Preoperative Testing for Radial Forearm Free Flaps to Reduce Donor Site Morbidity

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**Objective:** To compare the clinical Allen test, preoperative Doppler ultrasonography, and intraoperative surgical Allen test with postoperative clinical findings in reconstruction of complex head and neck defects using radial forearm free flaps.

**Design, Setting, and Patients:** Retrospective review of 143 consecutive patients who underwent radial forearm free flap reconstruction from January 1, 1992, through December 31, 2006, at Vanderbilt University Medical Center.

**Results:** Flap survival rate was 96.4%. No patients experienced digital necrosis or other findings of acute ischemia. Two patients (1.9%) who had normal results of clinical and surgical Allen tests developed hand contracture and palmar nodule formation. Surgical Allen test findings were normal in all patients who underwent reconstruction. Eighty-two arms had documentation of clinical Allen testing and Doppler ultrasonography in the patients’ medical records. Agreement between these measures was 92.7%. The clinical Allen test result was 100% sensitive and 75% specific in predicting an abnormal Doppler ultrasonographic finding.

**Conclusions:** The clinical Allen test is an appropriate preoperative evaluation before radial forearm free flap reconstruction. The addition of Doppler ultrasonography should be limited to patients with abnormal clinical Allen test results. The surgical Allen test provides reassurance but does not preclude the possibility of ischemic hand complications.


Since the development of flaps, surgeons have rapidly expanded their ability to resect extensive disease and provide multiple reconstructive options. Initially, rotation flaps were designed to transfer adjacent tissue for the closure of defects; however, pedicled flaps gained in popularity for their ability to transfer large amounts of soft tissue relatively long distances. Before the development of free flaps, pectoralis flaps were the most reliable and commonly used among head and neck surgeons. This technique provided nondiseased, nonirradiated tissue for coverage in many low anterior cervical resections, reducing the risk of fistula formation or carotid blowout syndrome. However, to attempt more complex reconstructions, the head and neck surgeon required the ability to transfer tissue of different size, shape, and thickness and the ability to alter the nature of the flap from fasciocutaneous, myocutaneous, or osseocutaneous. Microvascular free tissue transfer techniques have expanded to meet this need. Large studies have demonstrated their safety and efficacy, with 93% \(^1\) and more recently 96.4% flap survival. \(^2\)

Among free flaps, the radial forearm free flap (RFFF) has become one of the most commonly used by microvascular surgeons owing to its versatility and the ease of harvesting. The RFFF has pliability and reduced bulk, and the vasculature is thought to be largely resistant to atherosclerotic disease. Flap survival has been reported to be approximately 97%. \(^3\) Although flap failure is a risk, no preoperative method of predicting success currently exists; in the case of flap failure, other reconstructive options are often available. Among the most feared postoperative complications of RFFF procedures are ischemic hand complications (IHCs). The basis of the RFFF is the redundant blood supply to the hand formed by the radial and ulnar arteries. Both arteries anastomose to form the superficial and deep palmar arteries that branch to form the blood supply to the digits. Acute arterial insufficiency is exceedingly rare but has been reported. In the operative setting, IHC presents with profound pallor followed by progressive darkening as tissues become hypoxemic and necrotic. Rapid intervention with an arterial interposition graft is necessary to prevent severe deficits as sequelae of digital necro-
tracture, particularly in the case of hand trauma.11 were appropriately distinguished from Volkmann con-
selective data, and we cannot know whether these cases
lepsy, diabetes mellitus, carpal tunnel syndrome, a history
clude smoking, alcohol consumption, frozen shoulder, epi-
ronmental predispositions. Environmental factors in-
understood because it appears to have genetic and envi-

Dupuytren disease (DD) is a common fibro-
proliferative disorder affecting the palmar surface of the
hand. Chronic ischemia to the hand has a variable presen-
tation but may include pain, cold intolerance, discolor-
ation, frank ulceration, tissue necrosis, and gangrene of
the digits.3 Typically, these symptoms begin distally at the
fingertips and progress proximally.6 Subacute ischemia may
present as a late finding with Volkmann contracture, most
often described in orthopedics literature. Classic presenta-
tion is with an unrecognized postrumatic compart-
tment syndrome of the forearm, which leads to arterial in-
sufficiency and venous stasis. This pathologic manifestation
results in ischemic muscle degeneration; after 4 to 6 hours,
 irreversible muscle necrosis begins. Inflammatory signal-
results in worsening of the compartment syndrome.

Fibrosis is a late finding, with calcification in its final phase.
The result is a contracted hand with calcified nodule for-
mation.3 Although case reports document this complica-
tion after harvesting the radial artery, the occurrence is so
rare that no frequency has been established.8,9 In a recent
review by Leclère et al.,10 17 patients were treated for non-
traumatic vascular compromise of the hand and a mini-
imum ischemic time of 4 hours, of whom 14 achieved com-
plete remission, 2 developed ulcercation, and 1 had digital
contracture.

Dipryten disease (DD) is a common fibro-
proliferative disorder affecting the palmar surface of the
hands, which is often irreversible and progressive and fre-
quently bilateral. The exact pathogenesis of DD is poorly
understood because it appears to have genetic and envi-
ronmental predispositions. Environmental factors in-
clude smoking, alcohol consumption, frozen shoulder, epi-
lepsy, diabetes mellitus, carpal tunnel syndrome, a history
of manual labor, and hand injury. However, each of these
factors is highly controversial because all are derived from
selective data, and we cannot know whether these cases
were appropriately distinguished from Volkmann con-
tracture, particularly in the case of hand trauma.11

The basis of the RFFF is the redundant blood supply
to the hand via the ulnar and radial arteries to form su-
perficial and deep palmar arches, with the ulnar artery
most commonly the dominant contributor to the super-
ficial arch. The superficial palmar arches occur in
84% to 90% of patients, with considerable variation in
pattern.12,13 In a study by Ruengsakulrach et al.,14 50 ca-
daveric hands were dissected. They demonstrated a clas-
sic complete deep palmar arch in 90% of the hands and
at least 1 major arterial anastomosis between the radial
and ulnar arteries in 100% of the specimens examined.

Despite this reassuring study, clinical experience among
microvascular surgeons is that not all hands are suitable
for harvesting RFFF, and debate exists as to what is the
most appropriate preoperative test. We critically evalu-
ated the reliability of the clinical Allen test (CAT) in 143
consecutive patients and compared the results with those of
Doppler ultrasonography (DUS) and direct intraop-
erative visualization and clamping of the radial artery (sur-
gical Allen test [SAT]). Each of these measures was ex-
amined according to long-term clinical follow-up.

METHODS

This study received approval by the Vanderbilt University Medi-
cal Center institutional review board. We reviewed the med-
cal records of 143 consecutive patients who underwent RFFF
reconstruction from January 1, 1992, through December 31,
2006, at Vanderbilt University Medical Center. All records con-
tained operative reports that documented the SAT results. The
CAT results could not be located for all patients. In addition,
we reviewed reports of preoperative testing with DUS at the
Vanderbilt Vascular Laboratory. Postoperative clinic notes were
reviewed for complications.

Preoperative evaluation included CAT and DUS. Clinical Al-
len testing was performed in the standard manner of the modi-
fied Allen test and categorized according to flow as sufficient
(<5 seconds), indeterminate (6-10 seconds), and insufficient
(>10 seconds). Vascular testing was performed using DUS and
reviewed by a vascular surgeon. In addition to assessing the pal-
mar arches, ultrasonography was used in a similar fashion to
the CAT. The radial and ulnar arteries were compressed and
the hand was exsanguinated. The ulnar artery was released and
reperfusion was visualized sonographically.

Surgical Allen testing was performed after tourniquet ex-
sanguination of the hand and careful dissection and visualiza-
tion of the radial and ulnar arteries. Then the radial artery
was clamped and the tourniquet released, ensuring that all perfu-
sion of the hand was via the ulnar artery. Dichotomous assess-
ment was performed as continuous or noncontinuous flow. This
assessment was considered the criterion standard of sufficient
collateral flow before ligation of the radial artery.

Treatment of the donor site was closed using a split-
thickness skin graft harvested from the lower extremity fol-
lowed by a bismuth-impregnated petrolatum gauze (Xero-
form; Covidien) secured with silk sutures. The hand wrist was
placed in gentle extension with a splint followed by a cast from
below the elbow to the hand. The cast was removed 1 week
postoperatively. Patients were referred for rehabilitational therapy
1 month postoperatively.

All data were recorded in a database (Research Electronic Data
Capture, maintained by Vanderbilt University) and, after de-
identification, underwent statistical analysis by the Vanderbilt
Department of Biostatistics. We compared categorical variables
using the χ² test or the Fisher exact test where appropriate.

RESULTS

One hundred forty-three patients underwent RFFF re-
construction during the study period (Table 1). Of these,
139 patients had flap survival recorded, and 134 under-
went a successful RFFF reconstruction (96.4%). Thirty-
five patients were eliminated from further analysis owing
to incomplete postoperative clinical notes or other missing
data.

Among the initial 143 patients in the cohort, 66.7% Were
male, and the nondominant arm was used as a do-

Table 1. Baseline Characteristics of 143 Patients

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, mean (SD), y</td>
<td>59.1 (14.1)</td>
</tr>
<tr>
<td>Sex, %</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>66.7</td>
</tr>
<tr>
<td>Female</td>
<td>33.3</td>
</tr>
<tr>
<td>Nondominant arm used, %</td>
<td>80.1</td>
</tr>
<tr>
<td>Follow-up, mean (SD), mo</td>
<td>32 (32)</td>
</tr>
</tbody>
</table>
trauma to the nondominant arm. The 108 patients included had a mean follow-up of 32 (SD, 32) months. Documentation of the CAT was available in 90 patients. Two patients in the cohort developed classic findings of hand contraction and palmar nodules (1.9%). Both patients with IHCs had normal CAT results, normal intraoperative findings on examination with release of the tourniquet, and reperfusion of the hand (normal SAT results). Unfortunately, neither of these patients had a preoperative DUS finding available for comparison. Reperfusion of the hand was observed in all cases (positive SAT results). Furthermore, intraoperative reperfusion was considered a prerequisite for proceeding with RFFF reconstruction. However, 3 patients were found intraoperatively to have severely fibrotic or calcified radial arteries. Of these, 2 experienced flap failure (one had no recorded DUS or CAT finding, whereas the other had normal DUS and CAT findings). None of the 3 patients developed IHCs because their ulnar systems appear to have been intact.

The comparison of DUS and CAT results was based on arms rather than patients because some patients underwent 2 RFFF procedures or had documentation of right and left CAT and DUS in the preoperative workup for RFFF. Eighty-two arms were identified as having CAT and DUS findings in their medical records. Overall, we found 92.7% agreement among all measurements. In only 1 arm (1.3%) did DUS fail to demonstrate sufficient vascular flow; that arm had documentation of an incomplete palmar arch. This patient also had insufficient findings on the CAT. Furthermore, no patient had a normal CAT result with an abnormal DUS finding (100% sensitive in detecting an abnormal DUS finding). Of the 82 arms with DUS findings, 4 (4.9%) had indeterminate or insufficient CAT findings, and 3 of 4 also had abnormal DUS findings (75% specific in predicting DUS results) (Table 2). Nine patients had documented radial artery dominance on DUS, with 10 total arms having documented radial artery dominance. Only 1 patient had an associated incomplete palmar arch. This patient also had insufficient CAT findings. Eight of these patients subsequently underwent an RFFF procedure on the contralateral side. One patient was found to have bilateral radial artery dominance (no CAT finding was recorded) and underwent RFFF reconstruction without complication. The CAT result was recorded for 4 of the 10 patients with radial artery dominance; of these, 3 had abnormal CAT findings, as shown in the following tabulation:

<table>
<thead>
<tr>
<th>CAT Result</th>
<th>No. With Radial Artery Dominant on DUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sufficient</td>
<td>1</td>
</tr>
<tr>
<td>Indeterminate</td>
<td>0</td>
</tr>
<tr>
<td>Insufficient</td>
<td>3*</td>
</tr>
<tr>
<td>Not recorded</td>
<td>6</td>
</tr>
</tbody>
</table>

*Indicates abnormal CAT findings.

We then collapsed the tables for examining DUS and CAT by considering indeterminate and insufficient CAT results together as a single “failed” category. This combination demonstrated a high association between the 2 tests (P < .001).

The SAT was performed with the intraoperative release of the tourniquet while the radial artery was clamped and reperfusion was directly observed. In the 143 patients who went to the operating room for RFFF reconstruction, none experienced failure of this test, which would have required abortion of the case. Because no abnormal reperfusion test results were recorded, we could not determine whether DUS or CAT had a higher association.

Radial forearm free flaps are among the most versatile and commonly used free flaps for reconstruction of head and neck defects. They have a very low failure rate and provide thin, pliable soft tissue. Hand ischemia is among the most feared donor site–related complications, but its occurrence is rare, without an accepted incidence. In this study, 2 patients (1.9%) had IHCs. Unfortunately, neither of these patients underwent preoperative, documented DUS. Both patients had directly visualized reperfusion of the hand via the palmar arch while the radial artery was clamped and the tourniquet was released. Other ischemia-related problems reported in the literature include digital ischemia and necrosis, but these were not observed in the present cohort. We found no incidence of abnormal SAT findings in the study group, which would have required abortion of the case. Because of this, we compared SAT and DUS; however, we assumed that the patients who would have had abnormal SAT findings if they underwent the surgical procedure were prevented by appropriate preoperative examination. Because of the ability of DUS to assess the palmar arch objectively, many have considered this method to provide a more sensitive and objective measure of collateral sufficiency. However, no established literature demonstrates the reliability of DUS to predict postsurgical hand ischemia. Despite this lack, if we assume that DUS accurately predicts hand ischemia, this study demonstrates that CAT findings were abnormal in all cases in which DUS demonstrated abnormal flow or incomplete palmar arch. In cases of radial artery dominance but an intact palmar arch, 1 patient had a normal CAT finding, whereas the others demonstrated delayed reperfusion on CAT. Four arms (4.9%) had insufficient or failed CAT findings but normal DUS findings, evidence that DUS may be used in cases of an abnormal CAT result to provide additional assurance of the safety of the surgical procedure.
Finally, the presentation of hand ischemia after radial artery occlusion or ligation is varied, but classic acute presentation would include pain, pallor, and ultimately necrosis of the thenar aspect of the hand. The presentations of subacute and chronic ischemia are less well-defined. No patients in our series presented with acute findings. Hand contraction and the formation of nodules were clinically indistinguishable from DD. Dupuytren disease also results in hand contraction and nodule formation but is etiologically distinct, with myofibroblast-mediated fascial proliferation and thickening.15 Furthermore, risk factors for this condition are male sex, being older than 40 years, alcoholism, and smoking. All these factors are also associated with a higher incidence of malignant neoplasms of the head and neck, making the presentation after RFFF reconstruction difficult to distinguish between DD and ischemia-related contraction. The 2 patients who developed contracture in our series had uneven postoperative courses and indolent development of the hand complications. Because of the unilaterality of disease and the prior surgical intervention in the arm, the presentation was presumed to be secondary to circulatory changes in the hand.

In conclusion, ischemic hand complication after RFFF reconstruction is a rare but concerning possibility. In the presence of a normal CAT finding, no further testing appears to be of benefit; however, patients with abnormal CAT findings may be considered surgical candidates with normal DUS results. Although the SAT finding provides intraoperative reassurance, it does not exclude the possibility of IHCs. Surgeons should counsel patients in the preoperative period regarding the risks and measures taken to prevent IHCs.

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Author Contributions: Dr Burkey had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. Study concept and design: Wood and Burkey. Acquisition of data: Wood, Broussard, and Burkey. Analysis and interpretation of data: Wood and Burkey. Drafting of the manuscript: Wood. Critical revision of the manuscript for important intellectual content: Wood, Broussard, and Burkey. Statistical analysis: Wood. Obtained funding: Wood. Administrative, technical, and material support: Burkey. Study supervision: Burkey.

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REFERENCES