A Practitioner’s Resource Guide To

Hemodialysis

Arteriovenous Fistulas

The ESRD Network of Texas, Inc., is proud to offer this excellent educational resource written by Gerald Beathard, MD for distribution to the nephrology & surgical community in support of the Fistula First Project.

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ARTERIOVENOUS FISTULAS

The native arteriovenous fistula (AVF) comes the closest to be an ideal vascular access when compared to what is currently available. Although it does not meet all of the criteria that one would list, when the criteria are weighted according to clinical consequence, the AVF is definitely superior (2). The AVF has the best long-term primary patency rate (Figure 1) and requires the fewest interventions of any type of access (3, 4). NKF – K/DOQI guideline 29 suggest that we should have as a goal the creation of arteriovenous fistulas in 50% of all new patients and should achieve a level of 40% in prevalent patients (2).

![Figure 1 – Comparison of primary patency of AVF (F) and graft (G) from ref 4](Image)

Types Of Arteriovenous Fistulas

Although novel types of AVF have been created, there are three basic types of AVF – the radial-cephalic, the brachial cephalic and the brachial-basilic transposition. The order of preference for the creation of a permanent vascular access as recommended by NKF - K/DOQI guideline 3 (5) is shown in Table 1. Although a brachial-cephalic transposition fistula is listed as equivalent to a graft in this guideline, this is a mistake. A brachial-basilic transposition is superior to a graft (6). In a study of 172 AVFs created in the upper arm, Ascher et al (7) found that there was no significant difference between the primary patency of brachial-basilic and brachial-cephalic fistulas. They also found that the primary patency of both of these upper arm fistulas were superior to that of radial-cephalic fistulas in their patient population. The possibility of creating one of these three types of AVF should be exhausted before consideration is given to the insertion of a synthetic graft.

<table>
<thead>
<tr>
<th>Table 1 – Order of Preference for Permanent Vascular Access</th>
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<tbody>
<tr>
<td>• Radial-cephalic fistula</td>
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<tr>
<td>• Brachial-cephalic fistula</td>
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<tr>
<td>• Brachial-basilic transposition fistula</td>
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<tr>
<td>• Arteriovenous graft</td>
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Of the three types of AVF, the radial-cephalic fistula (Figure 2) is the easiest to create. The surgery is generally accomplished by means of an end to side – vein to artery anastomosis. This is in contrast to the classic Cimino-Brescia fistula that is created using a side-to-side anastomosis and can be complicated by venous hypertension in the hand. The radial-cephalic has a lower blood flow than is possible with the other two varieties of AVF, but its use as the first access preserves the upper arm vessels for later attempts if necessary.

The brachial-cephalic fistula (Figure 3) is created using the upper arm cephalic vein. It is more easily created than the brachial-basilic fistula (Figure 4) because it requires less dissection unless a long segment of cephalic vein needs to be mobilized to translocate the vein closer to the skin as is the case in obese patients. Because of the lateral and relatively superficial location of the vein from which it is created, the brachial-cephalic fistula is easy to cannulate. It also presents a long length of vein from which to select cannulation sites. This more proximal access has the potential for a higher blood flow than the radial-cephalic fistula but also has a slightly higher incidence of steal syndrome.

The brachial-basilic fistula (Figure 4) requires more surgical skill in its creation. The basilic vein lies on the inner surface of the forearm in the median bicipital sulcus. It continues upward to the middle third of the sulcus at which point it pierces the brachial fascia to run in a deeper plane. Therefore the vein
must be both elevated and transposed to make it usable as a dialysis vascular access. Elevated to make it superficial in its upper portions and transposed to move from its medial position to a location that is accessible to the dialysis nurse. It is associated with more patient morbidity related to creation. However, since the basilic vein is less accessible for venipuncture under normal circumstances because of its deep location, it tends to be better preserved and less involved with thrombotic and postphlebitic changes in comparison to the cephalic vein. The basilic vein is shorter than the cephalic vein; especially if it joins the brachial vein to form the axillary vein very low in the upper arm so there is less potential cannulation area with which to work. This shorter length, along with its more medial location, makes the brachial-basilic fistula somewhat more difficult to cannulate. Steal syndrome tends to be more common when the basilic vein is used for the vascular access. This may in part be related to its larger size. Additionally, the basilic vein access tends to be used primarily in patients who have had multiple prior failed access procedures. These patients tend to have a higher incidence of arteriosclerotic arterial disease making them more susceptible to steal.

![Figure 5 – Relative risk of AVF failure in relationship to time of first cannulation from DOPPS data (9)](image)

**General Characteristics of Arteriovenous Fistulas**

All AVF possess similar characteristics (Table 2). These derive from the fact that they are created using native vessels with out the interposition of synthetic, foreign material. Firstly, except for the brachial-basilic they can be created with very little patient morbidity in comparison to graft insertion. The surgical procedure is relatively simple and in general is quickly accomplished. They require time for maturation before use (8). This process involves an increase in diameter and a thickening of the vessel wall, changes that allow for repetitive cannulation. It has been stated that a newly created fistula should not be used any sooner than 1 month after creation and preferably not for 3 to 4 months (8). However, a study of the risk of fistula failure relative to the time of first cannulation has not supported this opinion (9). This study found that use prior to 14 days carried a significantly increased risk of failure; however, use at any time after 14 days was not associated with any significantly increased risk (Figure 5).

The AVF increases in size with time. This can eventually lead to cosmetic objections on the part of the patient. Additionally, there is also an increase in blood flow with time. This is advantageous, however, it is possible that the flow in an AVF can get too great and cause cardiac problems. It is important to realize that size and flow in the associated artery also increase. This is a rather abrupt initial increase at the time of creation, but a gradual increase over time is also seen.

Although complications do occur, venous stenosis and infection occur with much less frequency than seen with grafts. The thrombosis rate for an AVF is reported to be approximately one-sixth that for a graft while the infection rate is approximately one-tenth (10). The incidence of ischemic complications is also significantly less in the patient with an AVF in comparison to those with grafts.
Table 2 – General Characteristics Of Fistulas
- Created with minimal patient morbidity
- Require a period of maturation prior to use
- Increase in size with time
- Flow increases with time
- Lower complication rate than with AVG

Requirements For An AVF

For an AVF to be successful it must be usable. This means that several characteristics must be present (Table 3). Firstly, it must have blood flow adequate to support dialysis. In order to be used as a dialysis access, an AVF must be able to sustain the blood flow that is demanded by the dialysis prescription. Since an AVF can stay patent with a relatively low blood flow, the flow in the fistula only has to be marginally greater than the demands of the blood pump. Less flow will result in recirculation unless the dialysis prescription is modified. This generally means a flow in the range of 600 to 700 mL/min at a minimum. Additionally, fistulas with low flow may not develop adequate for use (early fistula failure).

In a study of radial-cephalic fistula maturation in 43 patients (11). Fistula function was evaluated post-operatively by clinical examination and non-invasively measured AVF blood flow. The blood flow in functioning AVFs was significantly higher compared to non-functioning AVFs at 1 (754 vs 440 cc/min), 7 (799 vs 524 cc/min) and 42 days (946 vs 532 cc/min) post-operatively.

Secondly, the AVF must be adequately matured to allow for repetitive cannulation, hopefully without undue frustration on the part of the dialysis facility staff. This requires time, flow and pressure. The native vein has a rather thin wall and is relatively fragile. The high pressure and flow artificially introduced when a fistula is created causes the involved vein undergo a series of changes characterized by dilatation and thickening of the wall. This process, referred to as maturation, eventually renders the fistula usable as a vascular access.

Thirdly, the fistula must be within 1 cm of the skin surface in order for it to be reliably cannulated. A fistula that is large, but deep is a problem. The solution for deep veins that are used to create an AVF is transposition. The vein can be dissected free and tunneled in a more superficial position.

Fourthly, the AVF must have a relatively straight segment available for cannulation. At a minimum this must be several centimeters long. The dialysis needle must be threaded into the vein in order to be stable. Attempts at threading a needle into a tortuous fistula are often met with disaster.

Table 3 – Requirements For An AVF
- Blood flow adequate to support dialysis
- Maturation adequate to allow for repetitive cannulation
- Within 1 cm of the skin surface
- Relatively straight segment available for cannulation
- Anatomical location that is accessible

Lastly, the AVF must be created in an anatomical location that is accessible with the patient in a sitting position. A fistula that is on the back of the arm is not easily used. The ideal location is on the volar surface of the forearm, the lateral surface of the upper arm or, in the case of a brachial-basilic fistula, the anterior surface of the upper arm.
**Time For AVF Creation**

Both the size and anatomical characteristics of the venous and arterial components of the AVF can affect the time required for a fistula to develop. Creating the AVF well before it is required for dialysis allows for this process to take place in an adequate fashion prior to use. Since there is no disadvantage to creating the access too early, one should not hesitate to send the patient to the surgeon well before the time of anticipated need (Table 4). NKF-K/DOQI guideline 8 suggest that the patient be referred for the creation of an AVF when the patient’s creatine clearance is at 25 mL/min or less, their serum creatine is 4 mg/dL or less, or within 1 year of anticipated need (12).

<table>
<thead>
<tr>
<th>Table 4 – Timing of AVF Placement</th>
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<tr>
<td>• Creatine clearance is at 25 mL/min or less</td>
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<tr>
<td>• Serum creatine is 4 mg/dL or less</td>
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<td>• Within 1 year of anticipated need</td>
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Even if the first attempt at AVF creation fails, early referral allows time for a second attempt at an alternative site without having to resort to the use of a catheter for the initial dialysis access.

**Patient Evaluation Prior To Access Placement**

Evaluation of the ESRD patient in preparation for the placement of a peripheral venous access is extremely important. Proper patient selection will materially enhance the opportunity to place an AVF. In order to determine the type of access most suitable for an ESRD patient a general physical examination as well as a detailed focused medical history is important (13). Emphasis should be placed upon aspects that might affect the placement of the vascular access. Any physical evidence (scars) that the patient has had previous central venous catheters should be documented. In most instances a patient will give a positive history for such an occurrence, but this is not always the case (10). The patient’s chest, breast and upper arms should be evaluated for the presence of swelling or collateral veins. In patients with normal venous pressure, central venous occlusion may not be associated with swelling; however, the presence of collateral veins should alert the examiner to the problem. The presence of scars indicating previous neck or thoracic surgery or trauma should also raise the possibility of a venous anomaly that might affect access creation.

In the creation of an AVF both the artery and vein are important and specially directed evaluations of both must be completed.

<table>
<thead>
<tr>
<th>Table 5 - Arterial Requirements for AVF</th>
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<tr>
<td>• Pressure differential &lt; 20 mmHg between arms</td>
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<tr>
<td>• Patient palmar arch</td>
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<tr>
<td>• Arterial lumen diameter 2.0 mm or greater at point of anastomosis</td>
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**Arterial Evaluation**

In relation to the arterial system, two issues are important. The vessel must be capable of delivering blood flow at a rate adequate to support dialysis and the utilization of the vessel for the creation of an access must not jeopardize the viability of the digits and hand. Arterial narrowing and calcification are relatively common in ESRD patients, especially those that are diabetic and hypertensive. This problem can usually be diagnosed before the patient is sent for surgery.
Optimally, three things relative to the arterial system (Table 5) should be present for the creation of an AVF (14). Firstly, the patient should have less than 20 mmHg differential in blood pressure between the two arms; a greater difference suggests the presence of arterial disease that should be evaluated before access placement. Secondly, the palmar arch should be patent. The palmar arch can be tested for patency using the Allen test (Table 6). Use of vascular Doppler can increase the effectiveness of the Allen test in predicting collateral arterial perfusion of the hand. Given adequate collateral flow, the Doppler should detect augmented pulsation in the palmar arch during occlusion of either the radial or ulnar artery (18). Failure of palmar arch pressures to increase during this maneuver suggests inadequate collateral circulation in the hand and predicts a higher risk for vascular steal if the dominant artery is used for access creation. And thirdly, the arterial lumen should be 2mm or greater in diameter at the point proposed for the anastomosis. This can best be determined using color flow Doppler.

### Table 6 - The Allen Test

1. Position the patient so that they are facing you with their arm extended with the palm turned upward.
2. Compress both the radial and ulnar arteries at the wrist.
3. With the arteries compressed firmly, instruct the patient to create a fist repetitively in order to cause the palm to blanch.
4. When the patient’s hand is blanched, release the compression of the ulnar artery and watch the palm to determine if it becomes pink. Then release all compression.
5. Repeat steps 2-4 for the radial artery.

**Interpretation** – when color returns to the blanched palm upon release of the arterial compression it indicates arterial patency and reflects upon adequacy of flow. Blanching that persists for 5 seconds or more after release of the ulnar artery is a positive test for radial artery insufficiency. Likewise, blanching that persists for 5 seconds or more following release of the radial artery is positive for ulnar insufficiency.

**Venous Evaluation**

Venous anatomy is extremely important for access creation. If there is a vascular problem that is going to interfere with the creation of an AVF it is more likely to be venous than arterial. The cephalic vein is ideal for an AVF because it is located on ventral surface of the forearm and the lateral surface of the upper arm. These features make for easy access in the dialysis facility with the patient in a sitting position.

Venous mapping should be performed in all patients prior to the placement of an access. Routine preoperative mapping results in a marked increase in placement of AV fistulas, as well as an improvement in the adequacy of forearm fistulas for dialysis (14-16).

In one study (15) in which preoperative vein mapping was performed on a cohort of 70 patients, an AVF rather than a planned graft was placed in 15% of the patients, unsuccessful surgical explorations decreased from 11% to 0% and an AVF was placed in 58% of the cases in contrast to a rate of 32% in their total patient population.

In another study in which preoperative sonographic evaluation of the upper extremity arteries and veins was obtained routinely (16), a doubling of the proportion of patients who were able to dialyze with a fistula was observed. The percentage of fistulas rose from 34% to 64%. An improvement in the adequacy rate for forearm fistulas also increased substantially particularly among women and diabetic patients. It is important to realize that vein mapping does not insure against early fistula failure. In fact in this report, only 54% of the fistulas that were created following vein mapping matured adequately to be usable for dialysis.
Early fistula failure has been reported to be more common in females, even with vein mapping to guide surgical creation of the access (17). Even with an aggressive approach to intervention for early failure, this report found a significant discrepancy between the success rate in females and males (17).

The primary goal of venous mapping is to identify a cephalic vein that is suitable for the creation of an arteriovenous fistula. Basically, there are three methods for doing venous mapping – physical examination, ultrasound and by angiography.

![Figure 6 – Appearance of the cephalic vein, note accessory vein (arrow)](image)

It is essential that the patient be evaluated with outflow obstruction so as to dilate the veins of the arm adequately for evaluation regardless of the method used for mapping. For physical examination, this is best done using a blood pressure cuff inflated to a pressure about 5 mm Hg above diastolic pressure. This should be left in place for periods of no more than 5 minutes at a time. In many patients, venous anatomy can be evaluated very well by this approach (Figure 6).

While this provides excellent information in many patients, most surgeons will want a more detailed venogram performed using either color flow Doppler ultrasound or angiography prior to surgery. Color flow Doppler ultrasound is considered to be the best method for visualizing the venous anatomy primarily because it avoids the use of radiocontrast. Optimum features on venogram (Table 7) for the creation of an AVF are a luminal diameter at the point of anastomosis of 2.5 mm or greater, a straight segment of vein, absence of obstruction and continuity with the proximal central veins (14).

![Table 7 – Venous Requirements for AVF](table)

<table>
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<tr>
<th>Requirement</th>
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<tr>
<td>Luminal diameter 2.5 mm or greater at anastomosis point</td>
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<tr>
<td>Absence of obstruction</td>
</tr>
<tr>
<td>Straight segment for cannulation</td>
</tr>
<tr>
<td>Within 1 cm of surface</td>
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<tr>
<td>Continuity with proximal central veins</td>
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In instances in which venous mapping cannot be done by ultrasound or if the technique is not available, equivalent results can be obtained by angiography (Figure 7). The disadvantage to this technique is that it results in exposure of a patient with residual renal function to radio-contrast. However, satisfactory results can be obtained with a minimum of contrast, 30 to 40 cc. In doing this, an IV should be started on the back of the hand; on the thumb side if possible to better fill the cephalic system. A tourniquet should be applied just above the elbow to examine the veins of the lower arm. It can then be moved to the axilla to examine the upper veins with outflow obstruction. The veins should then be filled with contrast and turned back and forth to determine the depth of the vein below the surface.
Maximizing Arteriovenous Fistulas Creation

Initial evaluation efforts should be directed towards the non-dominant arm; however, if suitable anatomy is not found, the dominant arm should be examined as a possible candidate for fistula creation. In instances in which the cephalic vein in the lower arm is not large enough to meet the 2.5 mm or greater size criteria, consideration should shift to a high level in the forearm or to the upper arm. If neither the lower or upper cephalic vein is suitable for fistula creation, the basilic vein should be considered. Venous side branches (accessory veins) are not infrequent. Since these can affect fistula maturation adversely, they should be ligated at the time of fistula creation.

A straight segment of vein suitable for cannulation is critical for a successful fistula. Unfortunately, this is not always present. In these cases, the novel vein transposition technique described by Silva et al (19) should be considered. By this procedure, an otherwise unsuitable forearm vein is identified, exteriorized and transposed to an optimal position on the volar surface of the forearm. This technique was reported to have a primary patency of 84% at one year.

If mapping reveals the presence of a suitable vein but that it is too deeply located to be usable, superficial transposition can yield a usable fistula. This may be especially useful for brachial-cephalic fistulas in patients with obese upper arms.

Fistula Development

Once a fistula is created it must develop to the point that it is usable. Basically, this requires two things – blood flow and physical characteristics that allow for repetitive cannulation. Without adequate inflow, the fistula will simply not develop but it must also be adequate to support dialysis as discussed above. The issue of repetitive cannulation is somewhat harder to judge. It involves characteristics that we refer to as maturation, for practical purposes this relates to its size and how it feels. There are other characteristics that are also important - its position on the arm, its configuration and its depth. Some of these can be measured; however, this evaluation also involves subjective elements that cannot be quantified.

Robbin et al (20) found that if fistula diameter was 0.4 cm or greater, the chance that it would be adequate for dialysis was 89% versus 44% if it was less than 0.4 cm. The chances that the fistula would be adequate for dialysis were 84% if the flow was 500 ml/min or greater but only 43% if it was less
than this level. Combining the two variables increased the predictive value of the measurements. A minimum fistula diameter of 0.4 cm and a minimum flow volume of 500 mL/min resulted in a 95% chance that the fistula would be adequate versus 33% if neither of the minimum criteria were met. Of considerable interest was the fact that experienced dialysis nurses had an 80% accuracy in predicting the ultimate utility of a fistula for dialysis. In this study, the ability of an experienced dialysis nurse to successfully cannulate the fistula and the ability of the access to support a minimum dialysis blood flow of 350 mL/min was used as the criteria to judge maturation.

Evaluation at 30 days to detect problems with adequacy has been recommended on an empiric basis (21). This was based upon the observation that an AVF that did not appear to be adequate at that time was generally not adequate at a later date. Actually, increased blood flow occurs very early. In one prospective study (22), average arterial blood flow preoperatively was $\pm 18$ mL/min. Within 24 hours of surgery to create a fistula, the fistula blood flow was up to $472 \pm 315$ mL/min, and by one week it had increased to $861 \pm 565$ mL/min. In another study in which patients were divided into two groups based upon the internal diameter of their feeding artery (23). It was found that blood flow increased from a preoperative level of $46 \pm 6$ ml/min up to $184 \pm 13$ mL/min at one day, $202 \pm 14$ mL/min at one week, $274 \pm 17$ mL/min at 3 weeks, $488 \pm 95$ mL/min at 8 weeks and $562 \pm 131$ mL/min at 12 weeks in the group with the best results. This group had a feeding artery with an internal diameter greater than 1.5 mm and a 12-week primary patency rate of 83%. Robbin et al (15) found that there was no significant difference in fistula blood flow in the second, third or fourth month following creation and that vessel diameter changed very little.

These studies suggest that a fistula that is going to be adequate for dialysis becomes so relatively early and that evaluation at one month should detect those that need further study. The fact that maturation can be judged with 80% accuracy by physical examination (20) and that the major causes of failure to mature can be diagnosed by physical examination (24, 25) suggest that the protocol for accomplishing this task can be very simple. An experienced person should examine a newly created fistula at 4 weeks. If it does not appear to be developing adequately for eventual use as a dialysis access, it should be studied angiographically.

**Complications Of Arteriovenous Fistulas**

Although the AVF is associated with fewer complications than are seen with other types of vascular access, they do occur and they should be dealt with effectively. We categorize the major complications that are seen in conjunction with arteriovenous fistulas under the headings of early failure, late failure, excessive flow, aneurysm formation and infection. Both early and late failures have multiple causes.

**Table 8 - Causes of Early Fistula Failure**

**Inflow problems:**
- Pre-existing arterial anomalies
  - Anatomically small
  - Atherosclerotic disease
- Acquired
  - Juxta-anastomotic stenosis

**Outflow problems:**
- Pre-existing venous anomalies
  - Anatomically small
  - Fibrotic vein (stenotic)
  - Accessory veins (side branches)

**Early AVF Failure**

A fistula that is never usable for dialysis or that fails within three months of use should be classified as an early failure (26). The distinction between early and late failure is made because there are certain
unique lesions that are seen in the early category. Unfortunately, these unique lesions are also major causes of late failure because they were not diagnosed and corrected during the early period. Nevertheless, we feel that the early and late distinction is worthwhile.

The causes of early failure can be classified as either inflow or outflow problems (Table 8). It is important to realize that most of the problems of both types can be obviated by proper patient evaluation prior to an attempt at access creation.

**Inflow Problems Resulting In Early Failure**

For an AVF to develop and function adequately for hemodialysis there must be good blood inflow. Both maturation and adequacy of flow are dependent upon pressure and volume of flow. Abnormalities of the feeding artery can result in early failure of the access. Anomalies such as an artery that is too small for the creation of a functional access and the presence of arterial disease such as atherosclerosis can prevent the development of an adequate AVF or result in its early demise. However, both of these problems should be preventable by proper patient evaluation prior to access placement.

The unique problem that results in early access failure due to inflow difficulties is an acquired entity that is referred to as **juxta-anastomotic stenosis**. This is a specific type of venous stenosis characterized by a very typical appearance (Figure 8). This lesion occurs in the segment of vein that is immediately adjacent to the anastomosis (21, 26, 27); thus the term juxta-anastomotic (26). The etiology of this lesion (Figure 8) is not clear. However, this is the segment of vein that is mobilized and manipulated by the surgeon in creating the fistula. It may be related to stretching, torsion or other types of trauma. This segment is often skeletonized in the process of mobilizing it for the creation of the fistula. This causes a loss of the vasa venosum, which supplies blood to the vein. The effect of the lesion is to obstruct fistula inflow. Since it occurs early, it results in early access failure.

This lesion is amenable to treatment. It can generally be successfully treated by percutaneous angioplasty (21, 26) or surgically (27). It is important to realize that juxta-anastomotic stenosis can be easily diagnosed by physical examination (24, 25).

**Outflow Problems Resulting in Early Failure**

For an AVF to develop and function adequately for hemodialysis there must also be adequate, low resistance blood outflow. The absence of good out flow can result in failure of the access. Anomalies...
that lead to outflow problems include veins that are too small for fistula development, veins that are fibrotic or stenotic due to past trauma such as venipuncture and the presence of accessory veins. The first two of these should be preventable by proper patient evaluation prior to access placement. Frequently, the presence of accessory veins is recognized and dealt with by the surgeon at the time of fistula creation; however, this is not always the case. In addition it must be remembered that all of the veins receiving the drainage from the newly created anastomosis enlarge. A small accessory vein may become enlarged with time.

![Figure 9a – Accessory vein; A – accessory vein, B – fistula.](image)

![Figure 9b - Collateral vein; A – fistula, B – collateral (below stenosis), C – stenosis, D – accessory vein (above stenosis), E – upper fistula.](image)

The optimum anatomy for the creation of a fistula is a single vein without side branches. Unfortunately, this is not always the case. The vein that is to become an AVF may have side branches. These side branches, referred to as accessory veins (Figure 9a), are normal anatomy. However, they must be distinguished from collateral veins (Figure 9b), which are pathological anatomy and always associated with a down stream (antegrade) stenosis. In ideal situations the presence of an accessory vein may be viewed as an advantage, the patient may develop an additional venous channel suitable for cannulation. However, under less than optimal conditions, its presence can result in early AVF failure (21, 26). Fistula development is dependent upon flow and pressure. Pressure necessary for fistula development is dependent upon the inflow pressure and the upstream resistance of the draining vein. Down stream (antegrade) resistance is decreased if the vessel branches because of the increased effective cross-sectional diameter represented by multiple vessels. Additionally, flow that should be limited to a single channel is partitioned into two or more channels, each receiving less than the total.

Accessory veins may be single or multiple. It is important to note that this anomaly can also be easily diagnosed by physical examination (24, 25). These veins can be ligated to convert the branched unusable fistula into a functional AVF (21, 26). Accessory veins along with juxta-anastomotic stenosis represent the two most common causes of early AVF failure in cases that have been properly evaluated prior to access creation (28). These two lesions often occur together (21, 26).

In a report of 100 cases of early fistula failure (26) a variety of lesions and combinations of lesions were seen (Table 9). Some of these lesions should have been avoided by pre-access evaluation (which was not done in the majority of cases). These cases were all treated aggressively. It was possible to
initiate dialysis using the fistula in 92% of the cases. Actuarial life table analysis showed that 84% were functional at 3 months, 72% at 6 months and 68% at 12 months.

<table>
<thead>
<tr>
<th>Table 9 – Lesions Identified in 100 Case of Early AVF Failure</th>
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<tr>
<td>• Accessory vein</td>
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<tr>
<td>• Accessory + JAS</td>
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<tr>
<td>• Accessory + PS</td>
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<tr>
<td>• Accessory + JAS + PS</td>
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<td>• Arterial anastomosis stenosis</td>
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Not all accessory veins need to be obliterated. The significance of the additional venous structure can be judged by its size and apparent blood flow. Small accessory veins seldom contribute significantly to the fistula’s failure to develop. In general, an accessory vein that is less than one-fourth the diameter of the main fistula is unlikely to prove to be significant. Palpation of the upper fistula when the accessory vein is manually occluded will also aid in determining the side branch’s significance. If it is affecting the fistula, an apparent augmentation should be evident when it is occluded.

If there is a down stream (antegrade) stenosis, the side branch is either a collateral that has developed because of the stenosis or an accessory (meaning that it is a normal venous structure) that is being augmented by the presence of the stenosis. There is no way to distinguish between these two possibilities. In any case, the significance of a side branch associated with a downstream stenosis cannot be evaluated adequately until the stenosis has been successfully treated. When presented with the combination of a large side branch associated with a down stream stenosis, the procedure that should be followed is to first treat the stenosis and then determine the significance of the side branch. It many instances it will be seen to have disappeared.

**Late Fistula Failure**

Late fistula failure is defined as failure that occurs after 3 months. The primary causes of failure occurring at this time are venous stenosis and acquired arterial lesions. These lesions are manifest as pathological changes in the fistula from increased pressure, and decreased flow leading to inadequate dialysis and eventually thrombosis. It is important to realize that the lesions typical of early failure are also commonly seen during this later period because they were not addressed in a timely fashion. It is also possible that these lesions of early failure have progressed in their ability to cause dysfunction.

**Venous Stenosis**

Fortunately, venous stenosis does not occur in AVFs with the same degree of frequency as is seen with synthetic grafts. Nevertheless it is the most common cause of late fistula loss (27). For this reason it is important that each dialysis facility have in place an organized program for the prospective diagnosis of venous stenosis (29). This program should consist of weekly monitoring (done by physical examination) and regular surveillance (done using specific tests). These techniques will be discussed later in association with graft stenosis.
Unlike the case with grafts, venous stenosis associated with the AVF generally develops more centrally at areas of vein bifurcation, pressure points and in association with venous valves. The development of collateral veins is frequent and often preserves flow in the access.

Prospective treatment of stenosis before thrombosis can occur is important and will materially prolong access survival. Percutaneous angioplasty has come to be the treatment of choice for these lesions with greater than 95% success rate (30). Long-term primary patency rates have been in the range of 84% at 3 months, 57% to 67% at 6 months and 35 to 51% at one year (30). Lesions associated with upper arm fistulas have not fared quite as well as those in the forearm. These numbers are comparable to those seen for the treatment of venous stenosis associated with grafts.

Unlike the situation for dialysis Grafts, pressure and flow measurements are not very sensitive for the detection of stenosis associated with AVFs (31). Blood entering the venous system of the AVF can return through multiple collateral veins originating peripheral to a stenosis. This can decrease the degree of pressure elevation despite the presence of a significant stenosis. Detection of recirculation on the other hand is valuable for screening because most AVFs can maintain patency at very low flow rates, less than those needed for dialysis. When the flow in the AVF is less than that of the blood pump, recirculation occurs.

**Thrombosis**

Even though AVFs have one-sixth the thrombosis rate of grafts, thrombosis is the most common mechanism for late fistula failures. This problem is generally associated with some type of anatomic lesion in the draining veins. Problems on the arterial side of the AVF have been reported to account for 17% of AVF thrombosis (27). Early studies reported relatively poor results with the treatment of thrombosed AVFs (27). However, recent reports have documented excellent success (30, 32, 33). Success in the treatment of thrombosed fistulas has ranged from 88 to 94% in these recent reports. Long-term primary patency has been reported in the range of 63 to 89% at 3 months, 52 to 74% at 6 months and 27 to 47% at one year (30, 31). These numbers are considerably better than those seen for treatment of thrombosed grafts.

![Graph showing primary patency following endovascular thrombectomy procedure for AVF versus grafts (AVG)](image)

*Figure 10 – Primary patency following endovascular thrombectomy procedure for AVF versus grafts (AVG)*

When referring to an AVF, thrombosis is actually only a clinical diagnosis. Many “thrombosed” fistulas contain very little or no thrombus. The flow has either stopped or decreased to a level that is undetectable clinically, but the fistula continues to be patent. Its patency is preserved by the presence
of small side branches and the fact that it is a native vein. The problem is due to the presence of a severe anatomical lesion – stenosis. Treatment of the anatomic lesion resolves the situation and restores flow. Failures are due to an inability to resolve the anatomical lesion.

**Acquired Arterial Lesions**

Many dialysis patients either have significant vascular disease when they begin dialysis or are predisposed to it development. Arterial lesions that develop or advance once dialysis is initiated can jeopardize the functioning AVF (Figure 11). This is especially true for those that were somewhat marginal from the beginning. One must keep in mind that with the presence of a low resistance AV shunt in place, flow in the artery and the overall size of the artery have a tendency to increase over time (5). This phenomenon has a tendency to offset the propensity for this problem to develop.

![Figure 11a](image1.png) – Stenosis of radial artery; A – stenotic lesion, B - radial artery, C – fistula

![Figure 11b](image2.png) – Occlusion of radial artery; A – fistula, B – occluded radial artery, C – enlarged palmar arch (feeding fistula)

**Excessive Flow**

Excessive flow, which is relative, can result in two problems – ischemia and high cardiac output. The creation of a low resistance shunt in the arm as represented by the AVF can result in the development of ischemic problems in the hand and fingers. This happens because the resistance to flow through the smaller vessels of the hand and digits far exceeding the resistance to flow through the shunt. This is an usual occurrence when proper vessel evaluation has been performed as described above. Also, it is much less likely to occur than with the creation of a graft.

As previously mention, blood flow in an AVF has a tendency to increase with the passage of time (5). Occasionally extremely high flow rates may be observed, in excess of 3 to 4 liters per minute. This can eventually lead to high output cardiac failure. When this occurs, the fistula may require ligation.

**Aneurysm Formation**

The increase in blood flow in an AVF that occurs with time has a tendency to cause the vessel to continue to increase in size. Over a period of years the AVF can dilate to aneurysmal proportions (Figure 12). A marked degree of aneurysmal change in a fistula is generally indicative of down stream (antegrade) venous stenosis. In addition, localized aneurysm formation can occur along the arterialized vein after repeated needle punctures at the same site. In general, an aneurysm is no more than a cosmetic problem unless it is associated with stenosis or thinning of the overlying skin. Stenosis, if present should be treated appropriately. Thinning of the skin should be evaluated carefully; this can
eventually lead to rupture with severe hemorrhage, exsanguination, and death. Indications for revision of the AVF relative to aneurysm formation (Table 10) are evidence of compromise to the overlying skin, changes in the skin suggesting the risk of rupture and enlargement to the point that cannulation sites are physically limited (34). In some instances, revision may be indicated because of the cosmetic appearance of the AVF.

![Figure 12 - Brachial - cephalic fistula with severe aneurysmal changes](image)

**Infection**
Infections of primary arteriovenous fistulas are rare and basically represent a vasculitis. In general, they should be treated as one would treat a bacterial endocarditis (35). Intensive antibiotic treatment based upon sensitivities for a minimum of 6 weeks is indicated. In some instances septic emboli may occur. In these cases it may be necessary to remove the AVF for control.

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<th>Table 10 – Indications For Revision of AVF Aneurysm</th>
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<td>• The skin overlying the aneurysm is compromised - thin, atrophic, translucent</td>
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<tr>
<td>• There is risk of rupture - ulceration, evidence of spontaneous bleeding</td>
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<tr>
<td>• Available cannulation sites are limited</td>
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<td>• Cosmetic appearance</td>
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**SECONDARY ARTERIOVENOUS FISTULAS**
A secondary AVF is defined as a fistula that is created following the failure of a graft. When a functioning graft is present in the lower arm, the veins of the upper arm undergo the same process of maturation as is seen with AVF development and for the same reasons (Figure 13). This makes these veins excellent candidates for the creation of an AVF. NKF - K/DOQI guideline 29 recommends that patients should be evaluated for the creation of an AVF after every failure of a dialysis arteriovenous access (36). In most instances this will involve the creation of either a brachial-cephalic or a brachial-basilic AVF.

Just as with vein mapping, it is very difficult to adequately evaluate the upper arm veins for a secondary fistula unless they are distended. As shown in Figure 14, the appearance of the vein can be very misleading if not distended. Venous anatomy should be evaluated when the graft in the lower arm
is functioning and the veins of the upper arm are under pressure (28). A vein that might be discounted by the surgeon treating a graft might actually offer an excellent opportunity for the creation of an AVF if seen under optimum circumstances.

![Veins draining a lower arm graft; A – basilic vein, B – Cephalic vein, C - graft](image)

**Figure 13 – Veins draining a lower arm graft; A – basilic vein, B – Cephalic vein, C - graft**

A patient that is experiencing recurrent graft problems should be evaluated at a time that the graft is functional. Plans should then be made to either create a secondary AVF immediately or with the next problem episode. It is important to establish this plan early in order to avoid the temptation to do a graft revision that might destroy any possibility for an AVF. Even a short graft extension to the upper arm can damage the vein making it unusable for fistula creation. Since the vein used for the creation of a secondary AVF has been exposed to prolonged pressure and high flow, it has already undergone the process of maturation. A brachial-cephalic fistula created in such circumstances could be safely used very early after creation. It can generally be safely used as soon as the operative trauma and swelling subside if not immediately. Since a brachial-basilic fistula involves transposition, this type of fistula should not be used for at least a month after creation to allow for adequate healing of the tunnel.

In one report (7) in which 331 fistulas were created over a 30-month period, 172 were placed in the upper arm. This included 109 brachial-cephalic and 63 brachial-basilic fistulas. Of these 29 (27%) and 20 (18%) of the brachial-cephalic, and 16 (25%) and 6 (10%) of the brachial-basilic fistulas were created in patients who had had prior fistulas or grafts, respectively. No significant difference in primary patency was seen between brachial-cephalic and brachial-basilic fistulas as a group. However, secondary fistulas (those created in cases with a prior access) did not fare as well as primary ones (those created in patients with no prior access history). The one-year primary patency rate for primary upper arm fistulas was 75% while that for secondary fistulas was 58% (p=0.02). Nevertheless this is better than that reported for synthetic grafts.
Figure 14a – Cephalic vein attached to a lower arm arteriovenous graft. The graft is thrombosed. The vein appears small.

Figure 14b – Same vein as shown in Figure 5a, but following opening of thrombosed graft. The vein is now distended and appears to be suitable for an upper arm fistula.
REFERENCES