Use of the Radial Artery for Hemodialysis Access

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**Hypothesis:** Under limited conditions, use of the radial artery (RA) for hemodialysis access in patients with end-stage renal disease is safe and effective.

**Methods:** The nondominant upper extremities of 211 consecutive patients with end-stage renal disease were evaluated with duplex ultrasonography to assess RA and ulnar artery (UA) flow contributions to their hands. Diameters and peak systolic velocities were measured in each artery, from which peak flows were calculated. Arteries of less than 2.0 mm in diameter were deemed unusable for access procedures or inadequate as the sole supply to the hand. Flow rates within 20% of each other were considered equivalent, and the RA was dominant if its flow exceeded that of the UA by 20%. Radial arteries with peak flow rates of less than 125 mL/min were judged inadequate, and RAs were not used in patients with peak UA flow rates of less than 100 mL/min.

**Results:** The RA flow was equivalent to the UA flow in 56 patients and was dominant in 120. Flow through the RA was adequate in 166 patients, but 41 had insufficient UA flow contributions and 15 had unsatisfactory UA diameters. Overall, 25 patients had inadequate RA diameters, 72 patients had inadequate UA diameters, and 16 patients had insufficient calibers of both vessels.

**Conclusions:** The RA carried sufficient flow to support a shunt or fistula in 78.7% of patients, but it would have been unwise to use it in about one third of those cases because of potentially insufficient perfusion to the hand by the UA. The RA could therefore be safely used in 49.8% of patients with end-stage renal disease evaluated for hemodialysis access.

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The radial artery (RA) is considered by many to be expendable. This opinion probably stems from early reports that the ulnar artery (UA) is dominant in up to 90% of upper extremities and from anecdotal experience with RA lines and the use of the RA for hemodialysis access. Recent studies, however, have shown that the RA carries as much flow to the hand as the UA and therefore may be more important than previously realized. Because almost all of these studies were carried out on normal volunteers, statements about arterial dominance in patients with renal failure cannot be made conclusively. This study was designed to give guidance as to when the RA can be safely used for hemodialysis access.

**METHODS**

From January 6, 1997, to June 5, 2000, duplex ultrasonography of the RA, UA, and cephalic vein (CV) was performed on all patients with end-stage renal disease referred to the vascular surgery service for hemodialysis access. The nondominant upper extremities were evaluated, if possible. Radial artery, UA, and CV diameters and peak systolic velocities (PSVs) were measured. Peak arterial flows were calculated from the vessel diameter and PSV as the cross-sectional area multiplied by the PSV. Peak RA flows of less than 125 mL/min were deemed too low to support a straight shunt or an arteriovenous fistula. Peak UA flows of less than 100 mL/min were considered to be too low to be the sole contributor to the hand. Any artery of less than 2.0 mm in diameter was considered to be unusable or inadequate for hand perfusion by itself, and flows within 20% of each other were considered equivalent. An artery was considered dominant if it had 20% or greater flow than the comparative artery.

**RESULTS**

During the study, 211 patients were evaluated, 60.7% men and 39.3% women. The mean age was 49.8 years, and there was no statistically significant difference in age between men and women compared with the entire cohort (P=.64 and P=.72, re-
respectively; 2-tailed \( t \) test). We studied the dominant upper extremity in 13 patients because they had central deep venous thromboses or all upper extremity vascular access sites had been used.

The causes of renal failure are shown in Table 1. Hypertension, seen in 84.8% of the study group, was the most common cause. Diabetes mellitus was found in 40.3%, and 34.1% had diabetes mellitus and hypertension. Less common causes were drug abuse (18.5%), glomerular nephritis (10.4%), and human immunodeficiency virus (HIV) in 5.7%. Fifteen percent (15.2%) of patients had other causes of renal failure, including systemic lupus erythematosus, polycystic kidneys, and obstructive uropathy. Many patients had multiple etiologies, and there was no significant etiologic difference between men and women by \( \chi^2 \) analysis (\( P = .78 \)).

The mean RA peak flow was 252 mL/min, and the mean UA peak flow was 173 mL/min (\( P < .001 \), 2-tailed \( t \) test). The mean RA diameter was 2.74 mm, and the mean UA was 2.24 mm (\( P < .001 \), 2-tailed \( t \) test). The mean CV diameter was 2.43 mm.

The RA was found to be dominant in 56.9% of our patients. Stratifying the population into right- and left-handed patients, the RA was dominant in 56.3% and 64.3%, respectively. In the 13 patients who had their dominant extremity studied, the RA was dominant in 69.2%. There were no statistically significant differences between men and women and right- and left-handedness (\( \chi^2 = 0.008, P = .93 \)).

The RA and UA carried equal (within 20%) contributions in 26.5% of individuals. There was no significant difference in this distribution by sex (\( \chi^2 = 0.02, P = .90 \)). The RA exceeded or equaled the UA flow in 83.4% of patients. Stratification by handedness revealed that 83.8% of right-handed patients and 78.6% of left-handed patients had dominant RAs or RA flow that was equivalent to that of the UA (Table 2).

Nearly 79% (78.7%) of our patients had peak RA flow of 125 mL/min, but only 59.2% also had peak UA flow of at least 100 mL/min. Only 49.8% of our patients also had both arteries at least 2.0 mm in diameter in addition to peak RA flow of 125 mL/min. A total of 186 patients had RAs larger than 2.0 mm, 139 had UAs greater than 2.0 mm, and 195 had both their RA and UA greater than 2.0 mm. Making the flow and diameter requirements more stringent, 71.1% of the patients could supply peak RA flow to at least 150 mL/min, but this fell to 48.3% when the minimum peak UA flow was set to 120 mL/min, and to 28.0% when requiring both arteries to be at least 2.5 mm (Table 3).

Forty-five percent of patients had CV diameters of greater than 2.5 mm, and 29.9% had CV diameters of greater than 3.0 mm. Almost 25% (24.6%) of our patients had a CV of 3.0 mm and peak RA flow of at least 125 mL/min. This diminished to 20.9% when requiring peak UA flow of 100 mL/min and arterial diameters of at least 2.0 mm. Requiring the peak RA flow to be 150 mL/min with a CV of 3.0 mm or greater identified only 18.0% of all the patients, and this fell to 13.7% when requiring peak UA flow of 120 mL/min and arterial diameters of at least 2.5 mm (Table 4).

### Table 1. Causes of Renal Failure in 211 Patients Being Evaluated for Hemodialysis Access

<table>
<thead>
<tr>
<th>Cause</th>
<th>Male</th>
<th>Female</th>
<th>Total No. (%) of Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>HTN</td>
<td>113</td>
<td>66</td>
<td>179 (85)</td>
</tr>
<tr>
<td>DM</td>
<td>45</td>
<td>40</td>
<td>85 (40)</td>
</tr>
<tr>
<td>DM and HTN</td>
<td>43</td>
<td>29</td>
<td>72 (34)</td>
</tr>
<tr>
<td>Drug abuse</td>
<td>23</td>
<td>16</td>
<td>39 (18)</td>
</tr>
<tr>
<td>Glomerular nephritis</td>
<td>13</td>
<td>9</td>
<td>22 (10)</td>
</tr>
<tr>
<td>HIV</td>
<td>7</td>
<td>5</td>
<td>12 (6)</td>
</tr>
<tr>
<td>Other</td>
<td>19</td>
<td>13</td>
<td>32 (15)</td>
</tr>
</tbody>
</table>

Abbreviations: DM, diabetes mellitus; HIV, human immunodeficiency virus; HTN, hypertension.

### Table 2. Number of Patients With Radial Artery Flow Greater Than or Equal to Ulnar Artery Flow

<table>
<thead>
<tr>
<th></th>
<th>Male</th>
<th>Female</th>
<th>Total No. (%) of Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>110</td>
<td>66</td>
<td>176/211 (83)</td>
</tr>
<tr>
<td>Right hand dominant</td>
<td>104</td>
<td>61</td>
<td>165/197 (84)</td>
</tr>
<tr>
<td>Left hand dominant</td>
<td>6</td>
<td>5</td>
<td>11/14 (79)</td>
</tr>
<tr>
<td>Studied on dominant side</td>
<td>7</td>
<td>3</td>
<td>10/13 (77)</td>
</tr>
</tbody>
</table>

COMMENT

The RA can serve as a conduit for hemodialysis access in 2 ways: as inflow for a straight shunt or for an autogenous fistula. Considering peak RA flow of 125 mL/min as an acceptable lower limit—because we expect the flow through the RA to achieve at least 200 mL/min as the shunt matures—then 78.7% of our patients had eligible RAs. But this percentage is obtainable only if there is no concern about perfusion to the hand after the operation, especially should the RA be obliterated because of complications after the operation.\(^{25-59}\) With this in mind, adding the requirement that the RA and UA must be at least 2.0 mm in diameter and that the UA must carry at least 100 mL/min peak flow, only 49.8% of the study group could have had their RAs used, which coincides with the percentage that the National Kidney Foundation’s Dialysis Outcome Quality Initiative guidelines suggest.\(^{60-66}\)

Making the requirements for peak RA and UA flows more stringent at 150 and 120 mL/min, respectively, with minimum RA and UA diameters of 2.5 mm resulted in 28.0% of patients being eligible to have their RAs used for hemodialysis access. This low rate suggests that, although these requirements appear reasonable, they may be excessive. Perhaps the RA models to augment flow after shunting flow away from the RA, or the interosseous arteries are more participatory than expected in perfusing the hand, making a low preoperative flow measurement in the UA less important than it would appear. This concept was not investigated in this study, but evaluating the flow contri-
must be able to support the fistula. Nearly 25% (24.6%) of the CV, the peak flow and diameter of the RA and UA of our patients being candidates. In addition to the size diameter requirement to 3.0 mm resulted in only 29.9% CV before attempting a Cimino fistula. Increasing the CV to at least 2.5 mm alone. Many surgeons prefer a larger diameter of at least 2.5 mm. The reason is that we doubt that any CV of less than 2.5 mm will mature sufficiently for use. Forty-five percent of our patients were eligible for Cimino fistulae based on having a CV diameter of 2.5 mm or greater. Increasing the CV to 3.0 mm resulted in only 29.9% of our patients having peak RA flows of greater than 125 mL/min and 3.0-mm-diameter CVs. Requiring that the RA carry at least 100 mL/min peak flow and that both arteries be at least 2.0 mm in diameter resulted in a loss of 8 patients, diminishing the pool of candidates for Cimino fistulae to 20.9%. Had the more stringent criteria of peak RA flow of 150 mL/min, UA flow of 120 mL/min, and RA and UA diameters of 2.5 mm been used, only 13.7% of our patients would have been candidates for Cimino fistulae. This is far below the guidelines of the National Kidney Foundation’s Dialysis Outcome Quality Initiative consensus statement, despite a high percentage of available RAs for Cimino fistulae. This was largely due to inadequate CVs in our population.

The RA carried as much or more flow than the UA in 83.4% of our patients. Clinical experience tells us that hand perfusion is uncommonly impaired, despite the use of the RA for arterial lines, blood gases, ligation in trauma, arterial conduits, free flaps, and hemodialysis access. Even if the RA thromboses from RA manipulation, numerous authors have suggested that it may re-canalize. What, then, is the clinical significance of this high percentage of RA dominance or equivalence? Studying wrist anatomy yields some possible answers (Figure). The hand is supplied by the RA, UA, and 2 interosseous arteries. The RA trifurcates at the wrist. Anteriorly, the RA bifurcates into superficial and deep palmar branches to the hand by the RA and UA after a shunt has been implanted might settle this issue.

One may question why PSV was chosen as a reflection of flow in the vessel when it is roughly 3 times the actual flow in that vessel. The reason is that we wanted an estimation of the maximal flow the vessel could supply after the shunt or fistula was placed. The peak flow in the RA is probably the best estimation of the maximal obtainable flow in it immediately after the operation. In time, the artery and vein are expected to dilate and achieve even greater flows than the PSV would have suggested by virtue of accommodation to higher flow rates.

Before using the RA for inflow into a Cimino fistula, CV patency and diameter must be ascertained. It is doubtful that any CV of less than 2.5 mm will mature sufficiently for use. Forty-five percent of our patients were eligible for Cimino fistulae based on having a CV diameter of at least 2.5 mm alone. Many surgeons prefer a larger CV before attempting a Cimino fistula. Increasing the CV diameter requirement to 3.0 mm resulted in only 29.9% of our patients being candidates. In addition to the size of the CV, the peak flow and diameter of the RA and UA must be able to support the fistula. Nearly 25% (24.6%)

Table 3. Number of Patients With Sufficient Radial Artery (RA) and Ulnar Artery (UA) Flow to Support the Safe Use of the RA for Hemodialysis

<table>
<thead>
<tr>
<th>RA Peak Flow, mL/min</th>
<th>UA Peak Flow, mL/min</th>
<th>RA Diameter, mm</th>
<th>UA Diameter, mm</th>
<th>Total No. (%) of Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>125</td>
<td></td>
<td></td>
<td></td>
<td>166 (79)</td>
</tr>
<tr>
<td>125</td>
<td>2.0</td>
<td></td>
<td></td>
<td>160 (76)</td>
</tr>
<tr>
<td>125</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
<td>120 (57)</td>
</tr>
<tr>
<td>125</td>
<td>2.0</td>
<td></td>
<td></td>
<td>125 (59)</td>
</tr>
<tr>
<td>150</td>
<td></td>
<td></td>
<td></td>
<td>150 (71)</td>
</tr>
<tr>
<td>150</td>
<td>2.5</td>
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<td></td>
<td>150 (71)</td>
</tr>
<tr>
<td>150</td>
<td>2.5</td>
<td></td>
<td></td>
<td>102 (48)</td>
</tr>
<tr>
<td>150</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
<td>89 (42)</td>
</tr>
<tr>
<td>150</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
<td>59 (28)</td>
</tr>
</tbody>
</table>

*Ellipses indicate any.

Table 4. Number of Patients Who Are Candidates for Use of the RA for Cimino Fistulae

<table>
<thead>
<tr>
<th>RA Peak Flow, mL/min</th>
<th>UA Peak Flow, mL/min</th>
<th>RA Diameter, mm</th>
<th>UA Diameter, mm</th>
<th>Cephalic Vein Diameter, mm</th>
<th>Total No. (%) of Patients</th>
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<tbody>
<tr>
<td>125</td>
<td></td>
<td></td>
<td></td>
<td>3.0</td>
<td>52 (25)</td>
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<td>3.0</td>
<td>44 (21)</td>
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<td>2.0</td>
<td>3.0</td>
<td>44 (21)</td>
</tr>
<tr>
<td>150</td>
<td></td>
<td></td>
<td></td>
<td>3.0</td>
<td>38 (18)</td>
</tr>
<tr>
<td>150</td>
<td>2.5</td>
<td></td>
<td></td>
<td>3.0</td>
<td>36 (17)</td>
</tr>
<tr>
<td>150</td>
<td>2.5</td>
<td>2.5</td>
<td></td>
<td>3.0</td>
<td>36 (17)</td>
</tr>
<tr>
<td>150</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
<td>3.0</td>
<td>29 (14)</td>
</tr>
</tbody>
</table>

*Ellipses indicate any.
arches, which anastomose to the UA. Posteriorly, the RA sends off a dorsal carpal branch, which forms the dorsal carpal arch. The anterior and posterior interosseous arteries, like the peroneal artery in the lower extremity, give off branches to the RA and UA in the wrist. If the RA is obliterated at the deep branch, it may have no effect because of collateral perfusion by 1 or both of the other RA branches. Obliterating the RA more proximally at the trifurcation, on the other hand, may have a profound effect if the UA or interosseous arteries or both are insufficient. Even if the UA or interosseous arteries are impaired, loss of RA flow may precipitate remodeling of the remaining vessels and avert ischemia. Alternatively, any 1 of the 3 RA branches may recanalize, or the RA connection to the interosseous arteries may help supply the hand. Still, it would be prudent to rule out the use of the RA in “obvious” cases in which the RA is strongly dominant and collateral perfusion is minimal or nonexistent, which this study suggests occurs more commonly than previously believed.

CONCLUSIONS

The RA carried sufficient flow to support a fistula or shunt 78.7% of the time, but it would have been wise to use it in a third of those cases because of potentially insufficient perfusion to the hand by the UA should the RA be obliterated. The RA could therefore be safely used in 49.8% of our patients with end-stage renal disease being evaluated for hemodialysis access. Because the CV was occluded or too small in 50.2% of patients, the RA was the preferred choice in 51.2% of patients with no other options.

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REFERENCES


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