INTRODUCTION

Soft tissue defects in the distal lower extremity represent a special challenge in deciding the operative method owing to the poor vascularity of the lower leg and the limited adjacent soft tissue. During the last few decades, various methods of lower-limb wound coverage have been described, such as local flaps, distant flaps, and free flaps. Among the various methods, the distally based fasci flap can be one of the several options for the reconstruction of the distal lower extremity in high-risk patients. We report our experiences with the versatile, delayed reverse sural flap for coverage of the distal lower extremity in high-risk patients.

Methods: From September 2015 to October 2016, seven patients with soft tissue defects of the distal lower extremity were treated with the delayed reverse sural flap based on a two-step procedure. All patients had significant medical co-morbidities, such as diabetes mellitus, peripheral arterial disease, and smoking. The delay period ranged from 10 to 14 days, and the flap size was from 7.5×2.0 to 14.5×4.0 cm.

Results: Six flaps survived without complications. One flap showed partial necrosis due to venous congestion but eventually survived.

Conclusion: Because the delay procedure improves flap viability, the delayed reverse sural flap may be a reliable and efficient alternative for reconstructing soft tissue defects of the distal lower extremity in high-risk patients.

Key Words: Sural, Lower extremity, Risk
Ciocutaneous sural flap was first reported by Donski and Fogdestam in 1983. Then, the sural flap has become the method of choice for the reconstruction of distal lower-extremity defects since its reintroduction in 1992 by Masquelet et al.

Since then, several modifications of the sural flap have been reported to improve flap viability and solve their complications. Delayed sural flap is one of various modifications of the sural flap.

In 2009, Parrett et al. published that delay procedures were associated with decreased ischemic flap complications in patients with comorbidities. Moreover, the authors reported that the reverse sural flap is reliable in young patients, but is associated with significant complication rates in patients with comorbidities, especially smokers. For such patients, they suggested that a surgical delay procedure should be considered. The advantage of the delay procedure is that it improves flap survivability in patients with significant medical comorbidities.

Accordingly, we treated seven high-risk patients with soft tissue defects of the lower extremity by using a delayed reverse sural flap, and the results were excellent. Therefore, the purpose of this study was to report the usefulness of the delayed reverse sural flap for the reconstruction of the distal lower extremity in high-risk patients.

MATERIALS AND METHODS

1. Patient characteristics

From September 2015 to October 2016, seven patients with soft tissue defects of the lower extremity were treated with a delayed reverse sural flap. Written informed consent was obtained from each patient in the study. All patients who had defects between the lower pretibia and the foot underwent a two-step procedure. Patients with significant medical comorbidities were especially selected for this flap surgery. The clinical characteristics of the patients are summarized in Table 1.

<table>
<thead>
<tr>
<th>Patient No.</th>
<th>Age (yr)</th>
<th>Cause of injury</th>
<th>Location of defect</th>
<th>Flap size (cm)</th>
<th>Donor site closure</th>
<th>Complication</th>
<th>Timing of defect prior to surgery (mo)</th>
<th>Follow-up (mo)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>32</td>
<td>Wound infection</td>
<td>Posterior ankle</td>
<td>10.0 × 3.0</td>
<td>None</td>
<td>Venous</td>
<td>12.0-3.5</td>
<td>8</td>
</tr>
<tr>
<td>2</td>
<td>57</td>
<td>Pressure sore</td>
<td>Heel</td>
<td>5.5 × 3.5</td>
<td>None</td>
<td>None</td>
<td>13.0-4.0</td>
<td>18</td>
</tr>
<tr>
<td>3</td>
<td>23</td>
<td>Wound infection</td>
<td>Lateral malleolar area</td>
<td>3.0 × 2.5</td>
<td>Teardrop</td>
<td>None</td>
<td>11.0-3.0</td>
<td>8</td>
</tr>
<tr>
<td>4</td>
<td>27</td>
<td>Pressure sore</td>
<td>Heel</td>
<td>7.5 × 2.0</td>
<td>Teardrop</td>
<td>None</td>
<td>13.0-5.0</td>
<td>18</td>
</tr>
<tr>
<td>5</td>
<td>85</td>
<td>Traffic accident</td>
<td>Lower pretibial area</td>
<td>3.0 × 2.5</td>
<td>Teardrop</td>
<td>None</td>
<td>12.5-5.0</td>
<td>8</td>
</tr>
<tr>
<td>6</td>
<td>40</td>
<td>Wound infection</td>
<td>Lateral malleolar area</td>
<td>4.0 × 3.5</td>
<td>Teardrop</td>
<td>None</td>
<td>14.5-4.0</td>
<td>8</td>
</tr>
<tr>
<td>7</td>
<td>51</td>
<td>Wound infection</td>
<td>Lateral aspect of heel</td>
<td>3.0 × 2.0</td>
<td>Teardrop</td>
<td>None</td>
<td>12.5-2.5</td>
<td>10</td>
</tr>
</tbody>
</table>

All patients are male. HTN: hypertension, DM: diabetes mellitus, PAD: peripheral arterial disease, CVD: cerebrovascular disease.
2. Surgical techniques

During the first operation, the patients were placed in the prone position. The perforating vessels from the peroneal artery, which is usually located approximately 5 cm proximal to the lateral malleolus, were marked on the skin by using a handheld Doppler device. A line of the vascular axis of the flap was drawn from the popliteal fossa to the lateral malleolus. The flap was designed as a teardrop-shaped skin paddle on the posterior calf and slightly larger than the defect size. The pedicle was kept long enough to prevent tension or kinking during the transfer of the flap. A pneumatic tourniquet was placed around the thigh to prevent excess bleeding. The skin was incised close to the midline to ensure the inclusion of the lesser saphenous vein in the pedicle. Thereafter, the skin flap was elevated with the deep fascia. During the operation, the flap viability was confirmed by deflating the tourniquet. After the assessment of flap viability, the flap was re-approximated at the donor site. Ten to 14 days later, the second operation was performed. The flap was elevated again and transposed into the defect. The donor site was covered with a split thickness skin graft or closed directly.

RESULTS

Seven delayed reverse sural flaps were raised with dimensions ranging from 7.5×2.0 to 14.5×4.0 cm. Of the seven flap donor sites, six were repaired with a split thickness skin graft and one was repaired through primary closure. Seven patients had comorbidities (Table 1); however, all flaps survived completely.

One patient (case 2) with diabetes mellitus and peripheral arterial disease developed partial flap necrosis due to venous congestion, which was managed with debridement and secondary healing because the patient refused additional skin grafting.

No complications were seen in the other patients.

1. Case 1

A 32-year-old man was referred to our department because of a soft tissue defect in the posterior region of the ankle. He had been injured while playing a sport, and the Achilles tendon of the right ankle was ruptured. He was treated with repetitive tenorrhaphy in the orthopedic surgery department. However, the wound dehiscence caused by infection progressed, resulting in a 10.0×3.0 cm defect. The defect with Achilles tendon exposure was covered by using a delayed reverse sural artery flap, and
the donor site was repaired with a split thickness skin graft. No complications occurred at the donor and recipient sites (Fig. 1).

2. Case 2

A 57-year-old man with diabetes mellitus and peripheral arterial disease presented with a 5.5×3.5 cm soft tissue defect in the left heel due to a pressure sore. Debridement was performed, and the defect was covered with a delayed reverse sural artery flap. The donor site was repaired with skin grafting. However, venous congestion of the flap occurred, which was reduced by using leech therapy. Nevertheless, partial flap necrosis due to venous congestion developed. Because the patient refused additional skin grafting, the defect was managed with debridement and secondary healing. Eventually, the flap survived (Fig. 2).

3. Case 3

A 23-year-old man developed a 3.0×2.0 cm soft tissue defect of the left lateral malleolar region caused by infection. After debridement and conservative management, the defect was covered with a delayed reverse sural artery flap and the donor site was repaired through primary closure. No complications were seen in this patient (Fig. 3).

DISCUSSION

Several techniques of covering soft tissue defects of the distal lower extremity are available1-6.

Skin grafts cannot be used to cover exposed tendon and bones, and internal fixation devices. Local flaps are widely used because of their simple surgical method; however, they have the drawbacks of limited flap size and mobilization.

Among the pedicle flaps, cross-leg flaps have been used successfully in adults. However, these have the disadvantages of causing discomfort in an immobile position, and prolonged periods of hospitalization. On the other hand, lateral supramalleolar flaps and posterior tibial artery perforator flaps are considered to be options for the reconstruction of the distal lower extremity; however, these options are limited by their requirement for surgical skill in dissection and steep learning curve14-16.

Currently, free flaps are the best method for large soft tissue defects of the distal lower extremity; however, free

Fig. 2. A case of heel defect. (A) Defect with exposure of the calcaneus. (B) Intraoperative photograph; the lesser saphenous vein (black arrow) and the sural nerve (white arrow) were identified in the pedicle. (C) Appearance immediately after 2nd stage of operation. (D) Appearance at 2 days after 2nd stage of operation. Venous congestion was seen. (E) Appearance at 15 months postoperatively.
flaps are always not the first choice because of their disadvantages, including their long operative time, need for a microsurgical technique and specialized instruments, donor site morbidity, and recipient vessel damage. Furthermore, in patients with multiple morbidities, free flaps are often not used owing to the high perioperative risks.

Another option for defect coverage of these areas is the distally based sural flap. This flap was first described in 1983 by Donski and Fogdestam, as a fasciocutaneous flap of the distal pedicle based on the perforators of the peroneal artery. In 1984, Angelats and Albert first introduced the idea of a delayed sural flap by presenting the case of a proximally based cross-foot delayed sural flap. In 1992, Masquelet et al. first described the concept of distally based neurocutaneous flap, which was a skin island flap supplied by the vascular axis of the superficial nerve, and presented one case of a distally based sural artery and nerve flap.

Since then, several authors have reported their anatomical studies and modifications of the sural flap to overcome complications. In 2003, Baumeister et al. announced that the reverse sural flap is associated with a higher rate of necrosis in high-risk, critically-ill patients with multiple comorbidities, as well as in older patients. As a result, a sural flap “delay” procedure was proposed by the authors to reduce flap failure. Two different delay procedures have been published. In the method of Erdmann et al., the flap is first raised, leaving about 50% of the proximal edge of the skin island intact. Then, a powder-free glove is located between the elevated fascia and the underlying gastrocnemius muscle, and the incised skin edges are closed. Two weeks later, the flap is reelevated without the remaining skin bridge and rotated into the defect site. By contrast, in the technique of Kneser et al., the flap is elevated completely without the residual skin bridge and then reapprorximated at the donor site. Seven to 15 days later, the flap is elevated again and transposed into the defect site. In 2005, three authors proposed a distally-based sural flap delay procedure. Among them, Erdmann et al. described a sural flap delay procedure to avoid flap necrosis in high-risk patients. These studies suggested that the delay procedure improves flap viability, especially in patients with significant medical comorbidities.

These techniques are not always satisfactory. However, of the flap options listed above, the distally based reverse sural flap was preferred in our seven cases because of its many advantages over other surgical options. The major advantages are the easy and quick dissection, preservation of the major arteries of the leg, reliable arterial supply, wide arc of flap rotation, avoidance of microvascular anastomosis, minimal donor site morbidity, and absence of functional problems in motion of the recipient site. However, despite these advantages, the rate of complications such as venous congestion, partial flap necrosis, and complete flap necrosis were higher in patients with...
significant medical comorbidities than in those with no comorbidities. Baumeister et al.\(^\text{10}\) found that patients with comorbidities such as diabetes mellitus, peripheral arterial disease, and venous insufficiency had a five-fold to six-fold higher risk of flap necrosis than patients with no comorbidities. They recommended delay procedures as a way to improve flap stability in patients with vascular risk factors. Moreover, Parrett et al.\(^\text{9}\) found that patients with a history of smoking, diabetes mellitus, and peripheral arterial disease had a significantly higher rate of complications than patients with no comorbidities. They found that the rate of ischemic flap complications was significantly lower in high-risk patients with a delay procedure than in high-risk patients with no delay procedure. Especially, the authors announced that smoking was the risk factor most independently associated with sural flap complications regardless of age\(^\text{9}\). In 1991, Goldminz and Bennnett\(^\text{19}\) studied over 900 flaps and grafts. The authors found that both chronic and new smokers had reduced cutaneous blood flow due to vasoconstriction after exposure to cigarette smoke. Nicotine stimulates catecholamine release in the adrenal medulla and sympathetic ganglia, leading to direct vasoconstriction, ultimately increasing peripheral vasoconstriction and tissue hypoxia. Smoking-induced hypoxia is enhanced by the actions of both nicotine and carbon monoxide. The hypoxic condition damages the normal wound healing process and results in an increased risk of infection and wound dehiscence\(^\text{20}\).

Because our patients had significant medical comorbidities, we added a delay procedure to improve flap viability. As a result, except for case 2, all flaps survived without complications. Unfortunately, in case 2, partial necrosis developed owing to venous congestion, but eventually the flap survived. Venous congestion in a reverse sural flap may exacerbate the ischemic condition of the distal flap, and will result in partial flap necrosis\(^\text{21}\). Therefore, prevention of venous congestion is especially important to avoid complications. Various technical modifications have been proposed to prevent venous congestion. First, a teardrop design allowed both macrovenous and microvenous return to facilitate venous drainage\(^\text{22}\). Second, inclusion of the lesser saphenous vein within the flap will enhance both venous drainage and arterial supply\(^\text{23}\). Third, limb elevation is important. Fourth, skin grafting helps to reduce compression of the flap pedicle\(^\text{24}\). Additionally, leech therapy can also be used to decrease venous congestion\(^\text{25}\).

On the other hand, the disadvantages of the delayed reverse sural flap are postoperative scarring of the donor site and the sacrifice of the sural nerve. Fortunately, the hypoesthesia of the lateral foot due to the sacrifice of the sural nerve gradually recovered in all cases. However, the postoperative scar of the posterior calf may be a concern for young female patients, and this necessitates further improvement.

**CONCLUSION**

Because the delay procedure improves flap viability, the delayed reverse sural flap has shown good results in patients with significant medical comorbidities. Therefore, we conclude that the delayed reverse sural flap may be a reliable and efficient alternative in reconstructing soft tissue defects of the distal lower extremity in high-risk patients.

**CONFLICTS OF INTEREST**

The authors have nothing to disclose.

**REFERENCES**

2002;48:496-504.


고위험군 환자에서 하지 원위부 재건 시 지연성 역류 비복피판의 범용성

박준규·김경식·김승홍·최 준·양정열
명지병원 성형외과

목적: 하지 원위부의 연부조직 결손은 재건하는 외과의에게 결손 부위를 재건하는 데 있어 특별한 도전 과제이다. 하지 재건에 대해서는 국소피판술, 원위피판술, 유리피판술 등 다양한 방법들이 기술되고 있다. 이러한 여러 가지 방법들 중에서 지연성 역류 비복피판은 고위험군 환자들의 하지 원위부 재건에 있어 몇 가지 선택지 중 하나가 될 수 있다. 우리는 고위험군 환자들에게 지연성 역류 비복피판을 이용한 하지 원위부 재건의 범용성에 대한 경험을 보고하고자 한다.

방법: 2015년 9월부터 2016년 10월까지 하지 원위부의 연부조직 결손이 있는 7명의 환자를 대상으로 지연성 역류 비복피판을 2단계로 진행하여 재건하였다. 모든 환자는 당뇨, 말초 동맥 질환, 흡연과 같은 심각한 의학적 동반 이환이 있었다. 10일에서 14일 동안 지연 처치를 하였으며, 피판의 크기는 7.5×2.0 cm에서 14.5×4.0 cm였다.

결과: 6예에서 피판이 합병증 없이 생존하였다. 1예에서는 피판이 정맥 울혈로 인한 부분적인 괴사가 있었으나 결국에는 치유되었다.

결론: 지연 처치는 피판의 생존력을 향상시키기 때문에 지연성 역류 비복피판은 아마도 고위험군 환자들의 하지 원위부 연부조직 결손에 대한 재건 방법으로 신뢰할 수 있고 효과적인 대안으로 보여진다.

색인단어: 비복, 하지, 위험