Fibula Free Flaps

The Role of Angiography in Patients With Abnormal Results on Preoperative Color Flow Doppler Studies

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Background: The reliability of normal color flow Doppler (CFD) study results in predicting the safety of fibula free flap harvest has been recognized. The significance of abnormal CFD study results when used for preoperative assessment of a potential fibula free flap donor site is less well defined.

Objective: To determine if abnormal preoperative CFD study results should exclude fibula free flap harvest or if patients, in whom the fibula free flap is thought to be the best reconstructive option, should undergo further evaluation with angiography to better determine fibula free flap candidacy.

Methods: A retrospective review identified 17 potential fibula free flap candidates (34 legs) evaluated by both a lower extremity CFD study and a lower extremity angiogram. The results of the CFD study were then compared with those of angiography.

Results: There were 16 legs with normal CFD study results and subsequent angiographic findings confirming the safety of each of these legs for fibula free flap harvest. There were 18 legs that demonstrated abnormal CFD study results. Angiography revealed anatomy that was considered to represent a high risk for fibula free flap harvest in 16 legs and considered safe in the other 2 legs. All 14 legs that had at least 1 vessel with a monophasic waveform or no flow on the CFD study revealed a high-risk angiogram result. Of the 4 legs with biphasic waveforms in all trifurcation vessels on the CFD study, 2 revealed angiogram results that showed that they were safe for flap harvest.

Conclusions: Preoperative CFD studies that reveal a monophasic waveform or absence of flow accurately identify unsafe donor sites. Fibula free flap harvest in these cases can be excluded based on abnormal CFD study results alone, eliminating the need to perform angiography.

Arch Otolaryngol Head Neck Surg. 2003;129:712-715

MICROVASCULAR FREE tissue transfer is commonly used today for reconstruction of complex head and neck defects. Many options exist for transfer of free vascularized bone for reconstruction of segmental mandibular and maxillary defects, with the fibula free flap being commonly used in these settings. Many potentially complicating factors must be evaluated when considering a fibula free flap harvest. The potential compromise of lower extremity vascularity associated with flap harvest, the presence of atherosclerotic disease in the peroneal vessel that could complicate anastomosis, and the presence of aberrant vascular anatomy in the lower extremities should be excluded. Consequently, preoperative assessment of lower extremity vascular anatomy should be performed to identify high-risk flap candidates before the fibula free flap is harvested.

Angiography has been the imaging technique most commonly used to assess the lower extremity vascularity prior to fibula free flap harvest. Most surgeons consider it to be the "gold standard" because of its accuracy in identifying atherosclerotic lesions and congenital anomalies. Angiography, however, is an expensive, invasive procedure and carries a 3% to 5% complication rate.[1] Because of the expense and inherent risks of angiography, noninvasive alternative methods have been investigated. A thorough history and physical examination, ankle-arm indices (AAIs), color flow Doppler (CFD) studies, and magnetic resonance angiography (MRA) have all been successfully used in clinical settings.[2-7]

Significant interest has focused on the use of CFD study in the clinical setting because of its accuracy in mapping the vascular anatomy and its relative cost savings when compared with both angi-

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ography and MRA. Moneta et al[8] found that CFD studies could accurately map 94% of anterior tibial arteries, 96% of posterior tibial arteries, and 83% of peroneal arteries. The reliability of normal CFD study results in predicting uncomplicated fibula free flap harvest has also been documented. Futran et al[4] reported a 100% success rate of flap transfer and no distal extremity complications in patients with normal results on preoperative CFD studies.

Less information is available regarding the significance of abnormal CFD study results. The objective of this study was to determine the clinical value of obtaining lower extremity angiograms when the results of CFD studies are abnormal in potential fibula free flap candidates.

METHODS

A retrospective chart review identified all potential fibula free flap candidates who underwent both CFD studies and lower extremity angiography between January 1997 and December 2000. The results of CFD studies, angiography, and the AAIs were all reviewed and assessed to determine candidacy for fibula free flap harvest. Angiography was used as the imaging study of choice in the preoperative assessment of potential fibula free flap candidates before 1997. In 1997, the transition to CFD studies for preoperative assessment was made. Because of limited experience with the CFD study, angiography was also performed to confirm the results of the CFD studies. During 1997, patients with both normal and abnormal CFD study results underwent angiography to confirm the CFD study results. Because of the excellent correlation between normal CFD study results and those of subsequent angiography, only those patients with abnormal CFD study results went on to undergo angiography after 1997.

The AAIs were classified as normal ($\geq$1.0), mildly abnormal (0.8-0.99), grossly abnormal ($<$0.8), or unable to be adequately obtained because of an inability to compress the vessels. Analysis of the CFD study results included recording waveforms and determining the presence of aberrant or absent flow in major vessels. Waveforms were recorded for the anterior tibial, posterior tibial, and peroneal vessels as triphasic, biphasic, or monophasic. Aberrant or absent flow was noted as absent or present.

The results of the CFD study of each lower extremity were then determined to be normal or abnormal. The results of a lower extremity CFD study were classified as abnormal if any of the following conditions were observed: (1) absence of flow in any of the trifurcation vessels; (2) a monophasic waveform in any of the trifurcation vessels; or (3) a biphasic waveform in any of the trifurcation vessels.

Findings on angiography determined the final decision regarding flap candidacy. If any of the following abnormalities were present on the angiogram, then the lower extremity was classified as a poor donor site: (1) occlusion of any trifurcation vessels; (2) significant stenosis ($\geq$50% of the vessel diameter) of any trifurcation vessels; or (3) congenital vascular anomalies.

A review of the medical history identifying major risk factors for peripheral vascular disease (PVD), such as hypertension, atherosclerotic coronary artery disease, atherosclerotic cerebral vascular disease, diabetes mellitus, hypercholesterolemia, and smoking history, was included. Finally, any postoperative complications were recorded.

RESULTS

There were 17 patients (34 lower extremities) who met the criteria for the study. There were 11 men and 6 women, with a mean age of 61 years. Twelve of the 17 patients presented with a squamous cell carcinoma of the oral cavity with mandibular involvement. One patient had a high-grade mucoepidermoid carcinoma with mandibular invasion. The other 4 patients presented with complications of prior cancer treatment, including osteoradionecrosis, pathologic fractures, or exposed reconstruction plates.

The results of CFD studies were normal in 16 lower extremities (10 patients). Angiography in all 16 of these lower extremities revealed anatomy that was considered safe for fibula free flap harvest. The 6 patients with bilateral normal CFD study results underwent uncomplicated fibula free flap reconstructions. There were 4 patients whose CFD studies revealed a normal and an abnormal lower extremity. Two of these 4 patients underwent successful fibula free flap reconstructions in the lower extremity that demonstrated normal angiographic findings. In one patient, a scapula free flap was eventually used because of the nature of the oromandibular defect; in the other patient, a bony reconstruction was not required.

The results of CFD studies were abnormal in 18 lower extremities (11 patients). A review of the angiograms revealed anatomy that was considered high risk for fibula free flap harvest in 16 of 18 lower extremities. A total of 6 patients had abnormal results on CFD studies and angiography in both lower extremities. Three of these patients underwent a scapula free flap, 2 patients did not require a bony reconstruction, and 1 patient underwent a fibula free flap reconstruction. One patient had bilateral abnormal CFD study results, but angiography revealed a high-risk lower extremity and an abnormal but low-risk lower extremity. A fibula free flap was performed in the low-risk lower extremity in this patient. All 14 lower extremities in which the CFD study revealed a monophasic waveform or no flow within at least 1 vessel were considered to be a high risk for fibula free flap harvest by angiography. Of the 4 extremities with CFD studies that revealed biphasic flow in all vessels, 2 had angiographic findings that were considered low risk. Compared with angiography, the sensitivity, specificity, and overall accuracy of CFD studies are 100%, 88.9%, and 94.1%, respectively.

There were 15 occluded vessels noted on angiography. The CFD studies identified no flow within 10 of these vessels. In the 5 vessels not identified as occluded, significant flow abnormalities were noted on CFD studies, including a monophasic waveform in 1 vessel and biphasic waveforms with velocity discrepancies in the other 4 vessels (all 4 vessels in the same patient). There were 9 significant stenotic lesions present in trifurcation vessels noted on angiography, and CFD studies identified all 9 of these as abnormal, with monophasic waveforms in all of the vessels. There were no vascular anomalies noted in any of the angiograms.

All 16 lower extremities with normal angiographic findings had AAIs greater than 1.0. Nine of the 16 lower extremities with abnormal angiographic findings had AAIs lower than 1.0, while 7 had AAIs greater than 1.0. The 2 lower extremities with abnormal CFD study results and normal angiographic findings both had AAIs lower than 1.0. There were 23 lower extremities with AAIs greater

than 1.0. However, the angiograms of 7 of the 23 lower extremities revealed anatomy that was considered unsafe for fibula free flap harvest, resulting in a 30% false-negative rate. Nine of 11 lower extremities with AAIs lower than 1.0 had corresponding abnormal angiographic findings, for an 18% false-positive rate.

The average age of the 6 patients with normal findings on bilateral lower extremity angiograms was 50 years. Furthermore, 3 of the 6 patients had no major risk factors for PVD, while the other 3 had only 1 major risk factor. The mean risk factor per person in this group was 0.5. There were 11 patients who had evidence of PVD in at least 1 lower extremity. The average age in this group was 67.3 years. Eight of these 11 patients had more than 2 major risk factors for PVD, while the remaining 3 patients had 1 major risk factor. The mean risk factor per person in this group was 1.9.

COMMENT

Controversy exists regarding the extent of evaluation that is required in the preoperative assessment of fibula free flap donor sites. On one end of the spectrum are reconstructive surgeons who believe that angiography is necessary in the preoperative assessment of all potential fibula free flap candidates.[1,9] At the other end, there are those who believe that a thorough history and physical examination should be the primary screening tools and that angiography should only be used for the small percentage of patients who have abnormal pedal pulses, a history of trauma, or a questionable history of claudication.[2,10]

One concern that would necessitate imaging for all fibula free flap candidates is a congenital aberration known as *peroneal arterial magna*.[2,9] In patients with this condition, the peroneal artery is the only vessel to the foot; however, the patients have normal distal pulse rates and deny claudication. Peroneal arterial magna has been noted to occur in 0.2% to 0.9% of the general population.[10,11] Patients with peroneal arterial magna cannot be diagnosed by a routine history and physical examination. The concern is that if an imaging study is not routinely ordered, this congenital anomaly would not be identified until the patient developed an ischemic foot after surgery.

Futran et al[3] have described the use of AAIs in the preoperative evaluation of potential fibula free flap candidates. In their study, they found good correlation between AAIs of less than 1.0 and subsequent PVD confirmed by angiography. However, they also found an unacceptable number of patients with AAIs greater than 1.0 who had PVD. Thus, they concluded that AAIs of less than 1.0 can exclude lower extremities as donor sites but that AAIs of greater than 1.0 indicate a need for further evaluation by CFD studies. Their findings are similar to ours in patients with AAIs greater than 1.0. Thirty percent of our patients who had AAIs greater than 1.0 also had abnormal findings on angiography, but we found an 18% false-positive rate in patients with AAIs lower than 1.0 when compared with low-risk angiographic findings. One patient had only a low-grade stenosis of the popliteal artery, and the other had proximal vascular disease but normal distal vascularity. Another disadvantage of AAIs is that this noninvasive study does not map the lower extremity anatomy; therefore, peroneal arterial magna would not be identified.

The advent of MRA presented another option for preoperative noninvasive assessment of lower extremity vascular anatomy. Manaster et al[6] demonstrated the success of MRA in the preoperative evaluation of 29 young patients who required fibula free flaps mainly for extremity reconstruction. In their study, MRA was extremely accurate in mapping distal lower extremity anatomy and identifying vascular anomalies. However, the study only included patients between the ages of 14 and 41 years, thereby raising the concern that subtle vascular abnormalities in an older population may not be readily identified. Winchester et al[12] studied the accuracy of MRA in identifying arterial occlusive disease. They found the sensitivity, specificity, and diagnostic accuracy of MRA to be 90%, 98%, and 93%, respectively. In a group of patients with osseous defects of the head and neck, Lorenz and Esclamado[7] used MRA in the preoperative evaluation for a fibula free flap. The results of MRA excluded the use of a fibula flap in 9% of the patients and changed the donor site in 12.5% of the patients. In all patients with acceptable findings on MRA, uncomplicated fibula free flaps were performed. The main disadvantage of MRA is the high cost, which nearly equals that of standard anigography.[1,6]

The reliability of CFD studies in predicting successful fibula free flap transfer has been demonstrated by Futran et al.[4] Thirty-two patients with normal CFD study results had normal anatomy noted intraoperatively, and all of them had uncomplicated fibula free flap transfers. Furthermore, CFD studies accurately identified vascular anomalies and were thought to be extremely effective in imaging peroneal vessels. Our findings agree with those of Futran and colleagues in that all 16 lower extremities with normal angiographic findings had corresponding normal CFD study results. Furthermore, all of our patients with normal CFD study results who underwent fibula free flap transfer had no complications.

At the University of Iowa, Iowa City, CFD studies have been used for preoperative assessment of patients who are potential candidates for a fibula free flap since 1997. A history and physical examination findings strongly suggestive of PVD would normally exclude patients from fibula free flap reconstructions without any further workup. In cases in which the patient has no concerning finding in the history and physical examination and normal CFD study results, fibula free tissue transfer is used without further evaluation. If a patient without a history or physical examination suggestive of PVD is noted to have abnormal CFD study results, but the use of the fibula free flap is strongly desired, lower extremity angiography is performed before surgery. However, the value of obtaining an angiogram in this situation is not well defined.

The accuracy of CFD studies in identifying abnormal vascularity is reported in the radiology literature to be 87.5% sensitive in detecting stenotic lesions and 95% sensitive in detecting occluded vessels.[13] Futran et al[5] reported a limited experience with the accuracy of CFD

studies in detecting PVD. In their study, 3 patients with PVD identified by angiography had abnormal CFD study results. Such studies, however, are evaluating patients with suspected vascular disease.This population is different from the patients in our study who are not suspected of having vascular disease and is undergoing imaging to rule out vascular anomalies and silent unsuspected atherosclerotic changes.

In the present study, we found that CFD imaging is extremely accurate in predicting poor donor sites in patients without strong histories of PVD. In this study, there were 18 legs in which the results of CFD imaging were abnormal. Angiography revealed anatomy that was considered high risk for fibula free flap harvest in 16 of these legs and safe in the other 2. Further analysis of the waveform abnormalities revealed that all 14 extremities with at least 1 vessel showing a monophasic waveform or no flow demonstrated high-risk abnormalities on angiography. The angiograms of 2 of the 4 lower extremities with biphasic waveforms revealed anatomy that was safe for fibula free flap harvest. One of the 2 patients involved did undergo an uneventful fibula free flap. The CFD studies identified 10 (67%) of 15 occluded distal vessels. The remaining 5 occluded vessels were identified as having abnormal flow on CFD studies. The CFD studies revealed abnormal monophasic waveforms in all 9 vessels reported as demonstrating stenotic lesions on angiography.

A fibula free flap was performed in 1 patient with a lower extremity in which the results of the CFD study were abnormal and in which angiography demonstrated a high risk. This patient did have 50% stenosis of the proximal posterior tibial artery and 40% stenosis of the proximal peroneal artery. The procedure was undertaken only after consultation with a vascular surgeon, who thought that the harvest could be performed with acceptable risk and who was available for lower extremity revascularization if required. The surgery was performed without complication, but with heightened concerns. In retrospect, other options could have been used, and would be today.

Based on our results, we find that a stratified classification system can be applied to the results of screening CFD studies for potential fibula free flap candidates. Normal CFD study results accurately predict acceptable fibula free flap candidates, and flap harvest can be performed without further evaluation. Abnormal CFD study results, which are defined by monophasic waveforms or no flow in any of the trifurcation vessels, can accurately predict high-risk fibula free flap candidates and exclude patients without any further evaluation. Biphasic CFD studies represent a heterogeneous group that in our small sample was associated with angiographic findings that were considered safe for fibula free flap harvest in 50% of the cases. Further evaluation of such patients should be performed to determine fibula flap candidacy and may be possible by including other noninvasive measures, such as the use of vessel velocities or AAIs, in the decision-making process. Angiography may still be required to adequately assess fibula free flap candidacy.

CONCLUSIONS

Patients with normal CFD study results can undergo fibula free flap transfer without complication. Abnormal CFD study results can also predict high-risk flap candidates in certain instances. Color flow Doppler studies that demonstrate the presence of either monophasic waveforms or no flow in any of the trifurcation vessels can accurately identify high-risk extremities, and potential flap candidates with these findings can be excluded without the need for angiography as a secondary assessment.

Accepted for publication October 18, 2002.

This study was presented at the at the annual meeting of the American Head and Neck Society, Boca Raton, Fla, May 12, 2002.

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