Early Mobilization after Free-flap Transfer to the Lower Extremities: Preferential Use of Flow-through Anastomosis

Shimpei Miyamoto, MD*
Shuji Kayano, MD*
Masahide Fujiki, MD†
Hirokazu Chuman, MD‡
Akira Kawai, MD‡
Minoru Sakuraba, MD†

Background: Prolonged bed rest and elevation have traditionally been considered necessary after free-flap transfer to the lower extremities. In this retrospective study, we tried to mobilize patients early after free-flap transfer to the lower extremity by means of flow-through anastomosis for both arteries and veins.

Methods: This study included 13 consecutive patients who underwent immediate free-flap transfer after wide resection of soft-tissue tumors of the lower extremity from March 2012 through July 2013. The defects were above the knee in 5 patients and below the knee in 8 patients. In all patients, flow-through anastomosis was used for both arteries and veins. The patients were mobilized starting on the first postoperative day, and their activities of daily life were gradually expanded, depending on the wound conditions. Postoperative complications and the progression of their activities of daily life were investigated retrospectively.

Results: No anastomotic failure or take back occurred. Partial flap necrosis occurred in 1 patient because of a poor perforator but was unrelated to early mobilization. All patients could move to wheelchairs on the first postoperative day. Within 1 week, 12 of 13 patients could start dangling and 10 of 13 patients could start ambulating.

Conclusions: This study demonstrates that early mobilization after free-flap transfer to the lower extremity is made possible by flow-through anastomosis for both arteries and veins. Flow-through flaps have stable circulation from the acute phase and can tolerate early dangling and ambulation. (Plast Reconstr Surg Glob Open 2014;2:e127; doi: 10.1097/GOX.0000000000000080; Published online 27 March 2014.)
lation of lower-extremity free flaps is unstable in the acute phase and is greatly affected by limb position.6 To enable early mobilization, the standard methods of anastomosis might need to be abandoned in favor of a new approach, such as flow-through anastomosis, that can stabilize the circulation of flaps in the acute phase.7 Therefore, in this study, we attempted to mobilize patients early after free-flap transfer, with flow-through anastomosis for both arteries and veins, to the lower extremity to repair oncologic defects.

MATERIALS AND METHODS

The subjects were 13 consecutive patients who underwent immediate free-flap transfer after wide resection of soft-tissue tumors of the lower extremity from March 2012 through July 2013 at the National Cancer Center Hospital, Tokyo, Japan. The patients were 8 women and 5 men with a mean age of 56.6 years (range, 19–89 years). Patients who underwent bony reconstruction were not included in this study. In all patients, flow-through anastomosis was used for both arteries and veins (Fig. 1).

The patients were mobilized starting on the first postoperative day. All patients were moved to wheelchairs, and the elderly patients were encouraged to ambulate. Thereafter, their activities of daily life were gradually expanded, depending on the wound conditions. Suction drains of the recipient site were kept until the volume of discharge per day becomes less than 20 ml. No patient received anticoagulation therapy.

The medical records of the 13 patients were analyzed for the following variables: defect location, surgical invasion of the joint, flap type, recipient vessels, postoperative complications, duration of drain placement, and progress of postoperative activities of daily life.

RESULTS

Detailed information about each patient is summarized in Table 1. The defects were above the knee in 5 patients and below the knee in 8 patients. Tumor resection extended into the knee joint in 1 patient and into the ankle joint in 4 patients.

The flap used was a latissimus dorsi musculocutaneous flap in 7 patients, an anterolateral thigh flap in 5 patients, and a thoracodorsal artery perforator flap in 1 patient. Accessory skin grafts were necessary at the recipient site in 4 patients, and the donor site was closed primarily in all patients. In patients with an above-the-knee defect, the recipient vessels were nonmajor arteries. In the patients with a below-the-knee defect, the recipient vessels were the posterior tibial vessels in 4 patients, the anterior tibial vessels in 2 patients, and the dorsalis pedis vessels in 2 patients. To prepare the T segment for flow-through anastomosis, the subscapular and circumflex scapular vessels were used in 4 latissimus dorsi flaps, and the thoracodorsal and the serratus branch vessels were used in 3 latissimus dorsi flaps and a thoracodorsal artery perforator flap. In all anterolateral thigh flaps, the proximal and distal stumps of the descending branch of the lateral circumflex femoral vessels were used. In 1 anterolateral thigh flap (case 5), a second venous anastomosis was added with end-to-end anastomosis because 2 comitant veins were present.

Postoperatively, no anastomotic failure or take back occurred. Partial necrosis of the anterolateral thigh flap (case 11) occurred because of a problem with the perfusion territory of the perforator but was unrelated to early mobilization. To treat this necrosis, debridement and an additional skin graft were performed on the 54th postoperative day.

Disclosure: The authors have no financial interest to declare in relation to the content of this article. The Article Processing Charge was paid for by the authors.
Miyamoto et al. • Mobilization after Lower-extremity Free Flaps

Patient 2 fell while walking on the eighth postoperative day but was not injured. All skin grafts took completely. The median duration of drain placement at the recipient site was 7 days (range, 5–29 days). No patients had delirium or symptomatic deep venous thrombosis.

All patients were able to move to wheelchairs on the first postoperative day. The timing of dangling and ambulation varied depending on the use of skin grafts and on the surgical invasion of the joints; however, within 1 week, 12 of 13 patients could start dangling and 10 of 13 patients could start ambulating. Two patients in their 80s were able to ambulate with a walking frame on the first postoperative day.

CASE REPORT (CASE 10)

An 89-year-old woman presented with a myxofibrosarcoma of the right leg. She walked with a cane preoperatively. Wide resection of the tumor resulted in a 19 × 13.5-cm skin defect. To reconstruct this defect, a latissimus dorsi musculocutaneous flap with a 24 × 11-cm skin island was harvested. The flap was transferred to the defect by interposing the T segments of the subscapular and circumflex scapular vessels to the transected anterior tibial vessels. The donor site was closed primarily.

The postoperative course was uneventful. The patient could ambulate with a walking frame from the first postoperative day. (See Video 1, Supplemental Digital Content 1, which shows the patient ambulating on the second postoperative day, http://links.lww.com/PRSGO/A25.) The flap survived completely, and the wounds healed without complication. She could walk with a cane when discharged from the hospital on the 23rd postoperative day (Fig. 2).
DISCUSSION

This study suggests that early mobilization of patients after free-flap transfer to the lower extremity is possible without increased risk of anastomotic failure or wound complications. Flaps with flow-through anastomosis have stable circulation in the acute phase and can tolerate early mobilization.

The major obstacle to early mobilization is flap congestion. After dangling, congestion develops easily in free flaps transferred with traditional methods. This congestion, if not treated, can result in flap loss. Not only does venostasis increase the risk of venous thrombosis, but arterial inflow also decreases in response to the elevated venous pressure, and the risk of arterial thrombosis increases. Cutaneous, subcutaneous, and muscular vascular resistances increase within a limb when venous pressure is greater than 25 mm Hg and decrease blood flow by up to 40%. This response to elevated venous pressure is termed the venoarteriolar response. The venoarteriolar response mechanism reportedly continues within tissues even after free-flap transfer. Ridgway et al have demonstrated that after dangling for 5 minutes on the seventh postoperative day, tissue oxygenation in a lower-extremity free flap decreases significantly and does not return to the baseline value for as long as 44 minutes. These findings support the common perception of many surgeons, who, therefore, start postoperative mobilization between 1 and 3 weeks after the transfer of free flaps to the lower extremity.

We hypothesized that this intolerance of free flaps of early mobilization can be attributed to the type of microvascular anastomosis. Although the choice of microvascular anastomosis for lower-extremity free flaps is controversial, end-to-end anastomosis remains the standard method for both arteries and veins. With end-to-end anastomosis on both the artery and vein, the flap becomes an end organ, and its...
circulation is a closed circuit. When the limb is dangled, the only forces driving venous return are the thoracic negative pressure by the respiratory pump and the inherent venous pressure of the flap. Because these driving forces are usually weaker than gravity, venostasis is inevitable after dangling; furthermore, flap congestion continues to worsen because arterial inflow continues without diversion. The affected limb must, therefore, be elevated to obtain sufficient venous return. (See Video 2, Supplemental Digital Content 2, which demonstrates our hypothesis about the circulation of the flap transferred with end-to-end anastomosis, http://links.lww.com/PRSGO/A26.)

On the other hand, with flow-through anastomosis, the flap circulation is an open circuit. Even if dangling causes venostasis, flap congestion is prevented because arterial inflow is diverted to the distal recipient artery. This advantage of open-circuit circulation has been demonstrated by Siemionow et al11 in a cremaster muscle flap model in rats. As for venous return, the effect of the distal pumps, such as the calf muscle pump or the sole pump, is preserved,12,13 and blood is continuously washed out against gravity from around the venous anastomotic sites. (See Video 3, Supplemental Digital Content 3, which demonstrates our hypothesis about the circulation of the flap transferred with flow-through anastomosis, http://links.lww.com/PRSGO/A27.) We speculate that these mechanisms help stabilize the circulation of flow-through flaps and make early mobilization possible.

Recently, flow-through arterial anastomosis has been increasingly used in extremity reconstruction but mostly to preserve recipient-artery continuity.14–17 In contrast, we used flow-through arterial anastomosis in this study to improve the patency rate and to stabilize the circulation of the flap, even when reconstructing recipient-artery continuity was unnecessary. We have previously demonstrated that flow-through arterial anastomosis has a higher patency rate than end-to-end and end-to-side anastomoses and increases the flow rate through the anastomotic site.7 In healthy humans, lowering a limb below heart level profoundly decreases limb blood flow through the postural vasoconstrictor response.18 We believe that flow-through arterial anastomosis helps maintain a high flow rate through the anastomotic site, even during dangling or ambulation, and facilitates early mobilization.

The use of flow-through venous anastomosis is not a new idea for lower-extremity free-flap transfer but is rarely reported.19,20 The present report is, to our knowledge, the first describing the physiological advantage of flow-through venous anastomosis. The venous pressure of the lower extremity is strongly influenced by body posture. The venous pressure at the ankle level is as high as 80–90 mm Hg in the motionless standing position but decreases to 25–30 mm Hg after only 10–25 m of ambulation.12,21,22 In addition, active movement of the foot is more effective than...
passive movement for promoting venous return, and this improvement in venous hemodynamics is maintained for up to 30 minutes after exercise stops.21,23 These findings mean that the drainage capacity of the recipient veins improves more with weight-bearing ambulation than with non-weight-bearing dangling. We, therefore, do not use orthostatic “flap training” before ambulation but encourage patients to immediately ambulate if the wound conditions allow. The use of flow-through venous anastomosis maximizes these beneficial hemodynamic effects and enables early weight-bearing ambulation.

The argument can be made that end-to-side anastomosis works as well as flow-through anastomosis because both have similar patterns of flap circulation. In fact, we previously preferred end-to-side arterial anastomosis in extremity reconstruction, in accordance with the suggestion by Godina24; however, we no longer perform end-to-side arterial anastomosis because our animal studies showed it has a lower patency rate than flow-through arterial anastomosis.7 As for early dangling, end-to-side anastomosis can divert arterial inflow to the distal recipient artery, as can flow-through anastomosis; however, the flow rate through the anastomotic site will decrease after dangling because it is only the flow required by the flap. (See Video 4, Supplemental Digital Content 4, which demonstrates our hypothesis about the circulation of a flap transferred with end-to-side anastomosis, http://links.lww.com/PRSGO/A28.) We, therefore, believe that end-to-side arterial anastomosis cannot be a substitute for flow-through arterial anastomosis if early dangling is attempted.

On the other hand, we speculate that end-to-side venous anastomosis is equivalent to flow-through venous anastomosis because the former also preserves the effects of distal pumps. The superiority of end-to-side venous anastomosis over end-to-end venous anastomosis has been demonstrated by several authors.10,25,26 We preferred flow-through venous anastomosis in this study only because end-to-side anastomosis is more technically demanding than flow-through anastomosis and precludes the use of a venous coupler.

To the best of our knowledge, only 1 previous report has described early dangling after the transfer of lower-extremity free flaps. Jokuszies et al27 have reported that the early and aggressive start of dangling on the third postoperative day does not compromise flap survival. Unlike us, however, they did not use flow-through anastomosis in any patient. Instead, they used end-to-end anastomosis or end-to-side anastomosis for arteries and end-to-end anastomosis for veins. In addition, they used a combined dangling/wrapping procedure and did not allow patients to ambulate in the first few days after surgery. The beneficial effects of wrapping for lower-extremity free flaps have been well described. Wrapping lessens the degree of decrease in tissue oxygenation of the flap during dependency and lessens the duration of this decrease after the lower extremity is elevated again.8 However, unlike Jokuszies et al,27 we do not wrap the flap until the seventh postoperative day owing to concerns about the effects of compression on the vascular pedicle. We believe that wrapping is not needed in the acute phase for the flaps with flow-through anastomosis because of its aforementioned hemodynamic advantages; therefore, we start wrapping from the second postoperative week, mainly to prevent edema of the limb and the flap.

The major limitations of this study were that it was retrospective and had a limited sample size. It lacked comparison with control group with conventional anastomosis. Because the wound condition or reconstructive method or both differed among patients, we could not establish a standard mobilization program. In addition, some patients could not ambulate immediately after surgery because they received skin grafts or their wounds extended to the joint or the sole. To optimize wound healing for these patients, we delayed the mobilization program slightly. Strict bed rest is unnecessary for these patients; however, the timing of dangling or ambulation should be determined for each patient on the basis of the wound conditions.

Another limitation of this study was that it included only patients after tumor resection but no trauma patients. We have only limited experience using our
method for traumatic reconstruction. Further study is needed to clarify whether early mobilization is possible for trauma patients.

The final limitation was that this study did not involve objective data. In this study, we judged the extent of flap congestion with only clinical observation because we do not have an instrument for measuring flap circulation. Further study with objective and quantitative measurement is necessary to determine whether flow-through anastomosis is superior to conventional techniques.

CONCLUSIONS

Early mobilization after free-flap transfer to the lower extremity is made possible by flow-through anastomosis for both arteries and veins. Flow-through flaps have stable circulation from the acute phase and can tolerate early dangling and ambulation.

Shimpei Miyamoto, MD
Division of Plastic and Reconstructive Surgery
National Cancer Center Hospital
Tokyo 104-0045 Japan
E-mail: shimiyam@ncc.go.jp; s-miya@hh.ii.nd.or.jp

ACKNOWLEDGMENT

We thank Dr. Yutaka Fukunaga for preparation of Figure 1.

REFERENCES
1. Chao AH, Chang DW, Shuaib SW, et al. The effect of neoadjuvant versus adjuvant irradiation on microvascular free flap reconstruction in sarcoma patients. Plast Reconstr Surg 2012;129:675–682.
2. Valerio I, Sabino J, Heckert R, et al. Known preoperative deep venous thrombosis and/or pulmonary embolus: to flap or not to flap the severely injured extremity? Plast Reconstr Surg 2013;132:213–220.
3. Rohde C, Howell BW, Buncke GM, et al. A recommended protocol for the immediate postoperative care of lower extremity free-flap reconstructions. J Reconstr Microsurg. 2009;25:15–19.
4. Xipoleas G, Levine E, Silver L, et al. Survey of microvascular protocols for lower extremity free tissue transfer II: postoperative care. Ann Plast Surg 2008;61:280–284.
5. Allen C, Glassiou P, Del Mar C. Bed rest: a potentially harmful treatment needing more careful evaluation. Lancet 1999;354:1229–1233.
6. Sakurai H, Yamaki T, Takeuchi M, et al. Hemodynamic alterations in the transferred tissue to lower extremities. Microsurgery 2009;29:101–106.
7. Miyamoto S, Okazaki M, Ohura N, et al. Comparative study of different combinations of microvascular anastomoses in a rat model: end-to-end, end-to-side, and flow-through anastomosis. Plast Reconstr Surg. 2008;122:449–455.
8. Ridgway EB, Kutz RH, Cooper JS, et al. New insight into an old paradigm: wrapping and dangling with lower-extremity free flaps. J Reconstr Microsurg. 2010;26:559–566.
9. Okazaki K, Fu Q, Martini ER, et al. Vasoconstriction during venous congestion: effects of venoarteriolar response, myogenic reflexes, and hemodynamics of changing perfusion pressure. Am J Physiol Regul Integr Comp Physiol. 2005;289:R1354–R1359.
10. Miyamoto S, Takushima A, Okazaki M, et al. Comparative study of different combinations of microvascular anastomosis types in a rat vasospasm model: versatility of end-to-side venous anastomosis in free tissue transfer for extremity reconstruction. J Trauma 2009;66:831–834.
11. Siemionow M, Andreassen T, Lister G. Hemodynamic variations between end-to-side and end-organ flap systems. J Hand Surg Am. 1995;20:205–212.
12. Kögler C, Strunk M, Rudofsky G. Venous pressure dynamics of the healthy human leg. Role of muscle activity, joint mobility and anthropometric factors. J Vasc Res. 2001;38:20–29.
13. White JV, Katz ML, Cicé P, et al. Venous outflow of the leg: anatomy and physiologic mechanism of the planter venous plexus. J Vasc Surg. 1996;24:819–824.
14. Devansh S. Lateral thigh free flap with flow-through vascular pedicle. Ann Plast Surg 2011;67:44–48.
15. Miyamoto S, Kayano S, Fujiiki M, et al. Flow-through divided latissimus dorsi musculocutaneous flap for large lower extremity defects. Ann Plast Surg 2013. Epub Aug 2; 2013.
16. Miyamoto S, Kayano S, Umezawa H, et al. Flow-through fibula flap using soleus branch as distal runoff: a case report. Microsurgery 2013;33:60–62.
17. Yokota K, Sunagawa T, Suzuki O, et al. Short interposed pedicle of flow-through anterolateral thigh flap for reliable reconstruction of damaged upper extremity. J Reconstr Microsurg. 2011;27:109–114.
18. Hassan AA, Tookie JE. Mechanism of the postural vasoconstrictor response in the human foot. Clin Sci (Lond). 1988;75:379–387.
19. Koshima I, Kawada S, Etoh H, et al. Flow-through anterior thigh flaps for one-stage reconstruction of soft-tissue defects and revascularization of ischemic extremities. Plast Reconstr Surg. 1995;95:252–260.
20. Koshima I, Saisho H, Kawada S, et al. Flow-through thin latissimus dorsi perforator flap for repair of soft-tissue defects in the legs. Plast Reconstr Surg. 1999;103:1483–1490.
21. McNally MA, Cooke EA, Mollan RA. The effect of active movements of the foot on venous blood flow after total hip replacement. J Bone Joint Surg Am. 1997;79:1198–1204.
22. Recek C. Venous pressure gradients in the lower extremity and the hemodynamic consequences. Vasa 2010;39:292–297.
23. Sochart DH, Harding K. The relationship of foot and ankle movements to venous return in the lower limb. J Bone Joint Surg Br. 1999;81:700–704.
24. Godina M. Preferential use of end-to-side arterial anastomoses in free flap transfers. Plast Reconstr Surg. 1979;64:673–682.
25. Halvorson EG, Cordeiro PG. Go for the jugular: a 10-year experience with end-to-side arterial anastomosis to the internal jugular vein in 320 head and neck free flaps. Ann Plast Surg. 2007;59:31–35.
26. Miyamoto S, Kayano S, Kurosawa K, et al. Large-to-small end-to-side anastomosis to the internal mammary vein: a solution to vessel size discrepancy. Microsurgery 2013;33:329–330.
27. Jokuszies A, Neubert N, Herold C, et al. Early start of the dangling procedure in lower extremity free flap reconstruction does not affect the clinical outcome. J Reconstr Microsurg. 2013;29:27–32.
7