Creating Arteriovenous Fistulas in 132 Consecutive Patients

Exploiting the Proximal Radial Artery Arteriovenous Fistula: Reliable, Safe, and Simple Forearm and Upper Arm Hemodialysis Access

William C. Jennings, MD

Hypothesis: Dialysis by native arteriovenous fistula (NAVF) clearly offers lower infection rates, fewer procedures, and lower mortality risk compared with access by catheter or graft, in addition to lower cost. However, NAVFs are utilized for vascular access in only 30% of hemodialysis patients in the United States. Wrist NAVFs are not feasible or successful in many patients and upper arm brachial artery NAVFs may be impractical or lead to additional procedures or complications. Careful preoperative evaluation of all options for NAVF construction including the proximal radial artery (PRA) as an arterial inflow site will find most, if not all, patients to be candidates for successful NAVFs.

Design: Retrospective review of consecutive operations for hemodialysis access performed by an individual surgeon from May 2003 to November 2004.

Setting: Two university-affiliated tertiary medical centers.

Patients: All patients underwent preoperative ultrasound evaluation by the operating surgeon. A wrist fistula was first choice for access when success was predicted by ultrasound and physical examination. The second choice, and most common operation, was a PRA NAVF with distal forearm (retrograde) flow established by disrupting the initial venous valve using a vessel probe.

Results: One hundred thirty-two patients aged 11 to 90 years (mean = 61) were reviewed. Sixty-eight patients had diabetes and 61 were female. Thirty-four had previous failed access surgery. Native arteriovenous fistulas were created in all patients. No grafts were used. A PRA NAVF was utilized in 105 operations. Overall (assisted) patency was 97%, with a mean follow-up of 11 months. Importantly, there were no infections or hospitalizations due to the NAVF access operations.

Conclusions: No grafts were used in this series of 132 consecutive patients. The PRA NAVF was the most common operation and an important addition to wrist, brachial, and transposition fistulas. Proximal radial artery NAVFs increase the opportunity for construction of successful NAVFs and are reliable, safe, and simple procedures with access sites often available in both the forearm and in the upper arm.

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The National Kidney Foundation Kidney Dialysis Outcomes Quality Initiative (NKF/DOQI) clinical practice guideline recommends native arteriovenous fistulas (NAVFs) as the best hemodialysis access. The NKF/DOQI practice guideline’s order of preference for vascular access is (1) radial artery–cephalic vein NAVF at the wrist (Brescia-Cimino fistula); (2) brachial artery–cephalic vein NAVF (upper arm NAVF); (3) arterial-venous graft or transposed brachial artery–basilic vein fistula; and (4) cuffed tunneled central venous catheters should be discouraged as permanent vascular access.

Compared with grafts or catheter-based dialysis, NAVFs offer longer patency rates, fewer interventions, infections, ischemic complications, and overall lower mortality rates. In addition, NAVF access has significantly lower costs than grafts or catheters. Despite these clear data indicating that NAVFs offer best practice vascular access, only 30% of patients undergoing hemodialysis in the United States use a NAVF for access. The rates of NAVF use in Europe and Japan are generally much higher than in the United States, although some US investigators have reported significant improvement and success in NAVF construction. With vascular access costs in excess of $1 billion per year in the United States, increasing the use of NAVFs is particularly important.
Successful wrist NAVFs are not feasible in many patients. Several reports have found wrist fistulas often fail or fail to mature, frequently owing to previous venous catheters or issues such as diabetes, peripheral vascular disease, and advancing age. Gracz et al reported mid-arm NAVFs in 1977; modified by others, these procedures extended opportunities to establish NAVF access. The brachial artery has generally been used as the arterial inflow site for mid-arm fistulas, usually offering upper arm access only. Establishing retrograde NAVF flow via the median cubital vein by disruption of venous valves further added to the opportunity for dialysis access, most often in the upper arm. Kooner and other authors have reported using the proximal radial artery (PRA) for NAVF inflow. In a previous report, we found the PRA NAVF to be safe and reliable. In those 73 patients with PRA NAVFs, 1-month patency rate was 98% and cumulative patency was 80% during follow-up of up to 42 months. Our use of preoperative ultrasound venous mapping was evolving during that time and we reported its importance in creating NAVFs.

This current study reviews a series of consecutive patients evaluated for hemodialysis access with the intent to avoid grafts in each individual. Careful preoperative evaluation of all options for NAVF construction, including the PRA as an arterial inflow site, was important in the care of these patients.

METHODS

All patients operated on for dialysis access from May 2003 to November 2004 have been included in a vascular access database detailing each patient’s preoperative evaluation, operative procedure, and follow-up information. All patients underwent preoperative ultrasound during their initial clinical evaluation. Operations were performed on an outpatient basis unless the patient was hospitalized for other reasons.

A radial-cephalic NAVF at the wrist was created as first choice when basic criteria were met: (1) a normal and uninterrupted forearm cephalic or median antebrachial vein 2.5 mm or larger in diameter by clinical and ultrasound evaluation and (2) a normal radial artery by clinical examination 2.0 mm or larger in diameter by ultrasound examination. If a wrist NAVF was not predicted to be successful, a PRA NAVF was the second access choice using the same vessel criteria (Figure 1). When creating a PRA NAVF, retrograde (distal forearm) flow from the fistula was established by placing a vascular probe through the initial retrograde valve, rendering it incompetent and allowing flow through the median antebrachial vein toward the hand.

Retrograde flow through the median antebrachial vein is easily accommodated by communicating branches to the deep venous system and through the cephalic and basilic veins. Brachial or transposition NAVFs were used when proximal or distal radial artery procedures were not possible.

Access patency was calculated to the end of the study period, death, transplantation, change to peritoneal dialysis, or loss to follow-up. Technical success was defined as full use of the NAVF 2 months after operation for repetitive hemodialysis access, or in those patients not yet requiring hemodialysis, clinical examination finding the NAVF ready for use. Local anesthetic with sedation was used routinely for NAVF construction. Axillary blocks were used occasionally for transposition procedures. Right- or left-handedness was considered secondary to best available vessels in selecting the extremity for NAVFs. During surgical follow-up, if a NAVF was not mature or clearly progressing to maturity by 1 month, physical and ultrasound examination findings were reviewed with the interventionalist and a fistulagram was obtained. Perioperative antibiotics were used only with transposition procedures.

ANASTOMOTIC TECHNIQUE FOR PRA NAVFs

The arteriotomy and venotomy sites must be carefully chosen and aligned to guard against twisting or distortion when the anastomosis is completed. The anastomosis length is approximately 5 to 8 mm, 2 to 3 times the internal diameter of the PRA. The length of the anastomosis for a PRA NAVF is not as important as vessel quality, diameter, and technique. If the size or quality of the PRA is marginal, the anastomosis may be best constructed where the PRA is largest, directly adjacent to the brachial artery and proximal to the recurrent radial artery. Suture technique throughout the anastomosis is critical, particularly at each end, incorporating only small amounts (≤1 mm) of tissue with each needle pass and using careful radial positioning of the suture as the corners are created. When an anastomosis is constructed in smaller vessels such as these, the amount of tissue incorporated in the suture becomes exponentially important in successful outcomes. A “back wall first” technique is generally used in these small vessels, similar to the method described by Tellis et al. This involves initiating the suture in the mid portion of the back wall and, using a running suture technique, closing the back wall from the inside of the anastomosis and then completing each corner (Figure 3). The front wall closure is completed with this same continuous running technique, tightening the suture except for the last 2 suture passes, which are placed but left loose to allow...
for introduction of an appropriate-sized vessel probe. The probe is passed through both proximal and distal venous outflow channels and proximal and distal arterial conduits. This allows flushing to remove any residual debris or clot and may relieve vessel spasm or detect a misplaced suture. Polytetrafluoroethylene suture (Gore-Tex; W. L. Gore and Associates Inc, Flagstaff, Ariz) is used routinely. Its handling characteristics allow precise tissue approximation, yielding a dry anastomosis without purse stringing or distortion. Clearly, other suture material and techniques such as interrupted suture, running segment suture, or vascular clips may be used successfully.

ESTABLISHING RETROGRADE FLOW FOR PRA NAVFs

After a venotomy is made in preparation for the anastomosis, a probe is passed distally through the vein identifying the first valve, which is usually seen within the incision (Figure 3A). The vessel probe is used to engage the valve leaflets under direct vision. Gently passing the tip of the probe along the inner wall of the vein until a valve leaflet is encountered, the probe is then pushed through the leaflet, carefully applying pressure directly along the center axis of the vein to prevent perforation. The probe is then passed on the opposite wall of the vein to encounter the opposite leaflet and the process is repeated. The valve may also be disrupted by a similar process using a gently curved Titus needle, injecting heparinized saline to distend the vein and fill the valve leaflets, making engagement of the valve a bit easier. As with the probe, the blunt tip of the Titus needle is forced through the valve leaflet in line with the axis of the vein to prevent perforation. After this initial valve is rendered incompetent, heparinized saline irrigation shows in most patients that flow is now present in a retrograde fashion through the median antebrachial vein with outflow through collateral vessels. In patients for whom retrograde flow is not clearly established, angiography through the venotomy site may be necessary to safely pass a probe further, or a valvulotome may be used through a distal counter incision if establishing forearm (retrograde) outflow is important. A short angioscopy film clip is available for viewing at our surgery department’s Web site: http://tulsa.ou.edu/surgery/fistula/index.htm.

RESULTS

One hundred forty-two consecutive vascular access operations were performed on 136 patients at 2 tertiary medical centers. Four patients were excluded from the final access analysis. They had access operations performed by other surgeons elsewhere and were referred for excision of infected graft segments or NAVF problems requiring ligation or revision because of steal syndrome or change to peritoneal dialysis. Six procedures were same-site revisions yielding 134 specific access site operations in 132 patients for analysis.

Age range was 11 to 90 years (mean=61). Table 1 shows other patient demographics. Native arteriovenous fistulas were created in all patients. No grafts were used. Table 2 lists the operations according to arterial inflow site. Overall (assisted) access patency during this period was 97% with a mean follow-up of 11 months. Fifteen successful NAVFs had occluded segments salvaged by surgical revision (n=4) or interventional techniques/angioplasty (n=11). Table 3 shows access patency according to type of operation. Figure 4 shows cumulative access patency.

Table 1. Demographics of 134 Patients With NAVFs

<table>
<thead>
<tr>
<th>Demographic</th>
<th>Count</th>
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<tbody>
<tr>
<td>Female</td>
<td>61</td>
</tr>
<tr>
<td>Diabetic</td>
<td>68</td>
</tr>
<tr>
<td>Obesity</td>
<td>31</td>
</tr>
<tr>
<td>Previous access ops</td>
<td>34</td>
</tr>
<tr>
<td>≥2 Access operations</td>
<td>25</td>
</tr>
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Abbreviation: NAVFs, native arteriovenous fistulas.
Four patients died with patent NAVFs of causes unrelated to dialysis access during the follow-up period. Five patients changed to peritoneal dialysis or underwent a successful transplantation with functioning fistulas. One patient was lost to follow-up with a functioning NAVF at 9 months. Forty-nine patients had a NAVF constructed in the dominant-handed extremity. Nineteen patients had a previous failed access in the same extremity as the new NAVFs reported here.

Four fistulas failed and were not salvaged during the follow-up period. Two of these patients had successful NAVFs created at different sites in the same extremity. The other 2 patients elected to maintain dialysis access with a central venous catheter. One of these was a chemotherapy patient with recurrent cancer and the other had significant congestive heart failure and several failed access attempts elsewhere.

Two patients had mild steal syndrome postoperatively. Both had complete resolution of symptoms by ligation or occlusion by coil placement of enlarged median cubital vein outflow branches, previously left open intentionally to augment flow. Both fistulas remain functional. One patient developed a benign skin lesion (angioendotheliomatosis) that was excised from the NAVF arm. Her NAVF remains functional. One patient was observed briefly for postcannulation bleeding from a mature fistula. Transfusion was not required. His fistula remains functional and no further bleeding episodes have occurred after review of cannulation sites and technique with the dialysis staff. An additional patient had a brief period of observation following successful fistulography and angioplasty. Three patients with PRA NAVFs had mild to moderate upper extremity swelling that resolved with observation, ligation of a competitive outflow vein, angioplasty of a central venous stenosis, and/or removal of central catheters. Infectious complications were not encountered with these dialysis access procedures and no hospital admissions for complications of the dialysis access operations occurred.

The PRA was the most common anastomotic site (n = 105). Overall patency for PRA NAVFs was 97.1%. The median antebrachial vein was used for venous outflow as a side-to-side anastomosis in 66 fistulas (62.8%). The deep communicating vein, median antebrachial vein, median cephalic vein, or other vein was utilized for venous outflow with an end-to-side technique in the remaining 39 operations (37.2%). Establishing retrograde flow into the forearm during PRA NAVFs was done by simple passage of a vessel probe in 80 operations (76%). Disruption of multiple distal venous valves to achieve retrograde flow was augmented by angioscopy or valvulotomes in 25 patients. Seventeen PRA NAVFs were constructed with either the upper arm or the forearm venous segment as the only accessible outflow tract.

Evaluation of technical success found that NAVFs were constructed in 22 patients who had not yet started dialysis. These fistulas have been determined to be technically successful. Eighty-six patients have NAVFs that have been used successfully for repeated dialysis access. Sixteen NAVFs are patent and maturing. Ten of these are within 2 months of the operative procedure and 3 await secondary transposition. All are expected to reach technical success in the next 1 to 2 months. Six patients received a transplant or died. Four NAVFs failed, and 2 of these patients are using catheters without a NAVF.

Increasingly, patients in need of dialysis access are older, chronically ill, and more likely to be obese and/or diabetic. The mechanics of treating their multiple medical problems leads to repeated venipunctures and intravenous therapy long before the need for a NAVF is recognized. These difficult access patients are well represented in this report as evidenced by the percentage of patients with diabetes, obesity, and previous access procedures. Several reports have found significant NAVF failure rates both overall and in these specific sub-

<table>
<thead>
<tr>
<th>Table 2. Vascular Access Operations According to Arterial Inflow Site</th>
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<tr>
<td><strong>No. of Operations</strong></td>
</tr>
<tr>
<td>Direct AV fistulas</td>
</tr>
<tr>
<td>Distal radial artery (wrist/Brescia-Cimino)</td>
</tr>
<tr>
<td>Proximal radial artery</td>
</tr>
<tr>
<td>Brachial artery</td>
</tr>
<tr>
<td>Transposition AV fistulas</td>
</tr>
<tr>
<td>Radial artery/basilic vein</td>
</tr>
<tr>
<td>Brachial artery/basilic vein</td>
</tr>
<tr>
<td>Femoral artery/saphenous vein</td>
</tr>
<tr>
<td>Total</td>
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Abbreviation: AV, arteriovenous.

<table>
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<th>Table 3. Access Patency in 134 AV Fistulas</th>
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<tr>
<td><strong>Overall (Assisted) Patency, %</strong></td>
</tr>
<tr>
<td>Direct AV fistulas</td>
</tr>
<tr>
<td>Distal radial artery (wrist/Brescia-Cimino)</td>
</tr>
<tr>
<td>Proximal radial artery</td>
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<tr>
<td>Total</td>
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Abbreviation: AV, arteriovenous.

Fig 4. Life-table display for primary and secondary arteriovenous fistula patency. Line numbers are fistulas at risk in a given interval.
Wrist fistulas (Brescia-Cimino) have been found by some investigators to have particularly high failure rates.\textsuperscript{16,29,33} Guidelines from the NFK/DOQI recommend a brachial artery NAVF as the second option when a wrist fistula is not possible or fails. Brachial artery NAVFs are generally created using an end-to-side technique resulting in upper-arm fistulas without the potential for forearm hemodialysis access. They pose a risk of developing steal syndrome and some will require ligation, banding, or bypass.\textsuperscript{5,34-37} Complications have been reported in up to 47\% of these patients, and fistula maturation may take as long as 6 months.\textsuperscript{38-40} Upper-arm NAVFs are difficult or impossible to access in obese patients and may require an exteriorization procedure.\textsuperscript{40}

Ultrasound examination has become a key element in preparation for dialysis access surgery and increases the percentage of NAVFs created.\textsuperscript{28,41-48} Patients in this report were evaluated preoperatively with ultrasound by the operating surgeon during their initial office visit. This direct observation of the vascular anatomy was critical in selecting the best site and strategy for creating a successful NAVF. Most patients are not suitable candidates for a classic Brescia-Cimino fistula at the wrist, as determined by physical examination and ultrasound evaluation.\textsuperscript{3,16,29,33,45} Oftentimes, the cephalic vein or it may have an interrupted segment (< 2.5 mm by ultrasound). The vein may be too small or it may have an interrupted segment that will prevent maturation of the fistula. In addition, the radial artery at the wrist may be inadequate for a direct anastomosis.\textsuperscript{40} Frequently, one extremity may offer good access opportunity after ultrasound examination of the opposite arm was not promising. The impact of avoiding NAVFs that are destined to fail is dramatic.

After ultrasound screening, if a wrist NAVF is not possible, one proximal forearm or the other will almost always offer an opportunity for a PRA fistula. The PRA is easily mobilized to an anterior position allowing a tension-free anastomosis. Arterial inflow is reliable, and a side-to-side anastomosis to the median antebrachial vein or an end-to-side anastomosis to the communicating vein allows dialysis access both in the upper arm and, in a retrograde fashion, in the forearm. Creating a NAVF at the PRA site allows the surgeon to consider ligation of major side channels such as an unused deep communicating vein or the median cubital vein. Preventing outflow into nondialysis venous channels may lead to earlier maturation of the fistula. Retrograde flow is established into the median antebrachial vein by disruption of the first valve with a small probe. Flow into both the upper and forearm venous segments offers the potential for continued and uninterrupted vascular access should one of the outflow branches fail. Proximal radial artery fistulas minimize the risk of steal syndrome and are routinely accomplished with local anesthetic and sedation. Prophylactic antibiotics are not needed with these simple NAVFs.\textsuperscript{47}

Finally, efforts to achieve reliable NAVF access require follow-up by the surgeon. Patients are generally evaluated 1 week postoperatively and again in 1 month, prior to initial access utilization. Most visits are brief and of little consequence. However, the later patient visits may detect a problem that results in some action. This might simply be additional short-term follow-up, a call to the dialysis nursing staff for information, or an imaging study. If there is any question about the size or location of the targeted fistula outflow segments, access sites are marked using ultrasound, prior to initial use of the fistula. Diligent follow-up is necessary to ensure that central venous catheters are removed as quickly as possible. If the NAVF is not clearly maturing, physical examination and ultrasound often localize the problem, and a fistulogram is obtained. Clear and specific communication with the vascular interventionalist is critical for success. This includes the operative procedure details, abnormal physical findings, ultrasound results, and a summary of clinical problem(s) to be solved. Most of these nonmaturing NAVFs can be successfully treated with angioplasty.

No grafts were used in this series of 132 consecutive patients. The PRA NAVF was the most common operation and an important addition to wrist, brachial, and transposition fistulas. Proximal radial artery NAVF increase the opportunity for construction of successful NAVFs and are reliable, safe, and simple procedures with access sites often available in both the forearm and in the upper arm.

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Successful vascular access surgery requires experience, precision in technique, patience, and most of all, innovation. As described by Jennings, the results of the proximal radial artery to distal forearm vein (reverse) AV fistula exemplify the best current outcomes in NAVF construction. On a regional basis, the prevalence of NAVFs in use for hemodialysis in North America is low, in the order of 40%, when compared with Europe and Australasia. A recent report1 on the almost 12000 patients in the southeastern Network 13 showed the overall prevalence of NAVFs to be 28.2% and use of central catheters to be 29.7%. A careful reading of Jennings’ methods gives us another technique to improve our rate of NAVF construction.

Although described previously, the reversed venous outflow fistula has not received wide application perhaps because of concern that the forearm would swell. Fortunately, this was not a problem in Jennings’ series. This direct arteriovenous anastomosis has several advantages over vein transposition: less dissection, earlier maturation of the in situ vein, less chance of twisting or kinking of the vein which can occur in translocation, reduced symptomatic steal syndrome, and a better access position on the arm for comfortable hemodialysis. The great benefit, however, is the secondary patency rate of 97% after 18 months. Kinking of the vein which can occur in translocation, reduced symptomatic steal syndrome, and a better access position on the arm for comfortable hemodialysis. The great benefit, however, is the secondary patency rate of 97% after 18 months.

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