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One versus Two Venous Anastomoses in Microvascular Free Flap Surgery

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Abstract

Background—The authors' goal was to determine whether one or two venous anastomoses results in superior blood flow through microvascular free flaps.

Methods—During flap harvest, blood velocity was measured in each of two venae comitantes using Doppler ultrasonography. Next, one of the two veins was occluded with a microvascular clamp and blood velocity was measured in the open vein. The clamp was then removed and placed on the other vein, and blood velocity was measured in the first vein. The pedicle was divided and microvascular anastomosis of either one or two veins was performed. Venous blood velocity was then compared between flaps with one versus two venous anastomoses.

Results—Eighty-one free flaps were performed. Before pedicle division, the peak venous blood velocity in each of the two venae comitantes averaged 6.3 ± 4.8 cm/second. When one of the veins was occluded, the peak venous blood velocity increased to 19.5 ± 17.3 cm/second ($p < 0.00001$). One venous anastomosis was performed in 69 flaps and two venous anastomoses were performed in 12 flaps. The mean blood velocity in flaps in which one venous anastomosis was performed was greater than the mean blood velocity in either vein when two venous anastomoses were performed (13.1 ± 7.3 cm/second versus 7.5 ± 4.3 cm/ second, respectively; $p = 0.001$).

Conclusions—When one vena comitans is occluded, blood velocity in the second vena comitans increases significantly. Venous blood velocity is significantly greater after a single venous anastomosis than in either of two veins when two venous anastomoses are performed. These results argue against routinely performing two venous anastomoses.

A subject of debate among microvascular surgeons is whether one or two venous anastomoses should be performed when there are two draining veins. Many authors have reported routinely performing two venous anastomoses, but their rationale for doing so is not clear, particularly when both venous anastomoses are performed to the venae comitantes of the pedicle artery, which usually have multiple interconnections.^{1,2} The goal of the present study was to compare venous blood velocity in free flaps in which one venous anastomosis is performed to free flaps in which two venous anastomoses are performed. Because vascular thrombosis is associated with low blood velocity states, knowing which

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technique results in greater blood velocity should support performing either one or two venous anastomoses in free tissue transfer. As a secondary goal, the arterial and venous blood velocities before pedicle division and after microvascular anastomosis were compared to evaluate how free tissue transfer affects blood flow through free flaps.

PATIENTS AND METHODS

Arterial and venous blood velocities were measured in microvascular free flaps performed by the primary author (M.M.H.) for reconstruction of head and neck and mastectomy defects after cancer resection between 2007 and 2009. Institutional review board approval was obtained before this study was undertaken.

A 20-MHz needle-type Doppler ultrasound probe, built by one of the authors (C.J.H.) in our laboratories, was held at a 45-degree angle to the flap artery or vein to measure blood velocity before flap pedicle division and 20 minutes after micro-vascular anastomosis.³ The needle-type probe was connected to a 20-MHz pulsed Doppler velocimeter, also constructed by one of the authors (C.J.H.). The audio output of the pulsed Doppler probe was connected to the audio input of a laptop computer, which was used to capture and store 10-second audio files (WAV files) for later analysis. In each case, the sound produced by the 20-MHz needle Doppler probe was recorded and analyzed using Spectrogram Version 11 (Visualization Software LLC, www.visualizationsoftware.com), an audio spectrogram software program. The resulting display can be analyzed using established methods as described below.^{4,5}

The arterial and venous peak blood velocities were obtained by averaging three representative spectral peak frequencies from each audio file. Blood velocities were then calculated using the following Doppler equation:

$$v = f \times c / [2 \times F \times \cos(q)],$$

where v is the blood velocity, f is the measured Doppler frequency, c is the acoustic velocity in blood (1.54×10^5 cm/second), q is the angle between the Doppler probe and the blood vessel axis (45 degrees), and F is the transmitted frequency (20 MHz).

During this study, all measurements were performed with the patient supine, under general anesthesia. Topical vasodilators, such as lidocaine or papaverine, were not used in this series. All patients received antihypertensive medication or fluid resuscitation, as appropriate, to keep their blood pressure in the normotensive range (90/60 to 140/90 mmHg) and heart rate between 60 and 100 beats per minute.

To determine how microvascular free tissue transfer affects blood velocity, arterial and venous blood velocities were measured before pedicle division and 20 minutes after free tissue transfer (Fig. 1). In each case, only one arterial anastomosis was performed. Some free flaps underwent microvascular anastomosis of one vena comitans, whereas other free flaps underwent microvascular anastomosis of two venae comitantes. To evaluate the effect of free tissue transfer on venous blood velocity, the peak venous blood velocity measured in the larger vena comitans before pedicle division (while the smaller of the two venae comitantes was temporarily occluded with a microvascular clamp) was compared with the peak venous blood velocity measured from the same vena comitans (the larger of the two) after free tissue transfer and ligation of the smaller of the two venae comitantes. Cases in which two venous anastomoses were performed were excluded from this comparison to simplify interpretation. A comparison of arterial and venous blood velocities in different free flap types was also performed to determine whether the flap type affected blood velocities.

To compare venous blood velocity between free flaps with a single draining pedicle vein and free flaps with two draining pedicle veins, three different experiments were performed:

1. *The effect of temporarily occluding one vena comitans during free flap harvest.* Before pedicle division, the blood velocity was measured in each of the two venae comitantes. Next, one of the two veins was temporarily occluded with a microvascular clamp and blood velocity was measured in the open vein (Fig. 2, *above*). The clamp was then removed and placed on the other vein, and the blood velocity was measured in the first vein (Fig. 2, *below*). A comparison was performed to demonstrate how occlusion of one of the two veins affects venous blood velocity while the flap was still connected to the donor-site blood supply (Fig. 3).
2. *Comparison of free flaps with one venous anastomosis and free flaps with two venous anastomoses.* After the pedicle was divided and the microvascular anastomoses of one artery and either one or two veins were performed, the venous blood velocity was measured (20 minutes after the anastomosis) and a comparison of venous blood velocities between flaps with one venous anastomosis and flaps with two venous anastomoses was performed.
3. *The effect of temporarily occluding one vena comitans after free tissue transfer with two venous anastomoses.* In the subset of cases in which two venous anastomoses were performed, one of the two veins was temporarily occluded with a microvascular clamp and the blood velocity was measured in the open vein, the same as was done before pedicle division with the flap still in situ at the donor site (Fig. 4, *above*). The clamp was then removed and placed on the other vein, and the blood velocity was measured in the first vein (Fig. 4, *below*). A comparison was performed to demonstrate how occlusion of one of the two veins affected venous blood velocity after free tissue transfer and anastomosis of two veins.

Reasons for performing one versus two venous anastomoses varied in this study. In some cases, a single venous anastomosis was performed because a second recipient vein was not available or a vein graft would have been necessary to reach a second recipient vein. Also, when pedicle geometry was such that performing a second anastomosis might kink the pedicle, only one venous anastomosis was performed. When only one venous anastomosis was performed, the larger of the two venae comitantes was always used for the anastomosis.

Statistical Analysis

All values are shown as mean $\pm$ SD. Differences between arterial and venous peak blood velocities were evaluated using the two-tailed *t* test. Differences in arterial and venous peak blood velocities measured between different flap types were evaluated using an analysis of variance test. A value of $p < 0.05$ was considered significant.

RESULTS

Blood velocities were measured in 81 free flaps performed on 77 patients. Free flap types and their vascular pedicle characteristics are summarized in Table 1. One venous anastomosis was performed in 69 free flaps and two venous anastomoses were performed in 12 free flaps. Arterial anastomoses for head and neck reconstructions were performed in end-to-end fashion to a branch of the external carotid artery or the transverse cervical artery. Venous anastomoses for head and neck reconstructions were performed in end-to-side fashion to the internal jugular vein or end-to-end fashion to the facial, external jugular, or transverse cervical veins. Arterial and venous anastomoses for breast reconstructions were

performed in end-to-end fashion to the internal mammary artery and vein, respectively. There were no reexplorations for flap compromise and there were no flap losses.

Peak arterial blood velocities measured before and after free tissue transfer are listed in Table 2. Peak venous blood velocities measured before and after free tissue transfer in which only one venous anastomosis was performed are listed in Table 3. Both arterial and venous blood velocities increased after free tissue transfer. There were no statistically significant differences in average peak arterial and venous blood velocities, before pedicle division or after anastomosis, when the four free flap types were compared.

Peak venous blood velocities of each vena comitans measured with the flap in situ at the donor site before pedicle division are listed in Table 4. Also listed are the peak venous blood velocities in each vena comitans when the other vena comitans was occluded with a microvascular clamp. In all flap types, the venous blood velocity was seen to increase in a given vena comitans in response to occlusion of the other vena comitans. The peak venous blood velocities were not significantly different between those observed in the larger and the smaller of the two venae comitantes ($p = 0.20$ cm/second). The mean peak venous blood velocity measured in both venae comitantes was 6.3 ± 4.8 cm/second. When one of the vena comitans was clamped, the mean peak venous blood velocity increased to 19.5 ± 17.33 cm/second ($p < 0.00001$).

A comparison of the peak venous blood velocities in flaps in which one venous anastomosis was performed and flaps in which two venous anastomoses were performed is summarized in Table 5. The mean peak venous blood velocity in flaps in which one venous anastomosis was performed was greater than the mean peak venous blood velocity in either vein when two venous anastomoses were performed. The mean peak venous blood velocities were not significantly different between the larger and the smaller of the two venae comitantes (8.3 cm/second versus 9.8 cm/second, respectively) in free flaps in which two venous anastomoses were performed ($p = 0.32$). The mean peak venous blood velocity measured in both venae comitantes was 7.5 ± 4.3 cm/second, and this was significantly less than the mean peak venous blood velocity of 13.1 ± 7.3 cm/second observed in free flaps in which only one venous anastomosis was performed ($p = 0.001$).

In the subset of free flaps that underwent two venous anastomoses, a repeat of the experiment performed with the flap in situ at the harvest site before pedicle division was performed (Table 6). That is, the peak venous blood velocity when one or the other vena comitans was occluded is shown. As observed when the same procedure was performed before pedicle division, an increase in the peak venous blood velocity of one vena comitans after the temporary clamping of the other vena comitans was observed, demonstrating that venous blood velocity increases in a given vena comitans in response to occlusion of the other vena comitans. The peak venous blood velocities were not significantly different between those observed in the larger and the smaller of the two venae comitantes ($p = 0.32$). The mean peak venous blood velocity measured in both venae comitantes was 7.5 ± 4.3 cm/second. When one of the vena comitans was clamped, the mean peak venous blood velocity increased to 17.0 ± 13.8 cm/second ($p = 0.003$).

DISCUSSION

Despite the fact that microvascular surgery is widely practiced, few studies have examined the hemodynamics of free flaps quantitatively. In the present study, several observations were made:

1. Both arterial and venous peak blood velocities increase after free tissue transfer.

2. Occlusion of one vena comitans results in an increase in the blood velocity in the other vena comitans before pedicle division and free tissue transfer.
3. The blood velocity in a vena comitans is higher after anastomosis and ligation of the other vena comitans than after anastomosis of both venae comitantes.
4. Occlusion of one vena comitans results in an increase in the blood velocity in the other vena comitans after free tissue transfer with anastomoses of both venae comitantes.

The increase in arterial and venous blood velocities after free tissue transfer is probably mainly attributable to decreased vascular resistance within the flap. Ichinose et al.⁶ previously observed decreased vascular resistance based on blood velocity measurements using color Doppler ultrasonography after free tissue transfer and suggested multiple reasons for this. Sympathetic denervation of the flap should immediately result in vasodilation and decreased vascular resistance throughout the flap. Within the minutes to hours after flap transfer, vasospasm of the pedicle caused by local factors decreases, resulting in decreased resistance. Restoration of vascular integrity after ischemia and reperfusion injury in the hours to days after microvascular anastomosis probably also plays a role in decreasing vascular resistance within the flap.^{7,8} Finally, over the first several days to weeks after free tissue transfer, resistance resulting from high interstitial pressures caused by edema within the flap decreases. In addition, blood velocities may be generally greater in the mammary and head and neck recipient vessels than the donor vessels, although this has not been previously studied.

Our primary goal was to determine whether there is value to performing two venous anastomoses in microvascular free tissue transfer. Because venous thrombosis is more common than arterial thrombosis, some surgeons have advocated performing two venous anastomoses, based on the hypothesis that multiple draining veins result in improved blood flow through the flap.^{9,10} After all, most flap pedicles are drained by two venae comitantes in their native site, at least until they either coalesce or communicate with a more proximal vein. However, objective data for routinely performing two venous anastomoses are lacking in the literature. To our knowledge, this is the first study to quantify differences in venous blood velocity between free flaps performed with one venous anastomosis and those performed with two venous anastomoses.

Based on our findings, the argument for performing anastomoses of both venae comitantes cannot be made based on objective findings of improved blood velocity. Lower venous blood velocity was observed when two venous anastomoses were performed. This fact is corroborated by the observations that venous blood velocity increases both with the flap in situ at the donor site and after anastomosis of two venae comitantes when one or the other of the venae comitantes is occluded.

That anastomosis of a second vena comitans results in reduced blood velocity makes intuitive sense. For a given volume of blood moving through a free flap over a period of time, increasing the venous cross-sectional area by performing a second venous anastomosis should result in a decrease in blood velocity according to the following formula: $F \propto V \times A$. In this equation, which relates flow of blood in a vessel to velocity, F indicates flow, V is velocity, and A is cross-sectional area.

Because thrombosis is associated with a low-velocity state (not a low-flow state), performing two anastomoses should theoretically increase the risk of thrombosis.¹¹⁻¹³ A recent study correlated intrinsic transit time, defined as the time it takes blood to flow from the arterial anastomosis to the venous anastomosis, with flap loss.¹⁴ Hypothesizing that low blood velocity is correlated with a higher risk for postoperative thrombosis, it was found that

flaps that required reexploration for vascular compromise had a longer intrinsic transit time than flaps that did not. Although there were no flap thromboses in the present study, and the rate of thromboses in microvascular free flap surgery is generally low, performing a single technically adequate venous anastomosis should be considered optimal in terms of minimizing the risk for thrombosis. Obviously, performing only one venous anastomosis is also more efficient in terms of saving operative time.

An argument that can be made is that performing two venous anastomoses provides a “backup” in case thrombosis of one of the two veins occurs. However, little evidence in the literature supports this hypothesis. Ross et al.² did find a significant difference in flap survival between flaps that had a single venous anastomosis and flaps that had two venous anastomoses (98.6 percent and 93.6 percent flap survival, respectively). However, the cause of the flap loss was not analyzed separately. Some authors have even raised the theoretical concern that thrombosis of one vena comitans may result in thrombosis of the second one because of clot propagation.¹⁵ In addition, awkward pedicle geometry created by an additional venous anastomosis may itself lead to mechanical obstruction and flap loss.²

Aside from the risk of an anastomotic thrombosis resulting in flap loss, it is unlikely that performing a single venous anastomosis will result in partial or total flap loss as a result of insufficient drainage of the flap because each vena comitans drains a different area of the flap. In reality, there are usually multiple interconnections between the two venae comitantes over the course of the pedicle and multiple micro-circulatory communications as well. A stronger argument for performing a second back-up venous anastomosis might be made in the case of replants or in flaps where donor or recipient vessel trauma cannot be ruled out. In such cases, thrombosis may occur because of unrecognized vascular injury, and it may be prudent to perform a second venous anastomosis.

Another argument for performing two venous anastomoses may be made when a flap has more than one draining venous system. For example, some authors have suggested that both the cephalic vein and a vena comitans of the radial artery be anastomosed to ensure drainage of the superficial and deep portions of the radial forearm.¹⁶ However, others have shown that anastomosis of a single radial vena comitans is adequate for reliable free tissue transfer of the radial forearm flap.^{15,17} Venous insufficiency caused by limited communications between the superficial and deep vascular networks has been observed clinically and experimentally in anatomical studies of the free transverse rectus abdominis myocutaneous and deep inferior epigastric perforator flaps.^{18,19} Dominance of one venous drainage system over another probably varies from one individual to another because most free transverse rectus abdominis myocutaneous and deep inferior epigastric perforator flaps, like radial forearm free flaps, can be transferred successfully without venous compromise following anastomosis of a single vena comitans. Without objective data, it is difficult to speculate on the impact of performing venous anastomoses of separate venous systems on the venous blood velocity and flow. We did not observe flap losses in this study despite only performing anastomoses of the pedicle venae comitantes. In practice, we reserve performing a second venous anastomosis for a separate venous draining system to situations in which the flap demonstrates signs of venous congestion.

The present study measured blood velocities only immediately before and after free tissue transfer. However, prior studies have addressed changes in blood velocity over time following free tissue transfer.^{20–22} For example, we previously found that arterial and venous blood velocity increases after microvascular anastomosis and that this increase is sustained, based on measurements taken daily for 5 days after free tissue transfer.²⁰ Numata et al.²¹ similarly found increased blood velocity and decreased vascular resistance using color Doppler ultrasonography on days 1 through 7 after free tissue transfer. Others have

found that the increase in flap pedicle blood velocity and flow is maintained long term, based on measurements obtained months after surgery.^{6,22} A potential follow-up to the present study would be to verify that blood velocity differences between flaps with one venous anastomosis and flaps with two venous anastomoses persist, at least during the critical postoperative time period when the risk of thrombosis is greatest.

Several different types of free flaps were included in the present study. Arterial and venous blood velocities before and after free tissue transfer were not significantly different between different flap types by analysis of variance, and the findings that arterial and venous blood velocity increases after free tissue transfer and venous blood velocity is higher in a single patent vena comitans than in two patent venae comitantes were consistent between different flap types. Prior studies have also not found significant differences in blood velocity or flow based on flap type.^{20,22} In reality, we suspect that vascular resistance varies based on numerous factors that are difficult to control for, including tissue type, local and systemic vasoactive factors, and flap size.

The recipient vessels in this study were limited to cervical and internal mammary blood vessels. These are generally considered “high-flow” systems because of their central location. Venous resistance is generally higher in the lower extremities. This is thought to be one reason that free flaps transferred to the lower extremities have a higher loss rate.²³ Based on this evidence, one could infer that any practice that promotes increased blood velocity, such as limiting venous anastomosis to a single vena comitans, would be preferable because blood flow and velocity may be reduced as a result of increased vascular resistance. However, further investigation is needed before definite conclusions can be drawn.

CONCLUSIONS

Arterial and venous blood velocities increase significantly after free tissue transfer, probably because of multiple factors affecting the vascular resistance within the flap. Blood velocity is greater in a given vein when only one venous anastomosis is performed. Because low-velocity states increase the risk for thrombosis, this argues against routinely performing two venous anastomoses in free tissue transfer. When a technically adequate venous anastomosis has been performed, dissection of a second recipient vein and performing an anastomosis of a second vena comitans increases operative time unnecessarily.

References

1. Chalian AA, Anderson TD, Weinstein GS, Weber RS. Internal jugular vein versus external jugular vein anastomosis: Implications for successful free tissue transfer. *Head Neck*. 2001; 23:475–478. [PubMed: 11360309]
2. Ross GL, Ang ES, Lannon D, et al. Ten-year experience of free flaps in head and neck surgery: How necessary is a second venous anastomosis? *Head Neck*. 2008; 30:1086–1089. [PubMed: 18528902]
3. Hartley CJ, Cole JS. An ultrasonic pulsed Doppler system for measuring blood flow in small vessels. *J Appl Physiol*. 1974; 37:626–629. [PubMed: 4411990]
4. Sekido M, Yamamoto Y, Sugihara T. Arterial blood flow changes after free tissue transfer in head and neck reconstruction. *Plast Reconstr Surg*. 2005; 115:1547–1552. [PubMed: 15861057]
5. Hartley CJ, Reddy AK, Madala S, Michael LH, Entman ML, Taffet GE. Doppler estimation of reduced coronary flow reserve in mice with pressure overload cardiac hypertrophy. *Ultrasound Med Biol*. 2008; 34:892–901. [PubMed: 18255218]
6. Ichinose A, Tahara S, Terashi H, Yokoo S. Reestablished circulation after free radial forearm flap transfer. *J Reconstr Microsurg*. 2004; 20:207–213. [PubMed: 15088205]

7. Gurlek A, Schusterman MA, Evans GR, Gherardini G. Blood flow and microcirculatory changes in an ischemia-reperfusion injury model: Experimental study in the rabbit. *J Reconstr Microsurg*. 1997; 13:345–349. [PubMed: 9258840]
8. Jokuszies A, Niederbichler A, Meyer-Marcotty M, Lahoda LU, Reimers K, Vogt PM. Influence of transendothelial mechanisms on microcirculation: Consequences for reperfusion injury after free flap transfer. Previous, current, and future aspects. *J Reconstr Microsurg*. 2006; 22:513–518. [PubMed: 17048133]
9. Kroll SS, Schusterman MA, Reece GP, et al. Timing of pedicle thrombosis and flap loss after free-tissue transfer. *Plast Reconstr Surg*. 1998; 98:1230–1233. [PubMed: 8942909]
10. Chen KT, Mardini S, Chuang DC, et al. Timing of presentation of the first signs of vascular compromise dictates the salvage outcome of free flap transfers. *Plast Reconstr Surg*. 2007; 120:187–195. [PubMed: 17572562]
11. Fernandez EJ, Nadal RD, Gonzalez SM, Caffee HH. The effect of stasis on a microvascular anastomosis. *Microsurgery*. 1983; 4:176–177. [PubMed: 6669013]
12. Strecker WB, Wood MB, Schroeder AR. Stasis-induced thrombosis of rat microvascular anastomosis. *J Reconstr Microsurg*. 1987; 4:69–73. [PubMed: 3316636]
13. Fahmy HW, Moneim MS. The effect of prolonged blood stasis on a microarterial repair. *J Reconstr Microsurg*. 1988; 4:139–143. [PubMed: 3361473]
14. Holm C, Dornseifer U, Sturtz G, Basso G, Schuster T, Ninkovic M. The intrinsic transit time of free microvascular flaps: Clinical and prognostic implications. *Microsurgery*. 2010; 30:91–96. [PubMed: 19790185]
15. Demirkan F, Wei FC, Lutz B, Cher TS, Chen IH. Reliability of the venae comitantes in venous drainage of the free radial forearm flaps. *Plast Reconstr Surg*. 1998; 102:1544–1588. [PubMed: 9774009]
16. Ichinose A, Terashi H, Nakahara M, et al. Do multiple venous anastomoses reduce risk of thrombosis in free-flap transfer? Efficacy of dual anastomoses of separate venous systems. *Ann Plast Surg*. 2004; 52:61–63. [PubMed: 14676701]
17. Futran ND, Stack BC Jr. Single versus dual venous drainage of the radial forearm free flap. *Am J Otolaryngol*. 1996; 17:112–117. [PubMed: 8820186]
18. Blondeel PN, Arnstein M, Verstraete K, et al. Venous congestion and blood flow in free transverse rectus abdominis myocutaneous and deep inferior epigastric perforator flaps. *Plast Reconstr Surg*. 2000; 106:1295–1299. [PubMed: 11083558]
19. Kwon SS, Chang H, Minn KW, Lee TJ. Venous drainage system of the transverse rectus abdominis musculocutaneous flap. *Scand J Plast Reconstr Hand Surg*. 2009; 42:312–314.
20. Hanasono MM, Ogunleye O, Yang JS, Hartley CJ, Miller MJ. Changes in blood velocity following microvascular free tissue transfer. *J Reconstr Microsurg*. 2009; 25:417–424. [PubMed: 19593731]
21. Numata T, Iida Y, Shiba K, et al. Usefulness of color Doppler sonography for assessing hemodynamics of free flaps for head and neck reconstruction. *Ann Plast Surg*. 2002; 48:607–612. [PubMed: 12055429]
22. Heitland AS, Markowicz M, Koellensperger E, Schoth F, Feller AM, Pallua N. Duplex ultrasound imaging in free transverse rectus abdominis muscle, deep inferior epigastric artery perforator, and superior gluteal artery perforator flaps: Early and long-term comparison of perfusion changes in free flaps following breast reconstruction. *Ann Plast Surg*. 2005; 55:117–121. [PubMed: 16034237]
23. Sakurai H, Yamaki T, Takeuchi M, Soejima K, Kono T, Nozaki M. Hemodynamic alterations in the transferred tissue to lower extremities. *Microsurgery*. 2009; 29:101–106. [PubMed: 18942645]

Fig. 1. Representative Doppler spectrograms obtained from an anterolateral thigh free flap pedicle artery before pedicle division (*above*) and after microvascular anastomosis (*below*). An increase in peak blood velocity is observed (*below*).

Fig. 2.

A 20-MHz needle-type Doppler ultrasound probe was used to measure venous blood velocity in an anterolateral thigh free flap pedicle vena comitans with (*above*) the medial vein temporarily occluded with a microvascular clamp and then (*below*) the lateral vein temporarily occluded with a microvascular clamp.

Fig. 3. Representative Doppler spectrograms obtained from an anterolateral thigh free flap (the same as in Fig. 1) pedicle vena comitans before pedicle division (*above*) and after microvascular anastomosis (*below*). An increase in peak blood velocity is observed (*below*).

Fig. 4. Representative Doppler spectrogram obtained from an anterolateral thigh free flap pedicle vena comitans following transfer and microvascular anastomosis of both veins before (*above*) and after clamping of the other vena comitans (*below*). An increase in peak blood velocity is observed (*below*).

Table 1**Microvascular Free Flap Types and Number of Venous Anastomoses Performed**

Flap Type	No. of Flaps (%)	No. of Flaps with One Venous Anastomosis (%)	No. of Flaps with Two Venous Anastomoses (%)
ALT	33 (41)	27 (39)	6 (50)
F	15 (19)	13 (19)	2 (17)
RFF	16 (20)	13 (19)	3 (25)
RA	17 (21)	16 (23)	1 (8)
Total	81 (100)	69 (100)	12 (100)

ALT, anterolateral thigh; F, fibula osteocutaneous; RFF, radial forearm fasciocutaneous; RA, rectus abdominis myocutaneous.

Table 2

Peak Arterial Blood Velocities in Free Flaps before and after Microvascular Anastomosis *

Flap Type	Velocity before Pedicle Division (cm/sec)	Velocity after Anastomosis (cm/sec)	<i>p</i>
ALT	28.3 ± 17.4	41.2 ± 13.1	0.036
F	24.5 ± 17.1	36.5 ± 18.3	0.015
RFF	35.0 ± 15.8	47.5 ± 12.1	0.036
RA	39.7 ± 11.8	48.0 ± 14.7	0.41
Total	31.0 ± 16.3	41.3 ± 16.4	0.00042

ALT, anterolateral thigh; F, fibula osteocutaneous; RA, rectus abdominis myocutaneous; RFF, radial forearm fasciocutaneous.

*
n = 81.

Table 3

Peak Venous Blood Velocities in Free Flaps before and after Microvascular Anastomosis *

Flap Type	Velocity before Pedicle Division (cm/sec)	Velocity after Anastomosis (cm/sec)	<i>p</i>
ALT	11.9 ± 6.8	14.6 ± 10.8	0.33
F	10.5 ± 4.2	21.6 ± 17.0	0.10
RFF	12.1 ± 5.0	19.5 ± 12.6	0.17
RA	18.7 ± 17.5	19.6 ± 2.8	0.78
Total	13.1 ± 7.2	18.3 ± 12.7	0.026

ALT, anterolateral thigh; F, fibula osteocutaneous; RFF, radial forearm fasciocutaneous; RA, rectus abdominis myocutaneous.

*
n = 69.

Table 4

Peak Venous Blood Velocities in Free Flaps, with and without One of Two Venae Comitantes Clamped, at the Donor Site before Pedicle Division *

Flap Type	VC-1			VC-2		
	Velocity (cm/sec)	Velocity When VC-2 Is Clamped (cm/sec)	p	Velocity (cm/sec)	Velocity When VC-1 Is	p
ALT	7.1 ± 4.6	11.9 ± 6.8	0.01	5.9 ± 4.8	14.5 ± 8.3	0.0003
F	6.4 ± 5.2	10.5 ± 4.2	0.28	6.0 ± 6.0	11.0 ± 11.1	0.016
RFF	7.5 ± 3.1	12.1 ± 5.0	0.039	4.4 ± 3.1	11.0 ± 5.6	0.013
RA	7.3 ± 2.3	18.7 ± 17.5	0.031	3.9 ± 2.2	17.9 ± 9.5	0.0034
Total	7.0 ± 4.0	13.1 ± 7.2	0.000081	5.3 ± 4.6	13.3 ± 9.0	<0.00001

VC-1, larger of the two venae comitantes; VC-2, smaller of the two venae comitantes; ALT, anterolateral thigh; F, fibula osteocutaneous; RFF, radial forearm fasciocutaneous; RA, rectus abdominis myocutaneous.

*
n = 81.

Table 5

Comparison of Peak Venous Blood Velocities after Transfer in Free Flaps with One Venous Anastomosis ($n=69$) and Free Flaps with Two Venous Anastomoses^{*}

Flap Type	VC-1 Single-Anastomosis Velocity (cm/sec)	VC-1 Double-Anastomosis Velocity (cm/sec)	VC-2 Double-Anastomosis Velocity (cm/sec)	$p^{\dagger}$
ALT	14.6 ± 10.8	5.1 ± 2.8	5.9 ± 3.6	0.00001
F	21.6 ± 17.0	11.6 ± 3.6	8.6 ± 3.4	<0.00001
RFF	19.5 ± 12.6	16.6	8.0	—
RA	19.6 ± 2.8	10.0 ± 8.1	6.0 ± 2.4	0.047
Total	18.3 ± 12.7	8.3 ± 5.3	9.8 ± 11.5	0.00070

VC-1, larger of the two venae comitantes; VC-2, smaller of the two venae comitantes; ALT, anterolateral thigh; F, fibula osteocutaneous; RFF, radial forearm fasciocutaneous; RA, rectus abdominis myocutaneous.

^{*}
 $n = 12$.

[†]VC-1 single-anastomosis peak blood velocity compared with VC-1 double-anastomosis peak blood velocity.

Table 6

Peak Venous Blood Velocities, with and without One of Two Venae Comitantes Clamped, after Transfer with Two Venous Anastomoses*

Flap Type	VC-1			VC-2		
	Velocity (cm/sec)	Velocity When VC-2 Is Clamped (cm/sec)	p	Velocity (cm/sec)	Velocity When VC-1 Is Clamped (cm/sec)	p
ALT	5.1 ± 2.8	15.8 ± 12.3	0.072	5.9 ± 3.6	21.2 ± 20.6	0.12
F	11.6 ± 3.6	13.1 ± 6.5	0.60	8.6 ± 3.4	16.7 ± 13.1	0.45
RFF	16.6	18.2	—	8.0	18.6	—
RA	10.0 ± 8.1	10.5 ± 4.9	0.75	6.0 ± 2.4	19.3 ± 22.0	0.70
Total	8.3 ± 5.3	14.3 ± 9.2	0.037	9.8 ± 11.5	19.8 ± 17.3	0.045

VC-1, larger of the two venae comitantes; VC-2, smaller of the two venae comitantes; ALT, anterolateral thigh; F, fibula osteocutaneous; RFF, radial forearm fasciocutaneous; RA, rectus abdominis myocutaneous.

*
n = 12.