were aspirated.

**Case Report**

A 47-year-old woman presented 20 minutes after sustaining a left foot avulsion. Local physical examination revealed that the avulsion was from the ankle joint, dorsi pedis, and foot sole to the interphalangeal joints of all 5 toes with an uncovered achilles tendon and calcaneus and severe contamination of the wound surface. The avulsed skin was pale and had a lower skin temperature compared with normal skin (Figure 1). Toe motion was limited, and their capillary filling was slow. Hypesthesia was found in the skin. Under combined block anesthesia, debridement and flap-vascular anastomosis were performed. The flap had no blood supply after venous end-to-end anastomosis, and it was not possible to perform arterial end-to-end anastomosis due to the poor vascular conditions in the flaps. Therefore, vascular anastomosis of venous arterIALIZation, namely that the arteriovenous anastomoses of the arteriae tarsea lateralis with the dorsalis pedis vein (Figure 2) and the arteriae plantaris medialis with the vena plantaris medialis, were performed. At the same time, end-to-end venous anastomoses of 2 dorsalis pedis veins and 2 vena plantaris mediales were performed. Intraoperatively, the skin flaps were ruddy, and the larger cutaneous deficiency required second-stage skin grafting.

The postoperative medication was the same as for severed finger reunion (ie, fluid expansion, anti-angiospasm, and analgesic drug). On postoperatively day 1, soft tissue swelling was marked, and filling was rapid in the left foot. On postoperative day 3, the avulsed skin had better blood circulation with mild swelling, and scattered vesicles occurred around the wound (Figure 3). On postoperative day 7, the vesicles disappeared. On postoperative day 12, the skin flaps were ruddy and survived with better blood circulation. Six months postoperatively, flap elasticity and appearance were close to that of normal skin, and foot function was better without scar contracture (Figure 4).

<table>
<thead>
<tr>
<th>Patient No./Sex/Age, y</th>
<th>Injury Mechanism</th>
<th>Avulsion Area, %</th>
<th>Manner of Venous ArterIALIZation</th>
<th>No. of Venous Anastomosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/F/47</td>
<td>Mangled injury</td>
<td>2</td>
<td>Arteriae tarsea lateralis with dorsalis pedis vein, arteriae plantaris medialis with vena plantaris medialis</td>
<td>2 dorsalis pedis veins, 2 vena plantaris medialis</td>
</tr>
<tr>
<td>2/M/34</td>
<td>Rotary avulsion</td>
<td>1</td>
<td>Arteriae tarsea lateralis with dorsalis pedis vein</td>
<td>2 dorsalis pedis veins</td>
</tr>
<tr>
<td>3/M/51</td>
<td>Mangled injury</td>
<td>1</td>
<td>Arcuate artery with dorsalis pedis vein</td>
<td>2 dorsalis pedis veins</td>
</tr>
</tbody>
</table>
RESULTS

All skin flaps survived in the 3 patients. In 1 patient, moderate postoperative swelling and more skin flap blisters gradually disappeared 1 week postoperatively. In the other 2 patients, mild swelling and fewer skin flap blisters occurred postoperatively. In 1 patient, second-stage skin grafting was performed due to a larger cutaneous deficiency around the skin flaps. In the other 2 patients, wound healing after 3-week dressing changes was attributed to smaller cutaneous deficiency around the skin flaps. Six months postoperatively, the flap elasticity and appearance were close to that of normal skin, and foot function was better without scar contracture.

DISCUSSION

The incidence of foot avulsions caused by high-energy injuries, such as road accidents, are gradually increased. Because the avulsed skin area in severe large-area foot avulsions is large and there is no blood supply, the effects of conventional therapeutic methods, including pressure dressing and reversing-removing skin for skin grafting, are not ideal. The incidences of skin necrosis and infection are higher and scar contracture can readily occur, which would affect foot appearance and function. For retrograde avulsions with fresh bleeding, venous anas-
omosis is performed to build circulatory paths that decrease venous pressure and improve arterial blood supply, promoting the survival of the avulsed skin flap. Effective methods exist to treat retrograde avulsions with no fresh bleeding. For venous arterIALIZation, no distal arteries are used for arterial anastomosis; vascular anastomosis of the proximal artery with a distal superficial vein is performed to reestablish blood circulation.

Currently, venous arterIALIZation has obtained the exact effects for the treatment of severed finger reunion and limb ischemia, but the specific blood circulation mechanism is unclear. The current authors performed venous arterIALIZation to treat large-area foot avulsions for the first time. In this study, the mechanism of venous arterIALIZation was similar to that of arterialized venous flaps. However, arterIALIZED venous flaps are generally used for smaller wound surfaces, which were not completely the same as that in this study. Regarding reperfusion injury, Djoric et al. reported that in the cases of limb ischemia, no statistical differences existed in lactic acid-reaction products and antioxidase between the control and venous arterIALIZation groups, demonstrating that venous arterIALIZation failed to increase reperfusion injury risk.

The blood supply of the foot comes from the anterior and posterior tibial arteries and their branches. The anterior tibial artery beyond the extensor retinaculum is named the dorsal pedis artery and mainly supplies blood to the dorsi pedis. The branches of the dorsal pedis artery include the lateral and medial anterior malleolar arteries, lateral and medial tarsal arteries, arcuate artery, distal dorsal metatarsal arteries, and dorsal digital artery. The posterior tibial artery is divided into the medial and lateral plantar arteries, which mainly supply blood to the foot sole. The lateral plantar artery is larger and forms the plantar arterial arch, which branches off into the metatarsal arteries and arteriae digitales plantares propriae. Many communicating branches exist between the dorsal pedis artery and plantar arteries. In the current study, 1 or 2 branching arteries were cut, which did not affect the overall blood supply of the foot. The foot-venous return system consists of deep and superficial venous systems. The deep venous system comprises arterial accompanying veins. The venous blood of foot-deep tissue flows into the deep venous system and reflows into the popliteal vein. The course of the dorsal superficial venous return system is as follows: dorsal digital vein to dorsalmetatarsal vein to arcus venosus dorsalis pedis to medial and lateral marginal veins to great and small saphenous veins. The plantar superficial venous return system is as follows: medial and lateral marginal veins to great and small saphenous veins. The foot-superficial veins form a venous network communicating with deep veins. Arteriovenous reticular distribution and no venous valves beyond the arcus venosus dorsalis pedis provide favorable conditions for the maze-like blood flow after venous arterIALIZation.

The dorsal vein system is rich with thicker blood vessels. The vein diameter may reach 2.5 to 4 mm in the medial venous arch, 1 to 2 mm in the lateral venous arch, 3 to 4 mm in the medial malleolus, and 1.5 to 2.5 mm in the lateral malleolus. The thicker veins and vascular anastomotic patency ensure that the sufficient blood from the arteries maintain an effective blood volume and perfusion pressure in the inflow vein system. Because several veins exist and although 1 or 2 veins are used for venous arterIALIZation, the remaining veins can meet the requirement for backflow. To ensure blood supply in patient 1, two veins were used for arterIALIZation and 4 were used for venous return. In the early phase, poor venous return led to marked skin flap swelling with blisters, but the swelling disappeared 1 week later with the occurrence of collateral circulation.

It is necessary to know the anatomy of the arterial and venous circulation of the foot and its soft tissue. It is suitable for a lateral dorsal degloving injury for the arteriae tarsalis lateralis to serve as a feeding artery. For a dorsomedial or plantar degloving injury, the arteriae tarsales mediales or medial plantar artery serves as a feeding artery; the lateral plantar artery does not serve as a feeding artery as much as possible to avoid affecting the toe blood supply. It is suitable for a degloving injury of the distal dorsi pedis for the arcuate artery or dorsal metatarsal arteries to serve as a feeding artery. After anastomosis of the lateral tarsal artery and dorsalis pedis vein in patient 1, who had a large-area degloving injury, the blood supply was better in the dorsi pedis but poor in the foot sole. Therefore, anastomosis of the medial plantar artery and the vena plantaris medialis was performed, which improved the blood supply in the foot sole. The above principles are not absolute; the protocol is determined based on the specific status and vascular variation.

When venous arterIALIZation is used to treat foot avulsion, the following points should be noted. Surgical indications are foot skin retrograde avulsion that is more than 1% of the body surface area, no fresh bleeding from the wound edge of avulsed skin after debridement, more complete avulsed skin, and superficial veins that do not completely separate from the avulsed skin. Venous arterIALIZation is not suitable for avulsions with fresh bleeding, avulsed skin in small fragments, and avulsions with subcutaneous venous network embolisms. During debridement, the subcutaneous venous network should be protected. Only a thin layer of subcutaneous fat should be removed to avoid exposing the vein stems outside the fat layer. If the avulsion is less than 1% of the body surface area, arterial-venous anastomosis can provide adequate blood supply. Venous-venous anastomosis is performed as much as possible to enhance venous return and decrease microcirculatory pressure, which is conducive to the establishment of effective blood circulation.
CONCLUSION

Venous arterialization cannot serve as a common treatment for large-area foot skin retrograde avulsion; it is only suitable in special cases. In venous arterialization, microcirculatory characteristics, nutritional support, and late vascular remodeling need to be further studied.

REFERENCES


