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

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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.)*

Free flaps are often transferred to the lower extremities after major trauma or extensive resection for tumors.[1,2] To ensure the survival of these flaps, prolonged bed rest and elevation have traditionally been considered necessary.[3,4] However, prolonged bed rest has several harmful effects, such as delirium, venous thromboembolism, pneumonia, prolonged hospital stays, and increased healthcare costs. Because of these harmful effects, early postoperative mobilization has been advocated in several fields of surgery.[5] We wondered whether early mobilization is possible after free-flap transfer to the lower extremities.

With standard methods of anastomosis, such as end-to-end and end-to-side anastomoses, the circu-

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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

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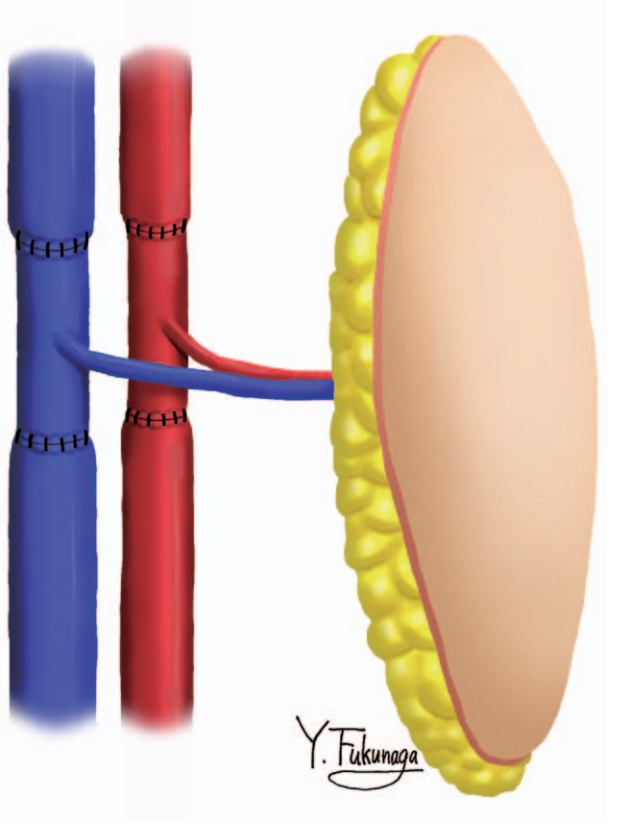


Fig. 1. Diagram demonstrating flow-through anastomosis for both arteries and veins.

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.

Table 1. Summary of Patients

Patient	Age (Y), Sex	Defect Location	Surgical Invasion of Joint	Flap	Recipient Vessels	Complication	Duration of Drain Placement (D)	Activities of Daily Life (Postoperative Day)		
								Wheelchair	Dangling	Ambulation
1	20 female	Thigh	No	LD	Branch of LCF	—	6	1	6	6
2	85 male	Thigh	No	LD	Perforating vessels of deep femoral	Falling	18	1	1	1
3	29 male	Thigh-knee	No	LD (+SG)	Branch of LCF	—	7	1	7	7
4	75 female	Thigh	No	LD	Medial circumflex artery, great saphenous vein	—	29	1	5	5
5	67 male	Thigh-knee	Yes	ALT	Vastus medialis muscle branch of superficial femoral	—	11	1	1	7
6	53 female	Ankle	Yes	ALT	Posterior tibial	—	6	1	5	11
7	60 female	Sole	No	LD (+SG)	Posterior tibial	—	6	1	9	10
8	19 female	Sole	No	LD (+SG)	Posterior tibial	—	7	1	6	6
9	62 male	Dorsal foot	Yes	ALT	Dorsalis pedis	—	8	1	5	8
10	89 female	Leg	No	LD	Anterior tibial	—	8	1	1	1
11	56 female	Ankle	Yes	ALT (+SG)	Posterior tibial	Partial necrosis	5	1	1	6
12	64 female	Dorsal foot	Yes	TAP	Dorsalis pedis	—	5	1	3	4
13	31 male	Leg	No	ALT	Anterior tibial	—	9	1	1	1

ALT, anterolateral thigh flap; LCF, lateral circumflex femoral vessels; LD, latissimus dorsi musculocutaneous flap; SG, skin graft; TAP, thoracodorsal artery perforator flap.

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).

Video Graphic 1. See Video 1, Supplemental Digital Content 1, which demonstrates the appearance of the patient (case 10) during ambulation on the second postoperative day, ***http://links.lww.com/PRSGO/A25.***

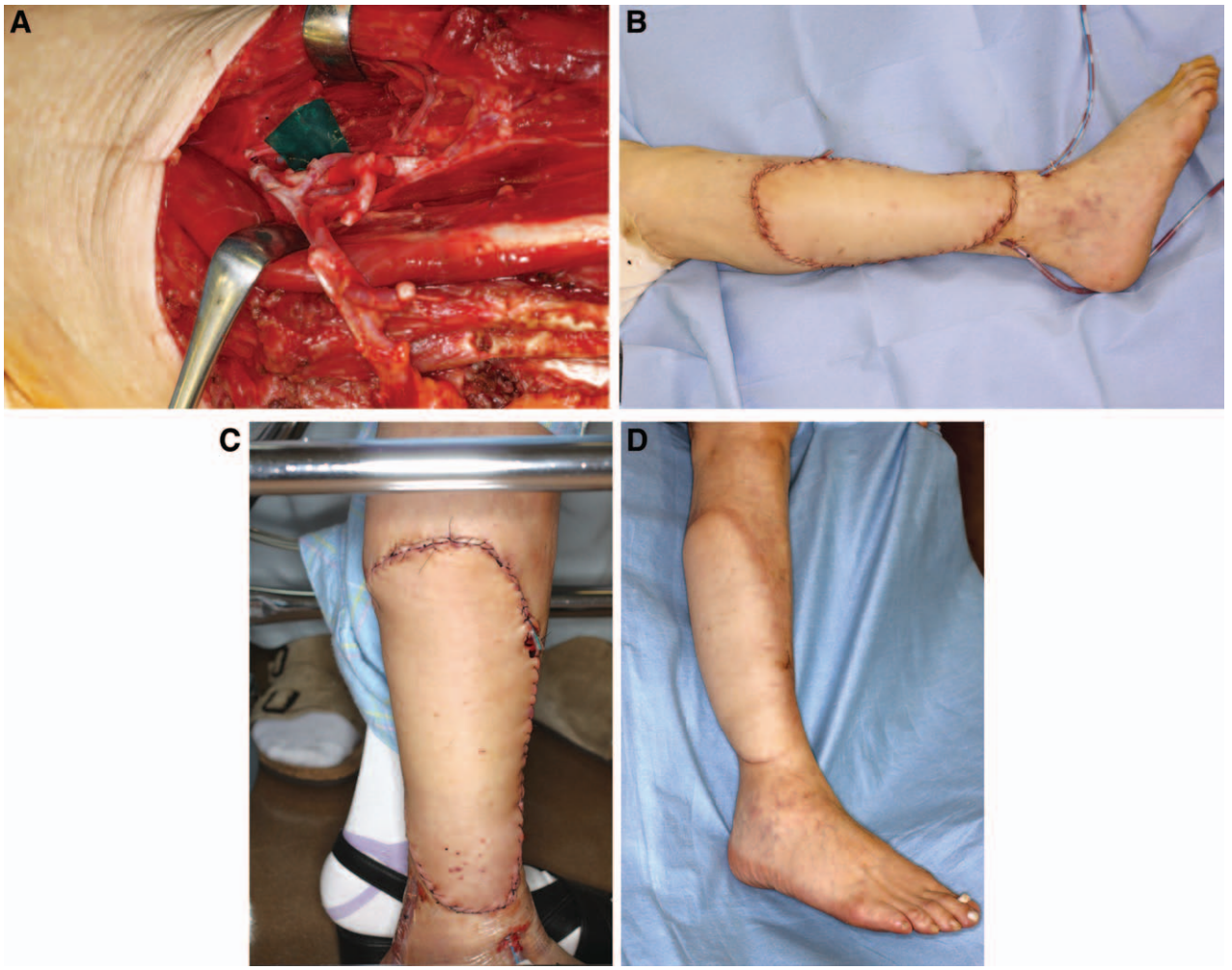


Fig. 2. Case 10. A, Intraoperative appearance of the anastomotic sites. B, Appearance immediately after flap transfer. C, Appearance of the flap after ambulation for 5 minutes on the second postoperative day. There was no sign of congestion. D, Eighth-month follow-up view of the leg.

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.[3] 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%.[8,9] This response to elevated venous pressure is termed the venoarteriolar response. The venoarteriolar response mechanism reportedly continues within tissues even after free-flap transfer.[6,8,9] Ridgway et al[8] 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.[3]

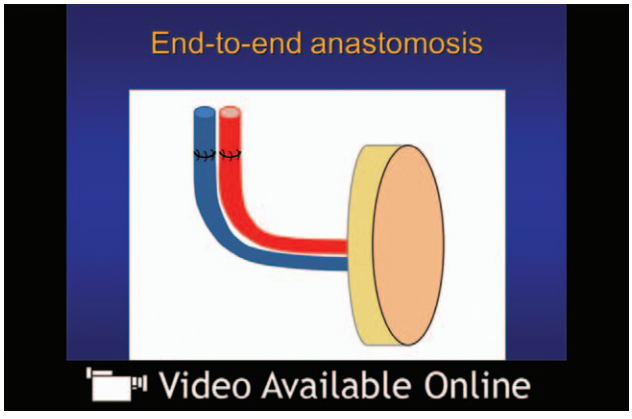
We hypothesized that this intolerance of free flaps of early mobilization can be attributed to the type of microvascular anastomosis. Although the choice of microvascular anastomosis for lower-extremity free flaps is controversial, end-to-end anastomosis remains the standard method for both arteries and veins.[10] 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***.)

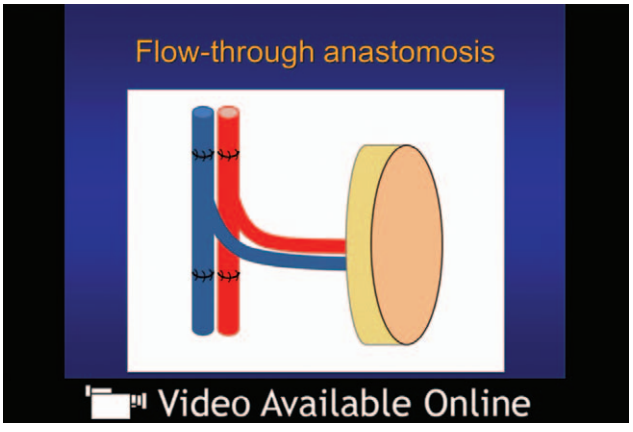
On the other hand, with flow-through anastomosis, the flap circulation is an open circuit. Even if dangling causes venostasis, flap congestion is prevented because arterial inflow is diverted to the distal recipient artery. This advantage of open-circuit circulation has been demonstrated by Siemionow et al[11] 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



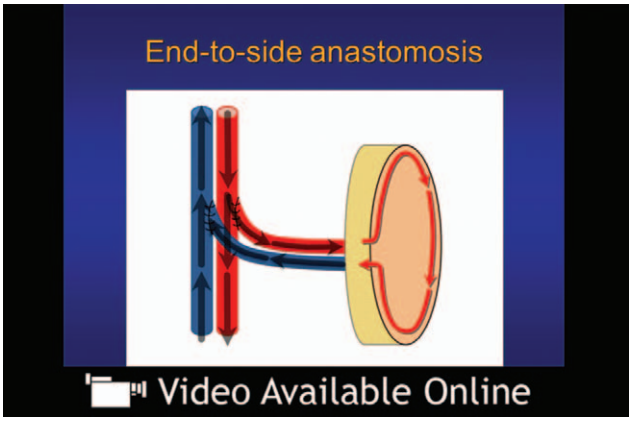
Video Graphic 2. See Video 2, Supplemental Digital Content 2, which demonstrates our hypothesis about the circulation of the flap transferred with end-to-end anastomosis. With end-to-end anastomosis, the flap circulation is a closed circuit. When the limb is dangled, the forces driving venous return are only the thoracic negative pressure by the respiratory pump and the inherent venous pressure of the flap. Because gravity is stronger than these driving forces, venostasis is inevitable after dangling; furthermore, arterial inflow to the flap continues and flap congestion continues to worsen. The affected limb must, therefore, be elevated to obtain sufficient venous return, ***http://links.lww.com/PRSGO/A26***.



Video Graphic 3. See Video 3, Supplemental Digital Content 3, which demonstrates our hypothesis about the circulation of the flap transferred with flow-through anastomosis. With flow-through anastomosis, the flap circulation is an open circuit. Even if venostasis occurs after dangling, the flow into the flap will be diverted to the distal recipient artery and the progress of the flap congestion can be prevented. As for venous return, the effect of the distal pumps is preserved and continuously washes out the blood around the venous anastomotic sites against gravity, ***http://links.lww.com/PRSGO/A27***.

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 Godina[24]; 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.



Video Graphic 4. See Video 4, Supplemental Digital Content 4, which demonstrates our hypothesis about the circulation of the flap transferred with end-to-side anastomosis. The flow into the flap will be diverted to the distal recipient artery after dangling like the flap transferred with flow-through anastomosis; however, the flow rate through the anastomotic site will decrease accordingly. As for venous return, the effect of the distal pumps is also preserved, ***http://links.lww.com/PRSGO/A28***.

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 al[27] 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.

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