Salvage of the Nonfunctioning Arteriovenous Fistula
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- Two factors are necessary for an arteriovenous fistula (AVF) to be usable as dialysis access. It must have adequate blood flow, and it must have a size that will allow for cannulation. An AVF can remain patent in the face of relatively low blood flow. For effective dialysis, the AVF only has to deliver a blood flow that is marginally greater than the pump rate. Unfortunately, dialysis may not be technically possible in these cases with lower flow because the AVF does not mature sufficiently to a size adequate for cannulation.

In 1996, failure of AVF development was the result of venous stenosis and/or the presence of accessory veins (venous side branches). The presence of these anomalies could be diagnosed by physical examination. After documentation by angiography, the patients were treated with angioplasty, venous ligation, or a combination of both. Three levels of venous ligation were performed depending on individual requirements: ligation of accessory veins (AVL), ligation of the median cubital vein, and temporary banding of the main fistula itself. The determining factor was the appearance of the fistula after each of the procedures was accomplished relative to potential for cannulation. Of these 63 patients with nonfunctional fistulae that ranged in age from 33 to 418 days, access was salvaged in 52 patients (82.5%). This included 9 of 12 patients who required repeat procedures. The results of this study validate angioplasty and AVL as therapy for the salvage of AVFs that fail to develop.

INDEX WORDS: Dialysis; dialysis access; angioplasty; arteriovenous fistula

MATERIALS AND METHODS

Design of Study

Recently, an attempt has been made to increase the number of AVFs in patients receiving dialysis treatments at our facility. As a result of this effort, a larger number of marginal cases have been attempted. In general, fistulae were not used before 3 months had been allowed for maturation; however, they were evaluated before that time to determine if they were going to be usable. If a fistula was not developing by 30 days or if it did not develop adequately for use over time, it was considered a candidate for a salvage procedure. The determining factor was whether it could be cannulated. If a fistula appeared on physical examination to have adequate inflows but appeared to be affected by venous stenosis, accessory veins, or both, the patient was scheduled for a fistulogram and possible treatment.

Possible treatment modalities consisted of percutaneous angioplasty (PTA), accessory vein ligation (AVL), median cubital vein ligation (MVL), and temporary banding of the main venous channel, i.e., mainstream banding (MSB). The latter three procedures were used in a stepwise fashion as required. If the fistula appeared to be usable after the AV procedure, nothing more was done. If it still appeared to be less than optimal for cannulation, the MVL procedure was

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performed. If it was still suboptimal, the VISI technique was performed. The determining variable was the size of the fistula and its potential for cannulation as judged by the operator at the time of the procedure. All the fistulae, both radiocephalic and brachiocephalic, were created by an end-to-side anastomosis. None of the fistulae involved in this study were usable for dialysis before evaluation and treatment.

Definitions
Venous stenosis was defined as a 50% or greater decrease in lumen diameter based on a comparison with the adjacent normal vein. An accessory vein was defined as a branch coming off the main venous channel that comprised the fistula. A successful fistula was defined as one that could be cannulated and could support a dialysis blood flow of at least 350 ml/min without recirculation for a minimum period of 90 days. The duration of functional patency was defined as the period of time that the fistula could be cannulated successfully and support a dialysis blood flow of at least 350 ml/min without recirculation.

Procedures Performed
 Fistulogram: A fistulogram was performed as follows: the fistula was entered just above the arterial anastomosis using a Micropuncture needle (Cook, Bloomington, IN). The micropuncture wire was introduced into the vein and was used to introduce a 5 Fr dilator. Contrast was injected through this dilator to visualize the fistula and draining veins up to the level of the subclavian. By occluding the fistula upstream from the tip of the dilator, the distal vein, arterial anastomosis, and distal artery were visualized.

PTA (Fig 1): A PTA (Fig 1) was performed as follows: if the stenotic lesion was upstream from the cannulation site, a Bentson guidewire (Cook) was introduced through the dilator that had been placed at the time of the preceding fistulogram. This wire was used to pass the angioplasty balloon. A sheath was not used, and the patient was not anticoagulated with heparin. If the lesion was at or downstream from the cannulation site, a second site was chosen far enough upstream to allow for easy retrograde access to the stenosis. This was entered using a Micropuncture needle. Either a Bentson or a Roadrunner (Cook) guidewire was used to cross the lesion. A 6-mm by 4-cm angioplasty balloon (HilalMax, Medi-Tech, Watertown, MA) was used to treat the stenotic lesion(s). Dilatations of 10 atmospheres were routinely used. Occasionally, a greater pressure of 15 or 20 atmospheres was required. After treatment, a repeat angiogram was performed to evaluate the results of the PTA.

MVL: An MVL (Fig 2) was performed as follows: when the initial fistulogram was performed, all accessory veins present were identified and their position was marked using a sterile felt-tip pen. A small incision was then made across the marked site. The vein was identified and ligated with a 4-0 silk tie. A repeat angiogram was performed to verify the result. The incision was then closed with a 4-0 suture.

MVE: The MVE procedure was identical to that for accessory veins. If the fistula did not have the desired appearance after the MVL procedure, the median cubital vein was identified using angiography and marked using a sterile
felt-tip pen. A small incision was then made across the marked site. The vein was identified and ligated with a 4-0 silk tie. A repeat angiosgram was performed to verify the result. The incision was then closed with a 4-0 suture.  

The MSB procedure was performed as follows: if the fistula size was not judged adequate after other procedures, this operation was performed. First, a 4-mm angioplasty balloon was inserted over a guidewire. The balloon was passed up to a point just below the bend of the elbow (Fig 3A). An incision was made over the fistula at this point.
and the vein was isolated. The balloon was then inflated to 10 atmospheres. A 5-0 Vicryl (Ethicon, Somerville, NJ) was placed around the fistula using the inflated balloon as a stent. After the ligature was firmly tied, the balloon was deflated and removed, leaving a point of marked venous stenosis (Fig 3B). An angiogram was then performed to verify the result and ensure that the fistula was not occluded. This was a temporary band; Vicryl resorbs in 3 to 4 weeks.

MSB was used as a procedure of last resort. It was used only if it was apparent that the fistula was not usable after all else had been done. Patients were examined 3 to 4 weeks after the procedure to evaluate the status of their fistula.

Sedation and Analgesia

Patients were sedated for all procedures except angiography. Midazolam (Versed: Roche Laboratories, Nutley, NJ) and ketamine (Abbott Laboratories, North Chicago, IL) were used for this purpose. Patients were continuously monitored by electrocardiography, blood pressure, and pulse oximetry while sedated.

Collection of Data

Data collected on these patients included patient age, primary disease, date fistula was created, location of fistula, if fistula become usable, date usable fistula was first used, duration of functional patency, and details of the procedures performed. The Kaplan-Meier method was used to calculate life-table analysis data.

RESULTS

During the 3.5-year period of this study, 71 patients were identified that had AVFs that did not develop adequately for use. Eight patients either had a weak pulse or no pulse at the arterial anastomosis. These were believed to have inadequate inflow. They were not studied further. Sixty-three of these patients were believed to have adequate arterial flow by physical examination. They were the subjects of this study. The average age of these 63 patients was 56.8 years (range, 24 to 89 years; median, 59 years). The range and frequency of primary diseases are shown in Table 1. Sixty percent had diabetes.

Table 1. Primary Renal Diseases

<table>
<thead>
<tr>
<th>Disease</th>
<th>No. of Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diabetes mellitus</td>
<td>37</td>
</tr>
<tr>
<td>Hypertensive renal disease</td>
<td>7</td>
</tr>
<tr>
<td>Polycystic</td>
<td>2</td>
</tr>
<tr>
<td>Chronic glomerulonephritis</td>
<td>2</td>
</tr>
<tr>
<td>HIV renal disease</td>
<td>2</td>
</tr>
<tr>
<td>Chronic analgesic abuse</td>
<td>1</td>
</tr>
<tr>
<td>Lupus</td>
<td>1</td>
</tr>
<tr>
<td>Multiple myeloma</td>
<td>1</td>
</tr>
<tr>
<td>Pyelonephritis</td>
<td>1</td>
</tr>
<tr>
<td>Unknown</td>
<td>7</td>
</tr>
</tbody>
</table>

Abbreviation: HIV, human immunodeficiency virus.

Forty-three patients had a left radiocephalic; 13 patients had a right radiocephalic; 4 patients had a left brachiophelial, and 1 patient had a right brachiophelial fistula. Although a lack of adequate development was apparent 30 days after creation, treatment was frequently delayed. The mean interval between fistula creation and intervention was 149 days (range, 33 to 418 days; median, 126.5 days). In only five patients was the interval less than 60 days. In one patient, transferred from another center, the fistula had been in place for 418 days. Interventional procedures were performed on all 63 patients. The types and numbers of procedures performed are listed in Table 2.

Angioplasty was performed in 21 patients. The distribution of the treated lesions is shown in Table 3. The vein immediately adjacent to the arterial anastomosis (Fig 1A) was affected in 85.7% of these 21 patients. Angioplasty was successful (Fig 1B) in all except one instance. Vein ligation was performed in 52 patients. A single accessory vein was present in 40.4% of the patients (Fig 2A). Multiple veins were present in the remainder. One patient had six accessory veins. The number of veins ligated in each patient is shown in Table 4. In all cases of MSB, the stricture created by the procedure (Fig 3B) was gone by 3 to 4 weeks and left no residual stenosis. In the two MSB failures, it was possible to cannulate the fistula; however, flow was inadequate to support dialysis. Physical examination of the MSB patients at 3 to 4 weeks postprocedure showed that the stricture was no longer evident and no stenosis was present.

All the successive procedures were not performed during the same session, as shown in Table 5. Additional procedures were required in 12 cases (19%). Of these, only nine cases (75%) could ultimately be used for dialysis. The total success rate for the 63 patients was 82.5% (52
cases). The interval between the time of the procedure and use of the fistula was a mean of 25.5 days (range, 2 to 68 days; median, 22 days). The time between the creation of the fistula and its use was a mean of 174.6 days (range, 72 to 444 days; median, 151 days). In 5 of the 11 failed procedures, a brachiocephalic fistula was created after failure of a radiocephalic fistula to develop adequately for use despite these interventions. In all these cases, the secondary AVF was successful. The success rates for the various individual and combinations of procedures is shown in Table 2.

The duration of functional patency is shown in Fig 4. At 90 days, 82.5% of the fistulas were in use (the definition of success). At 6 months, 78%, and at 1 year, 74.7% were still functionally patent. These losses were caused by a progressive decrease in flow to a point at which effective dialysis could not be performed, or the access thrombosed.

**DISCUSSION**

AVF development is dependent on two factors: there must be inflow adequate to support effective dialysis and there must be vein maturation adequate to allow for repeated cannulation with a 15- or 16-gauge needle. Both are essential for successful AVF access. These are separate problems in one sense, but they are so closely linked that they must be considered together. An AVF can remain patent in the face of relatively low blood flow. For effective dialysis, the AVF must have a valveless inflow that is larger than the inflow pressure, adequately developed.
original cases of this evaluation. These problems can usually be diagnosed before surgery is performed through physical examination and other noninvasive procedures, such as upper extremity pressures and duplex ultrasound mapping. Of the two major types of AVFs, the radiocephalic and the brachioccephalic, the former is more often associated with poor inflow.

The optimum venous anatomy for AVF development is a single cephalic vein stretching from the wrist to the antecubital space. In many instances, however, this is not the case. The cephalic vein may have one or several side branches. We have chosen to refer to these as accessory veins rather than collateral veins because they are part of the normal anatomy of the patient in whom they are found. In this series, we saw as many as six of these accessory veins (Table 4). Each of these accessory veins diverts blood flow from the main channel. This has the effect of reducing resistance and reducing blood flow to the vein above the level of the branches. This in turn reduces the pressure on the vein wall that is essential for expansion, dilation, and arterIALIZation to occur. Ligation of these accessory veins redirects flow and promotes the development of a usable AVF. Unfortunately, the increase in resistance that occurs with vein ligation also results in some decrease in flow. The significance of this decrease depends on the individual situation. As noted in this study, it is possible to create a fistula that can be cannulated, but does not have adequate flow to support dialysis.

Inadequate development of an AVF can also be caused by venous abnormalities. The development of venous stenosis is not as common in association with fistulae as it is with grafts. However, it can occur and occur quite early, as shown in this series. The most common site of occurrence is adjacent to the arterial anastomosis. These lesions can result in failure of the AVF to develop or in its loss after it has developed. This lesion was present in 85.7% of the 21 patients in this study who had venous stenosis (Table 3). The cause of this lesion is not clear. However, when the fistula is created, this portion of the vein is relatively skeletonized and is manipulated. It is possible that it may also be subjected to traction or torsion during this process.

Ligation of the median cubital vein provides two functions. First, it increases the resistance to flow within the AVF, causing dilatation of the vein. Second, it diverts all flow to the cephalic vein of the upper arm. This serves to develop that vein for future use. In 5 of the 11 failed accesses in this series, a successful brachiocephalic fistula was created after failure of a radiocephalic fistula. It was observed that if the AVF was not salvaged by the initial procedure, it was worthwhile to reevaluate the patient. Additional procedures were performed in 12 cases (Table 5) and were successful in 75%.

The three variants of vein ligation used in this study were used in a stepped approach. If the AVF appeared to be of adequate size to allow for cannulation after the accessory veins were ligated, the procedure stopped there. If its size was still judged to be inadequate, the median cubital vein was ligated. If the AVF was still believed inadequate, MSB was used. This was the procedure of last resort. By this point, it was obvious that inflow was definitely less than optimum. MSB was successful in only three of five cases. The AVF could be cannulated in the two failures, but flow was not sufficient to allow for effective dialysis.

Angioplasty, either alone or in combination with various forms of vein ligation, was very successful in fistula salvage. In this series of 63 patients with unusable AVF, the access was salvaged in 82.5% (52 cases). The time required to accomplish this averaged almost 6 months, but the results were gratifying. Although an attempt was made to accomplish this as early as possible by evaluating patients at 30 days post-AVF creation, this goal proved difficult because of patient compliance and scheduling problems. As a result, the average age of the fistula treated was approximately 4 months. Almost by definition, all these cases were associated with less than optimal flow, but flow was adequate for successful dialysis. The median age of the patients was 59 years, and 60% had diabetes. Flow problems are to be expected in older patients with diabetes.

The frequency at which primary nonfunction of an AVF occurs is directly related to the aggressiveness of the surgeon in attempting creation of this type of access. By the time an AVF is 1 month old, whether it will be adequate for cannulation should be obvious. If it does not develop adequately for use, it should not be abandoned.
but should be evaluated. This evaluation can be accomplished by simple physical examination of the AVF to a degree adequate to justify the performance of a fistulogram. Aggressive treatment is frequently rewarded by the development of a usable dialysis access. The results of this study validate angioplasty and AVL as therapy for the salvage of AVFs that fail to develop.

REFERENCES