Vascular Mapping of the Leg with Multi–Detector Row CT Angiography prior to Free-Flap Transplantation[1]

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Abbreviation:
MIP = maximum intensity projection

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PURPOSE: To retrospectively evaluate multi–detector row computed tomographic (CT) angiography in determining donor- and recipient-site arterial suitability for successful vascularized free-flap transplantation.

MATERIALS AND METHODS: The institutional review board granted approval; informed consent was waived, and the study was HIPAA compliant. Lower extremities of 20 (12 male, eight female; mean age, 51 years; range, 10–84 years) patients undergoing vascularized free-flap procedures were examined at multi–detector row CT angiography. In five patients, legs were assessed as potential fibular free-flap donors for mandibular, maxillary, or radial reconstruction. In 15 patients, legs were assessed as recipient sites for free flaps. Vascular maps obtained with volume rendering, maximum intensity projections, and curved planar reformations were generated, and assessment was made in the depiction of calf vessels and presence of stenosis, occlusion, and anatomic anomaly. Findings of CT angiography, physical examination, and surgery were compared, where applicable, and successful CT-based prediction of the surgical intervention was assessed. Immediate and long-term (>70 days) viability of the graft was assessed in all patients.

RESULTS: CT angiography depicted the entirety of all four major calf arteries in 29 of 32 legs scanned. In three legs, external-fixation hardware obscured some segments. There were no discrepancies between CT findings and those identified at the time of surgery. Arterial abnormalities, including stenosis, occlusion, and variant anatomy, were seen in 12 lower extremities in 10 patients. Only two were suspected on the basis of physical examination findings. In five of 20 patients, CT findings resulted in changes to the surgical plan. There was a 100% immediate viability of all grafts, which remained well vascularized between 70 days and 37 months after the procedure.

CONCLUSION: Multi–detector row CT angiography provides a noninvasive means of preoperatively assessing lower extremity arteries for abnormalities, which could jeopardize graft viability or pedal arterial supply after free-flap procedures.

The use of vascularized free flaps has become a robust method for reconstructing extensive bone and soft-tissue defects that arise from a variety of causes. Conventional angiography is a standard component of the preoperative evaluation for vascularized free-flap reconstruction in many institutions, including that of the authors, and is considered the reference standard for obtaining information regarding the anatomy and abnormalities of the target vessels prior to such procedures (1–5). Because of its cost, invasive nature, and potential associated morbidity, some controversy has arisen regarding its routine preoperative use in patients with normal results of peripheral vascular physical examination.

Since the description of their use in 1975 (6), fibular free flaps have become one of the most commonly used donor sites of bone and tissue for reconstructive surgery. In the setting of fibular free-flap transfer procedures, the peroneal artery is routinely resected along with the fibular flap so that once anastamosed to an artery at the implantation site the arterial blood supply is preserved to the graft. The peroneal artery is a major contributor to the vascular supply of the foot in about 7%–12% of all lower extremities (7,8). This occurs with substantial occlusive disease of the anterior tibial or posterior tibial arteries and with certain anatomic variants. In this setting, ischemia of the foot can be a major complication of fibular free-flap procedures. In addition, the peroneal artery may be congenitally absent or unsuitable for free-flap transfer if it is diseased.

The spectrum and prevalence of calf arterial anatomic variants have been described (9–11). Kim et al (10) proposed a unified angiographic classification of such variants. Type III variants, classified as having hypoplastic or aplastic branches of the popliteal artery with altered pedal supply, are most germane to the topic of fibular free flaps and lower extremity reconstruction.

Perhaps even more common than surgical procedures using fibular free flaps are those where the lower extremity is a recipient site for reconstructive free flaps. This situation is most often encountered in the setting of trauma, infection (often resulting from trauma), or tumor resection (12). In such cases, knowledge regarding the zone of injury and relationships of the vascular, bone, and soft-tissue anatomy can be critical in the preoperative planning of posttraumatic lower limb reconstruction.

Whether the lower extremity is serving as a donor site or as a recipient site for a vascularized tissue flap, there is a need for a safe, accurate, and cost-effective imaging strategy prior to the free-flap procedure to avoid potential complications of foot ischemia, to determine the likelihood of graft viability, and to detect aberrant anatomy that might alter the surgical procedure. During the past several years, multi–detector row computed tomographic (CT) angiography has become a routine and clinically accepted method at our institution for the evaluation of lower extremity vasculature. Thus, the purpose of our study was to retrospectively evaluate multi–detector row CT angiography in the determination of arterial suitability at the donor and recipient site for successful vascularized free-flap transplantation.

MATERIALS AND METHODS

Patients

The lower extremities of 20 consecutive patients (12 male, eight female) who underwent vascularized free-flap transfer procedures had been examined with multi–detector row CT angiography between May 2000 and May 2003. Our retrospective evaluation was performed under a protocol approved by our institutional review board, with waiver of informed consent. Our study was compliant with the Health Insurance Portability and Accountability Act. Twelve patients underwent bilateral imaging, while the remaining eight patients underwent unilateral imaging. All patients being evaluated for possible fibular free-flap procurement underwent bilateral CT examinations. Patients ranged in age from 10 to 84 years, with a mean age of 51 years. In five of these patients, the legs were assessed as potential fibular free-flap donors for mandibular, maxillary, or radial reconstruction. In the other 15 patients, the legs were assessed as recipient sites for free flaps in patients who had sustained trauma to a lower extremity ($n = 11$), who had undergone extensive tumor resection ($n = 2$, malignant fibrous histiosarcoma), or who had chronic osteomyelitis ($n = 2$). All patients had normal renal function and no history of allergy to iodinated contrast material. A clinical history that included details regarding the cause and extent of injury requiring reconstructive surgery and physical examination, with specific attention to the posterior tibial and dorsalis pedis pulses, was obtained by a plastic surgeon (J.C., with 9 years of experience) prior to scanning.

CT Technique

CT angiograms were obtained with one of three multi–detector row CT scanners: four–detector row scanner (Volume Zoom; Siemens Medical Systems, Erlangen, Germany) in eight patients and 12 legs, eight–detector row scanner (Lightspeed Ultra; GE Medical Systems, Waukesha, Wis) in eight patients and 15 legs, or a 16–detector row scanner (Lightspeed; GE Medical Systems) in four patients and five legs.

An initial scout image was obtained to determine the scan volume. For the 13 examinations performed before 2002, a dynamic timing bolus acquisition was performed at a stationary level in the leg at the proximal end of the scan volume (generally in the distal superficial femoral artery or popliteal artery) with 5-mm collimation at a rate of one image every 2 seconds for a total of 30 seconds. Time to peak enhancement at this level was determined with region-of-interest analysis, and this was used as the scan delay for CT angiography. The region of interest was placed by the radiologist monitoring the examination; it was centered within the artery and sized to include only the lumen. Timing for the seven examinations performed after January 1, 2002, was achieved with automated bolus detection and scan triggering.

Nonionic contrast material with 300 mg of iodine per milliliter (iohexol, Omnipaque 300; Nycomed, Princeton, NJ) was administered intravenously at a rate of 5 mL/sec into the antecubital vein via a 20-gauge needle by using a power injector (EnVision CT; Medrad, Indianola, Pa). The total volume of contrast material administered was determined as the product of scan time (in seconds) and injection rate for the 13 patients scanned with a separate timing bolus. For the seven patients for whom the scan delay was determined with bolus triggering, the total contrast material volume was the product of scan time plus 8 seconds times the injection rate.

All CT angiograms were acquired with 1.0- (four–detector row scanner) or 1.25-mm (eight– and 16–detector row scanners) nominal section thickness except for one pediatric scan, where 0.625-mm-thick sections were obtained, and one adult scan, where 3-mm-thick sections were obtained by using a four–detector row scanner. Sections were reconstructed with 0.6–1.0-mm intervals. The x-ray tube potential was 120 kVp for all scans, and the tube current ranged from 226 to 440 mA. All scans were acquired with a pitch between 1.25 and 1.5 and gantry rotation times of 0.5 or 0.6 second. Table speeds were 12–30 and 16.9–27 mm/sec for the four- and eight–detector row scanners, respectively. A table speed of 45.833 mm/sec was used for all scans obtained with the 16–detector row scanner. Scan times ranged from 13.7 to 74.8 seconds, with an overall mean of 42.9 seconds (Table 1). Additional maximum intensity projections (MIPs) and volume-rendered reconstructions were generated at 15° increments about the craniocaudal axis. There were no complications from the use of multi–detector row CT angiography.

Image Interpretation

Vascular maps obtained by using volume rendering and maximum intensity projections and curved planar reformations were generated by trained technologists (2–7 years of full-time experience in three-dimensional reconstruction) on an independent workstation (Advantage Windows; GE Medical Systems, Milwaukee, Wis) in all cases. Prior to the surgery, the transverse images and three-dimen-

Figure 1. Anteroposterior MIP from lower extremity CT angiography shows normal bilateral popliteal artery trifurcations and calf arteries, with dominant supply to the pedal arch from the bilateral anterior tibial (solid arrow) and dorsalis pedis (open arrow) arteries and only minor contribution from the posterior tibial arteries.

TABLE 1
Scan Time and Anatomic Coverage according to the Number of Detector Rows

No. of Detector Rows	Scan Time (sec)		Coverage (mm)	
	Mean	Range	Mean	Range
4	69.1	41.7–83.7	955	701–1252
8	30.6	14.3–47.8	776	387–1290
16	25.2	13.7–33.5	1156	628–1535
Overall	43.0	13.7–83.7	932	387–1535

sional renderings were independently reviewed by two board-certified radiologists (G.D.R, L.C.C., with 10 and 5 years of experience, respectively, in interpreting CT angiograms) who were blinded to all clinical information except the underlying disorder. Scans were assessed for the depiction of the major arteries of the calf and foot, including the popliteal, anterior tibial, posterior tibial, peroneal, and dorsalis pedis arteries. In addition, the dominant arterial supply to the pedal arch, when patent, was identified. The images were also reviewed for the presence of arterial abnormalities (stenosis, occlusion) or anatomic anomalies. Discrepant cases were reviewed together, and consensus was achieved.

In cases of lower extremity reconstruction, the proximity of the leg vessels, including the femoral, popliteal, anterior tibial, posterior tibial, and peroneal arteries, to the zone of injury (within, adjacent to, not adjacent to) was reported. The extent, configuration, size, and location of fractures; soft-tissue edema; hyperemia; and skin defects were also reported to aid in surgical planning.

Analysis

In all cases, arterial abnormalities were categorized as *(a)* those that may confer an increased risk of postsurgical pedal ischemia, *(b)* those in which graft viability may be compromised, and *(c)* those in which arterial variation may complicate intraoperative identification of vasculature. Multi–detector row CT angiographic findings were compared with physical (pulse) examination findings. Abnormalities that resulted in an alteration of the surgical plan were identified. At the time of surgery, the surgeons (J.C., M.B.K.) noted the vascular anatomy and patency of the lower extremity vessels, as permitted by the surgical field. The extent, configuration, size, and location of bone and soft-tissue injury were also noted. Results of CT angiography were then compared with the surgical findings, whenever possible, to identify discrepancies (L.C.C., M.B.K., A.N.). The adequacy of the CT-based prediction of surgical intervention was assessed. Immediate and long-term (>70 days) graft viability was assessed in all patients by the operating surgeons (J.C., M.B.K.) on the basis of findings obtained at physical examination, which included palpation of pulses, tissue perfusion, and capillary refill, and Doppler ultrasonography (US) performed in the immediate postoperative period.

RESULTS

Adequacy of CT Angiography

Multi–detector row CT angiograms depicted the entirety of all four major arteries of the calf, including the popliteal, anterior tibial, posterior tibial, and peroneal arteries, in 29 of 32 lower extremities (Fig 1). For three lower extremities, CT angiograms were limited because of streak artifact that resulted from internal or external fixation hardware. In these three extremities, some segments of the lower extremity arterial vasculature were obscured to varying degrees in regions where transversely oriented metallic pins were located, but overall runoff patency could still be confirmed (Fig 2). The dominant arterial supply to the pedal arch was identified in 27 feet where the pedal arch was demonstrated to be patent.

Vascular Anomalies and Abnormalities and Their Effect on Surgical Procedure and Outcome

Overall, abnormalities or anomalies of the popliteal trifurcation, calf, or pedal arteries were seen in 12 lower extremities in 10 patients (Table 2). These 12 abnormalities resulted in the alteration of the surgical plan in five (25%) of the 20 patients scanned. Only two of these abnormalities, which were present in one patient, were suspected on the basis of abnormal physical examination findings and are discussed subsequently. Four of the 12 abnormalities in three patients appeared to be congenital anatomic variants, while the other eight abnormalities in seven patients were acquired.

In the setting of free-flap reconstructive surgery involving the lower extremities, vascular abnormalities can be grouped into *(a)* those that may confer an increased risk of postsurgical pedal ischemia, *(b)* those in which graft viability may be compromised, and *(c)* those in which arterial variation may complicate intraoperative identification of vasculature. In this study, eight of 12 abnormalities were considered risks for pedal ischemia and included occlusion of the anterior tibial, posterior tibial, or both arteries or occlusion of the dorsalis pedis artery. In four of these eight lower extremities, the peroneal artery represented the dominant arterial supply to the foot.

Type IIIB branching, whereby the per-

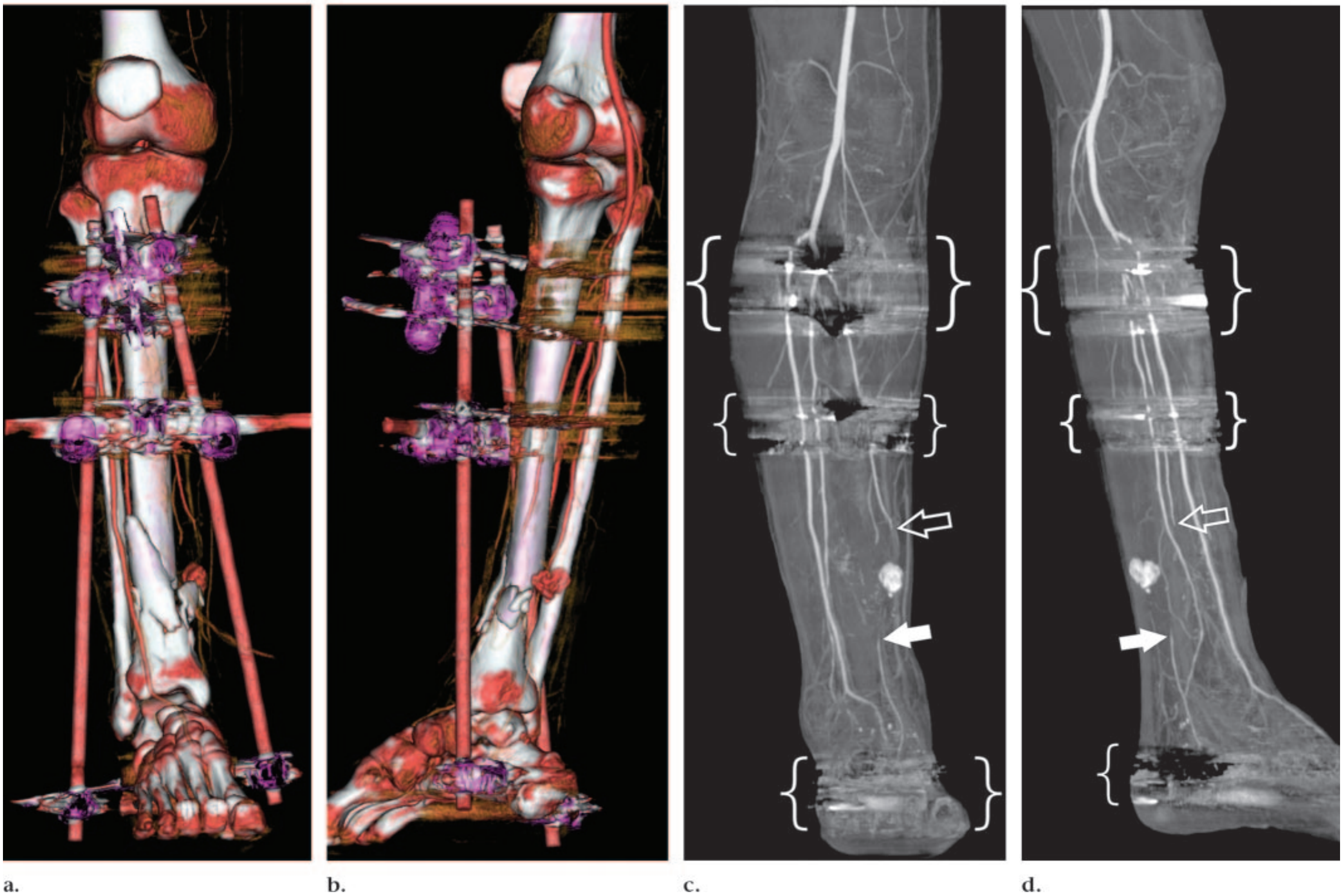

Figure 2. Images in a 45-year-old man with open fracture of right tibia and/or fibula. **(a)** Frontal and **(b)** lateral volume-rendered images from CT angiography demonstrate the extent of bone injury and fixation hardware to good advantage. **(c)** Frontal and **(d)** lateral MIPs from CT angiography show artifacts resulting from hardware (brackets), which compromise depiction of vessels only at planes where there are hardware junctions with screws and horizontally oriented rods. Vertically oriented fixation rods did not result in substantial artifacts, and lower extremity runoff was still visible. Abrupt termination of the posterior tibial artery (open arrow) was identified at the level of tibial fracture and was found to be completely transected at surgery. Reconstitution of the distal posterior tibial artery is noted (solid arrow).

oneal artery reconstitutes the distal aspect of the hypoplastic anterior tibial artery, was seen in one patient without evidence of atherosclerosis or other vascular abnormalities, which suggests that this finding represented a variant anatomy. As would be expected, this anomaly was unsuspected on the basis of physical examination findings, because the patient had palpable posterior tibial and dorsalis pedis pulses on the affected side. Because of the risk of pedal ischemia, a radial free flap was used instead of a fibular flap in this patient. Another patient had hypoplastic anterior tibial arteries bilaterally, which were unsuspected on the basis of physical examination findings, with reconstitution of the dorsalis pedis artery by the peroneal artery (type IIIB branching) on one side and a single-vessel runoff to the foot on the contralateral side. A facial artery musculomucosal flap was used for facial reconstruction after treatment for an invasive squamous cell carcinoma in this patient (Fig 3).

In another two patients, the peroneal artery represented the dominant blood supply to the foot as a result of acquired lesions. In one patient, severe atherosclerosis resulted in intermittent occlusions and/or tight stenoses of the anterior and posterior arteries throughout the right calf, with dominant supply to the foot arising from the peroneal artery and its collaterals. This patient had faintly palpable bilateral dorsalis pedis and posterior tibial pulses. In the other case, the anterior tibial artery was occluded at the level of the distal tibial fracture with complicating osteomyelitis and was reconstituted beyond this level by the peroneal artery. Because the dorsalis pedis artery was ultimately reconstituted by peroneal collaterals, a normal dorsalis pedis pulse was present, and this abnormality was not detectable at physical examination. These findings resulted in the alteration of the surgical plan, with anastamosis of the latissimus dorsi free flap to the posterior tibial artery instead of the anterior tibial artery (Fig 4).

Another patient with tibial osteomyelitis after a fracture had a similar finding at CT angiography, with abrupt termination of the anterior tibial artery at the level of prior fracture and distal reconstitution by collaterals. Complete transection of the artery at this level was identified during surgery. Neither dorsalis pedis nor posterior tibial pulse was palpable on the affected side, although the posterior tibial artery was demonstrated to be widely patent at CT angiography. In another patient with a history of lower extremity trauma, there was occlusion of the right posterior tibial artery that was unsuspected at physical examination. In the final patient believed to be at risk for

Figure 3. Anteroposterior MIP from CT angiography in a 74-year-old man evaluated for possible fibular free-flap procedure for facial reconstruction shows hypoplastic bilateral anterior tibial arteries, which terminate in the middle of the calf (solid arrows), with stenosis at the origin of the right anterior tibial artery (open arrow). The left dorsalis pedis artery is supplied by the peroneal artery (arrowheads). The right dorsalis pedis artery was not depicted.

a. b.

Figure 4. Images of right lower extremity in a 54-year-old man with chronic tibial osteomyelitis after fracture. **(a)** Oblique MIP from CT angiography after subtraction of osseous elements shows occlusion of anterior tibial artery (large solid arrow), with adjacent collateral vessels and regional hyperemia (*). Distal anterior tibial artery is reconstituted by a branch from peroneal artery (curved arrow). Posterior tibial artery (open arrow) and plantar arch (small solid arrows) are patent and well depicted. **(b)** Oblique volume-rendered image from the same CT angiographic data set as **a** shows the relationship of vessels, including occluded anterior tibial artery (arrow), to underlying bone structures. Note fracture deformities of fibula and tibia.

developing pedal ischemia, an incomplete dorsalis pedis artery prompted fibular free-flap procurement from the contralateral leg (Fig 5).

Abnormalities of three legs in two patients brought into question the potential viability of vascularized grafts. Proximal occlusion of the left peroneal artery was seen in one patient. Diminutive bilateral anterior tibial and peroneal arteries in another patient (Fig 6) resulted in essentially single-vessel arterial supply to each foot and precluded procurement of a lower extremity flap. At physical examination, bilateral dorsalis pedis and posterior tibial pulses were absent, despite patency of the bilateral posterior tibial arteries on a CT angiogram. In this case, a rectus abdominis free flap was used for facial reconstruction after cancer resection. Finally, in one leg, there was early branching of the posterior tibial artery at the level of the knee prior to a long anterior tibial-peroneal trunk (type IIB branching using the classification proposed by Kim et al [10]) (Fig 7). The contralateral leg in this patient demonstrated a normal popliteal trifurcation.

CT findings were confirmed intraoperatively, where possible, which allowed all surgeries to proceed as planned without any procedural modifications. There were no discrepancies identified at the time of surgery regarding information provided at CT. The extent of the underlying pathologic process in flap-recipient sites with bone and soft-tissue changes was well delineated and served to determine the size and shape of the free flap. There was 100% immediate viability of all grafts, which remained well vascularized between 70 days and 37 months following the free-flap procedures. The average clinical follow-up for these patients was 12 months.

DISCUSSION

Within the past 20 years, microvascular reconstructive techniques, including vascularized free-flap transfer procedures, have become routine at many centers. Such techniques now allow the repair of large soft-tissue defects related to trauma, nonhealing wounds, chronic infection, and sites of cancer resection, thus dramatically improving the potential for limb salvage. Various arterial conditions, including variant anatomy and severe atherosclerotic disease, can adversely affect the outcome of fibular free-flap procurement or lower extremity reconstruction. Because the peroneal artery is procured along with a fibular graft, any situation in which the peroneal artery represents a substantial supply to the foot could result in pedal ischemia (3,5,13). Assessment of peroneal artery patency plays a fundamental role in patients being evaluated for either fibular free-flap

TABLE 2
Pertinent Lower Extremity Vascular Abnormalities Identified at Preoperative CT Angiography

Patient No./Age (y)/Sex	Site	Side	Indication	Pertinent CT Finding	Condition	Suspected at Pulse Examination	Procedure	Change in Patient Treatment
1/48/F	Donor	Left	Infection of radius requiring resection	High origin of PT artery with long AT/peroneal trunk (type IIB)	Variant anatomy	No	Fibular free flap from right leg to left forearm	None
2/45/F	Donor	Right	Squamous cell carcinoma of left ankle/heel	Right AT artery tapers and ends above ankle, DP artery reconstituted by peroneal artery (type IIIB)	Variant anatomy	No	Left radial free flap and skin graft to left ankle/heel	Fibular free flap not used because of risk of pedal ischemia
3/79/F	Recipient	Right	Trauma (right tibial plateau fracture) with open wound over knee	Intermittent atherosclerotic occlusions of AT/PT arteries; peroneal artery is dominant pedal supplier	Disease	No	Right gastrocnemius free flap to right anterior knee soft-tissue wound	None
4/56/M	Recipient	Right	Right tibial osteomyelitis from open fracture	Right AT artery occluded and reconstituted by peroneal artery	Disease	No	Latissimus dorsi flap anastamosed to right PT artery	Anastamosis to PT artery instead of AT artery
5/84/M	Recipient	Left	Left leg sarcoma with postresection wound break-down	Proximal occlusion of peroneal artery	Disease	No	Split-thickness skin graft	None
6/45/M	Recipient	Right	Tibial/fibular open fracture	PT artery terminates at level of fracture (complete transection found at surgery)	Disease	No	Rectus abdominis free flap	None
7/69/M	Recipient	Left	Posttraumatic left tibial osteomyelitis	AT artery occluded at level of fracture, reconstituted distally by collaterals	Disease	No	Rectus abdominis free flap	None
8/78/F	Donor	Bilateral	Mandibular carcinoma	AT and peroneal arteries diminutive bilaterally	Disease	Yes	Rectus abdominis free flap	Rectus abdominus graft instead of fibular free flap
9/52/M	Donor	Left	Maxillary sinus tumor	Left DP artery occlusion	Disease	No	Right fibular free flap	Right leg used for fibular flap
10/74/M	Donor	Bilateral	Squamous cell cancer of tongue	Hypoplastic bilateral AT artery; left DP artery reconstituted by peroneal artery	Variant anatomy	No	Facial artery musculomucosal flap	Fibular free flap not used because of risk of pedal ischemia

Note.—AT = anterior tibial, DP = dorsalis pedis, PT = posterior tibial.

harvesting or lower extremity reconstruction with the goal of preserving two-vessel runoff to the foot.

Anatomic variations in the lower extremity arterial circulation have been well documented (10,11,14). In a study (10) of 1000 conventional leg arteriograms, anatomic anomalies involving the popliteal or major calf arteries were identified with a prevalence of 7.8%. Bardsley and Staple (11) documented that 8% of 235 extremities studied at arteriography had variant popliteal branching. Although the number of patients examined in our study was small, CT depicted 12.5% (four of 32) of lower extremities to have anatomic anomalies in the calf arteries.

Fibular flap procurement in the setting of peroneal arteria magna, where the peroneal artery represents the only supply to the foot with hypoplastic anterior tibial and posterior tibial arteries, could result in a catastrophic ischemia of the foot. Even situations where either the dorsalis pedis or distal posterior tibial arteries are supplied by the peroneal artery as a result of either congenital variation or acquired vascular disease would be relative contraindications to fibular flap procurement. In addition, an absent or diseased peroneal artery also precludes the harvesting of a vascularized fibular free flap. It should be pointed out that such lesions would escape detection with pedal pulse examination or bedside Doppler US of the dorsalis pedis and posterior tibial arteries. In our study, the peroneal artery was a substantial supplier to the foot in 12.5% (four of 32) of the lower extremities.

Preoperative lower extremity conventional angiography has been used to evaluate the donor- or recipient-site arterial suitability prior to vascularized fibular free-flap procedures or lower extremity reconstructive surgery (1,3,5,13,15–18). Although uncommon, conventional angiography is associated with substantial potential morbidity, including access site hematoma, pseudoaneurysm, dissection, and arterial occlusion, which leads some to question the necessity of using this modality routinely (2,19–23).

The specific indications for preoperative anatomic screening with imaging are controversial. Several investigators (2,23) have concluded that routine preoperative conventional angiography is unnecessary in patients with normal pedal pulses, and they reserve preoperative imaging only for patients with abnormal pedal pulses. Lutz et al (19,21) suggest that preoperative angiography is only indicated when pedal pulses in both feet are absent or if there is a history of "sig-

a.

b.

Figure 5. MIPs from CT angiography in a 50-year-old man requiring fibular free-flap procedure for mandibular reconstruction. **(a)** Anteroposterior MIP shows normal bilateral popliteal arteries (long solid arrows) and trifurcation vessels, including the anterior tibial (straight open arrows), peroneal (short solid arrows), and posterior tibial (curved open arrows) arteries. **(b)** Oblique MIP of the feet shows early termination of the left dorsalis pedis artery (arrow), which was believed to be congenital in nature given the absence of disease in other vessels. Right pedal arch is normal. Fibular free flap was harvested from the right side for this reason.

Figure 6. Anteroposterior MIP from CT angiography in a 78-year-old woman with mandibular carcinoma undergoing evaluation for possible fibular free flap shows early termination of bilateral anterior tibial (long solid arrows) and peroneal (open arrows) arteries and single vessel runoff to the feet via the bilateral posterior tibial artery (short solid arrows). A rectus abdominis free flap was used for facial reconstruction because of the marginal patency of peroneal arteries.

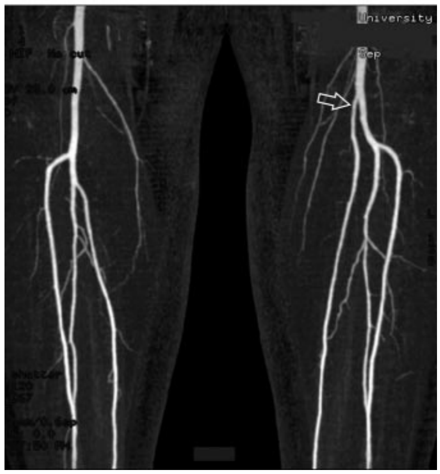

Figure 7. Anteroposterior MIP from CT angiography in a 48-year-old woman with infection of the radius requiring resection and flap reconstruction. MIP of bilateral calves demonstrates high origin of the left posterior tibial artery (arrow) as the first calf branch from the popliteal artery, with tibioperoneal trunk giving rise to anterior tibial and peroneal arteries.

nificant previous lower leg trauma." In their study of 36 patients undergoing lower extremity reconstructive microsurgery, 29 patients had palpable posterior tibial and dorsalis pedis pulses. Of these, three had abnormal injured peroneal arteries and one had a pseudoaneurysm of the anterior tibial artery, but these findings were not considered relevant to the planning of the free-flap procedure.

Because of the prevalence of congenital variant vascular anatomy, as well as the possibility of altered collateral flow resulting from acquired lesions, other authors (1,3,5,15,17,18,24,25) have concluded that preoperative vascular imaging remains a critical component of the routine preoperative evaluation prior to free-flap transfers. Young et al (3) found in a study of 28 consecutive patients evaluated with conventional angiography that 25% (n = 7) had vascular abnormalities that altered the surgical plan and that of these, nearly half (n = 3) had normal pulse examination findings. Seres et al (17) reviewed 64 angiograms obtained in 39 patients and found vascular anomalies in 10 (15.6%) extremities. In another study of preoperative angiography, Blackwell (5) found congenital vascular anomalies in the calf in four (21%) of 19 patients and angiographic abnormalities that altered the surgical plan in 21% of patients (three related to atherosclerotic disease, one related to congenital anomaly). The results of our study are concordant with those of prior studies. In our series, five of 20 patients had vascular abnormalities identified a CT angiography that altered the surgical plan.

The method of preoperative evaluation of the arterial vasculature is also a controversial topic. A wide variety of techniques are currently in use in the work-up of such patients, including conventional angiography (1,3,5,13,15–18), simple pedal pulse examination (2,19,21,23), Doppler US (26,27), magnetic resonance (MR) angiography (25,28,29), and CT angiography (30). In 2000, a survey of surgeons in England who perform free-flap procedures found that 98% palpate pedal pulses, 53% use angiography, 55% use Doppler US (without color flow imaging) at the bedside (38%) or in a vascular laboratory (17%), and 8% use MR imaging as part of the initial preoperative evaluation (16).

Doppler US has been suggested as an alternative, noninvasive means of screening these patients (26,27) but does not provide a complete vascular map and is highly operator dependent. Moreover, isolated Doppler US of the posterior tibial and dorsalis pedis arteries, while more sensitive to flow, still has the same weaknesses as simple palpation. False-negative findings can occur as a result of lower extremity edema, and the presence of a pulse will not help distinguish a normal vessel from one replaced to the peroneal artery.

Finally, MR angiography has also been used as a preoperative means of assessing the lower extremity vasculature. Manaster et al (25) described the use of two-dimensional time-of-flight MR angiography for this application in 1990, when they found that this technique was able to accurately depict the popliteal branching pattern and all vascular anomalies in 32 legs where fibular free flaps were procured. A decade later, Koelemay et al (28) found that three-dimensional gadolinium-enhanced MR angiography was able to improve the diagnostic performance in this application when compared with that of two-dimensional time-of-flight MR angiography.

Limitations of this study include the lack of a true anatomic reference standard in many instances. While CT angiographic findings were confirmed with surgical findings whenever possible, an anatomic reference standard in all cases would have required a full surgical dissection of at least the popliteal, anterior tibial, posterior tibial, and peroneal arteries in every lower extremity that was scanned. This limitation is of particular importance in cases where an abnormality identified at CT angiography resulted in a change to the surgical plan, precluding intraoperative confirmation. Other imaging examinations such as conventional angiography and MR angiography were not clinically warranted and therefore not performed in these patients. In addition, a relatively small number of patients were studied.

At the authors' institution, conventional angiography has traditionally been used to routinely evaluate patients prior to free-flap procedures. Because of the cost, invasiveness, and risks associated with conventional angiography, there is a clear need for an accurate but noninvasive imaging technique. CT angiography is an attractive alternative to conventional angiography for multiple reasons. CT angiography is noninvasive, has lower risk, is less expensive, and provides information regarding the bones and soft tissues, which may be particularly helpful in patients with trauma to the lower extremities. In addition, CT angiography does not require several hours of postprocedural bed rest and monitoring. Because CT angiographic data are acquired as a volumetric data set, images can be reconstructed in any plane or projection desired, thereby reducing the radiation exposure by as much as fourfold when compared with that of conventional angiography (31). In addition, postprocessing allows one to either include or exclude soft tissues and osseous structures. The introduction of four–detector row CT scanners in 1998 resulted in a substantial increase in imaging speed when compared with that of single–detector row spiral CT scanners (32). In that study (32), the relevant arterial anatomy was scanned in an average of 69.1 second by using a four–detector row scanner. Scans obtained with eight- and 16–detector row scanners were even faster, averaging 30.6 and 25.2 seconds, respectively. Our protocol of using a pitch of 1.375, a gantry rotation time of 0.6 second, and a nominal section thickness of 1.25 mm with the 16–detector row scanner allows scanning with a table speed of 45.8 mm/sec.

In this study, multi–detector row CT angiography provided a noninvasive means of obtaining information regarding vascular, soft-tissue, and osseous anatomy, which was useful for surgical planning prior to both lower leg reconstructive surgery and fibular free-flap harvesting. In the case of fibular free-flap procedures, the potential for pedal ischemia justifies routine preoperative vascular mapping. In the 20 patients studied, no discrepant findings arose at the time of surgery, and all surgeries were successful without vascular complications. However, in 25% of these patients, information garnered from multi–detector row CT angiography led to changes in the surgical plan, which suggests that multi–detector row CT angiography may become the preferred method for preoperative evaluation in these patients.

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