Analysis of Flow Changes to the Foot after Sacrifice of One of the Major Arteries

Ahmet Sönmez, M.D.,1 İhsan Akpinar, M.D.,2 Tevfik Şatir, M.D.,1 Nihal Durmuş, M.D.,1 and Mehmet Bayramiçli, M.D.1

ABSTRACT

The objective of this study was to find out whether a compensatory increase in blood flow to the foot is observed after sacrifice of one of the tibial arteries. Eleven patients who had one of the tibial arteries as the recipient artery of free tissue transfer to their lower extremities were included. The arterial diameter, cross-sectional area, maximum flow velocity, minimum flow velocity, and flow rate were measured by a Doppler ultrasound in the nonrecipient tibial artery and perforating peroneal artery in the operated limb. The same parameters were measured in the anterior and posterior tibial arteries and the perforating peroneal artery in the contralateral limb. The arterial diameter, cross-sectional area, flow velocity, and flow rate were increased significantly in the nonrecipient tibial artery of the operated limb with respect to the same artery on the contralateral limb. The same changes were not demonstrated in the perforating branch of the peroneal artery. Total blood flow to the foot in the operated extremity was not different from that of the nonoperated foot. The results reveal that if a major feeder to the foot is sacrificed, the other tibial artery compensates for it, and resting blood supply to the foot is not altered.

KEYWORDS: Lower extremity reconstruction, blood flow to the foot, Doppler flow meter analysis

Intervention of blood flow to the hand through the radial artery causes subjective and objective complaints such as decrease in grip strength, pinch strength, and forearm circumference, cold intolerance, and decrease in sensitivity of the superficial radial nerve area.1-3 Establishing the normal blood flow through vein grafts after sacrifice of the radial artery has been proposed4 as an attempt to alleviate these symptoms. In two separate studies, it was found that both resting5 and maximal blood flow6 to the hand is preserved by compensatory dilation of the collaterals after the sacrifice of the radial artery. Therefore it was not necessary to restore the blood flow through vein grafts.2

The validity of these findings in the upper extremity has not been tested for the lower extremity. Sacrifice of one of the main suppliers to the foot is a common clinical situation. For example, anterior tibial artery can be elevated with a dorsalis pedis skin flap or during a toe-to-thumb transfer. Anterior or posterior tibial arteries may also act as the recipient arteries in free tissue transfers to the lower extremity.7 Hemodynamics of the lower extremity are different than the upper extremity. The effect of gravity is more pronounced and the arteries are more prone to atherosclerosis,8 which causes an increased thickness and decreased compliance. This study aims to find out whether a similar

1Department of Plastic and Reconstructive Surgery; and 2Department of Radiology, Marmara University Medical School, Istanbul, Turkey. Address for correspondence and reprint requests: Ahmet Sönmez, M.D., Marmara Üniversitesi Hastanesi, Plastik ve Rekonstrüktif Cerrahi A.D., Tophanelioglu Cad. No: 13-15, 81190 Altunizade, Istanbul, Turkey (e-mail: ahsonmez@yahoo.com). J Reconstr Microsurg 2009;25:35–38. Copyright © 2009 by Thieme Medical Publishers, Inc., 333 Seventh Avenue, New York, NY 10001, USA. Tel: +1(212) 584-4662. Received: February 7, 2008. Accepted: April 15, 2008. Published online: October 21, 2008. DOI 10.1055/s-0028-1090608. ISSN 0743-684X.
compensation mechanism, as in the upper extremity, exists in the lower extremity after sacrifice of one of the major arteries (anterior or posterior tibial) so that the total blood flow to the foot is preserved.

PATIENTS AND METHODS

Patients who had had free-flap transfers to the lower extremity between January 2001 and June 2005 were reviewed retrospectively. Patients with end-to-end arterial anastomosis either to the anterior or posterior tibial artery at the ankle level were included in the study. Patients with known diabetes and peripheral arterial disease were excluded.

Arterial Blood Flow to the Foot

Anterior and posterior tibial arteries are the major blood vessels that supply the foot. Anterior tibial artery passes under the extensor retinaculum and continues as the dorsalis pedis artery to the foot. The posterior tibial artery passes under the flexor retinaculum and gives the medial and lateral plantar branches to the foot. Numerous anastomoses between these arteries are present around the ankle. The peroneal artery, which is one of the main arteries to the leg, does not contribute to the foot vasculature postoperatively. It gives a perforating branch that traverses the interosseous membrane ~5 cm above the lateral malleolus and reaches the anterior leg. Here it contributes to the anastomosis around the lateral malleolus and continues to the dorsum of the foot.9,10

Vascular Examination

Anterior and posterior tibial arteries and the perforating branch of the peroneal artery were examined both in the operated foot and in the contralateral foot. Arterial diameter, cross-sectional area, maximum flow velocity (peak systolic flow velocity \([V_{\text{max}}]\)), minimum flow velocity (end diastolic flow velocity \([V_{\text{min}}]\)), and blood flow were measured by Doppler ultrasound (GE Logic 500 PRO, GE Medical Systems, Milwaukee, WI) using a 7.5-MHz linear probe. No measurement was made for the flap recipient artery because it did not contribute to the foot vasculature postoperatively. Contralateral extremities served as controls. The same radiologist evaluated all the patients included in the study. All parameters were measured three times, and the mean value was included in the statistics to minimize a measurement flaw. The patients were examined in supine position with knee flexed and foot on the table for the anterior tibial artery and perforating peroneal artery and left or right lateral decubitus positions for the posterior tibial artery. All measurements were performed at the level of the malleoli. All three arteries were imaged in axial and sagittal in gray-scale ultrasound followed by color and pulsed Doppler examination. External arterial diameter in sagittal plane and luminal cross sectional area of each vessel were measured. A spectral analysis of pulsed Doppler was used to obtain quantitative Doppler measurements. Absolute flow velocities with angle correction and blood flow in milliliters per minute were measured.

Arterial diameters, cross-sectional areas, \(V_{\text{max}}\), \(V_{\text{min}}\), and blood flows were compared by Student \(t\) test for paired samples, where appropriate. The nonparametric Wilcoxon signed rank test was used when the correlation between the pairs was not significant for a parametric test. A \(p\) value < 0.05 was considered significant.

RESULTS

Between January 2001 and June 2005, 57 patients had free-flap transfers to their lower extremities. Of these, 17 flaps had either the anterior or the posterior tibial artery as their recipient arteries at the level of the ankle joint.
with end-to-end anastomosis. The rest either had their anastomosis at a more proximal or more distal level or had end-to-side anastomosis. Six of 17 patients were lost to follow-up. Therefore, the study was conducted with 11 patients. The mean age of the study group was 37 years (minimum, 8-year-old; maximum, 63-year-old) and the mean follow-up was 42 months (minimum, 10 months; maximum, 68 months). None of these patients had any arterial trauma, diabetes mellitus, or peripheral arterial diseases that could endanger free-flap transfer. Preoperative Doppler examinations revealed triphasic flow in the anterior and posterior tibial arteries and the peroneal artery. None of the flaps were lost. Table 1 presents the characteristics of the study population.

Table 2 presents the results of the Doppler measurements. It was shown that arterial diameter, cross-sectional area, Vmax, Vmin, and blood flow were all increased significantly in the nonrecipient tibial artery of the operated limb with respect to the same artery on the contralateral limb (p = 0.001, 0.007, 0.038, 0.02, and 0.011, respectively). The same parameters were also compared between the perforating peroneal artery of the operated limb and the perforating peroneal artery of the contralateral limb. There was not a significant difference between the diameter, cross-sectional area, Vmax, and blood flow of the perforating peroneal arteries of both limbs. The only significant difference was seen in end diastolic flow velocities between the operated and contralateral limbs (p = 0.006). Total blood flow to the operated foot (sum of the blood flow to the nonrecipient tibial artery and perforating peroneal artery) was compared with the total blood flow to the contralateral foot (sum of the blood flow to the anterior tibial, posterior tibial, and perforating peroneal arteries). There was not a significant difference between the two extremities (p > 0.05).

**DISCUSSION**

This study reveals that if a major feeder to the foot (anterior or posterior tibial artery) is sacrificed, the other tibial artery compensates for it, and resting blood supply to the foot is not altered. The increased blood flow in the tibial artery is obtained both by an increase in the luminal cross-sectional area and an increase in the flow velocity. A similar compensation in the perforating peroneal artery, considered as an extension of the peroneal artery to the dorsum of the foot, was not demonstrated.

The results of this study are an extension of the concept of vascular compensation for the upper extremity to the lower extremity. It is well demonstrated that after harvesting a radial forearm flap in the upper extremity, blood supply to the hand diminishes initially, but collateral circulation develops within months and
blood flow to the hand increases to the preoperative values.\textsuperscript{5,11,12} The same results are supported by the studies that harvest the radial artery for coronary artery surgery.\textsuperscript{6,13} However, this finding for the upper extremity merits further discussion when applied to the lower extremity. The effect of gravity is more pronounced in the lower extremity and arterial walls are thicker with a thick muscular layer and diminished elasticity. These factors lead to a decrease in the compliance of the lower extremity arterial system.\textsuperscript{14} Because of these different properties between the upper and lower extremity, it was necessary to test whether the same principle of arterial compensation for the upper extremity applies to the lower extremity.

Doppler ultrasonography is an objective method of evaluating the blood flow to the foot. We evaluated the anterior and posterior tibial arteries and the perforating branch of the peroneal artery as the main contributors to the foot vasculature. The lateral calcaneal branch of the peroneal artery was not examined due to its inconsistent pattern and the relatively limited area it supplies.

An initial decrease in the blood flow to the foot is expected in the early postoperative period. Therefore patients with long follow-up periods were selected for the study. The mean follow-up period was 42 months and the minimum follow-up was 10 months. The study group was selected from patients with no evidence of peripheral arterial disease or diabetes. The same findings may not be observed in patients with pronounced atherosclerotic changes.

End-to-side anastomosis is the preferred anastomosis type in the lower extremity when possible. In our study population, the surgeon preferred end-to-end anastomosis, however, because of the specific clinical situation of each patient.

Although sacrifice of one of the tibial arteries is not a rare situation, the clinical significance of the loss of one of the major arteries to the foot after reconstructive surgery procedures has not yet been established. The main reason is the difficulty in standardization due to variable confounding factors such as the associated trauma or the type of the reconstructive surgery. It is difficult to assess whether clinical signs and symptoms like pain or claudication at rest or during exertion are attributable to the operation itself or to the loss of one major artery or both. The findings of this study indicate that if one of the tibial arteries is sacrificed, resting blood flow to the foot is not altered. Blood flow to the foot should also be investigated upon exertion.

In conclusion, this study shows that if one of the tibial arteries to the foot is sacrificed, the other tibial artery both enlarges in diameter and increases the blood flow velocity through it to compensate for the total blood flow to the foot. A similar compensation in the perforating branch of the peroneal artery was lacking.

REFERENCES