Section: Arteriovenous Fistula Planning and Decision-Making

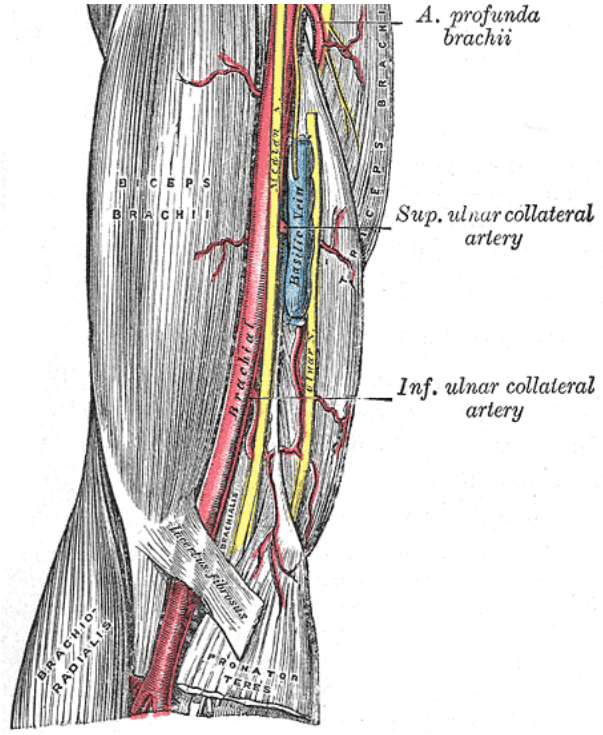
Jerry Svoboda, Richard Davis

Background:

In very poor countries, options for chronic renal insufficiency are few. As a country advances economically however, penetration of hemodialysis will increase. The surgeon will be called on to place temporary or permanent dialysis catheters and to create arteriovenous fistulas.

The basic principle of an arteriovenous fistula is this: when a vein is subjected to arterial blood flow, it dilates and its wall becomes thickened. Such a fistula should have enough blood flow to permit rapid withdrawal and replacement of blood during hemodialysis (350-800mL/minute.) The thickened walls are able to withstand repeated venipuncture. If such a vein is near enough to the skin, it can be repeatedly accessed by a non-physician for hemodialysis. Reaching this condition takes at least 6 weeks, sometimes several months.

Decision on criteria for long-term hemodialysis is generally not the purview of the surgeon. (Conversely, the surgeon must be well aware of the criteria for short term dialysis in case of acute kidney injury. Briefly, they are acidosis, volume overload, uremia, hyperkalemia and need for clearance of toxins.)



The brachial artery in the upper arm runs within the muscle fascia. It is covered by the bicipital aponeurosis, a band of fibrous tissue that runs between the biceps and the pronators and flexors of the wrist. This structure must be divided to access the artery at the level of the elbow. Though the median nerve runs just medial to the artery, it is most often not seen during fistula surgery. Injury to this structure is unlikely with careful dissection. The ulnar nerve runs posteromedial to these structures, and is vulnerable to injury during careless dissection of the basilic vein.

Anatomy:

The arm is preferred over the leg for fistula creation. Whereas the arterial anatomy of the arm varies only rarely, the venous anatomy is highly variable.

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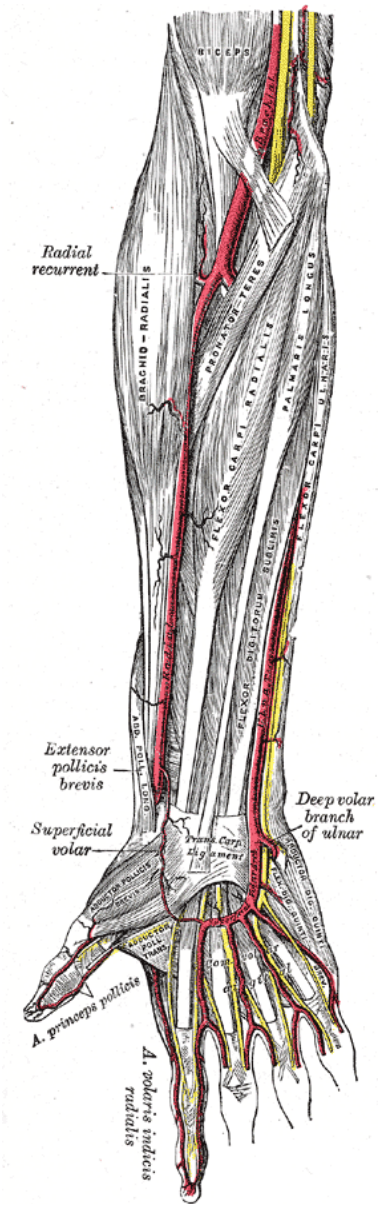
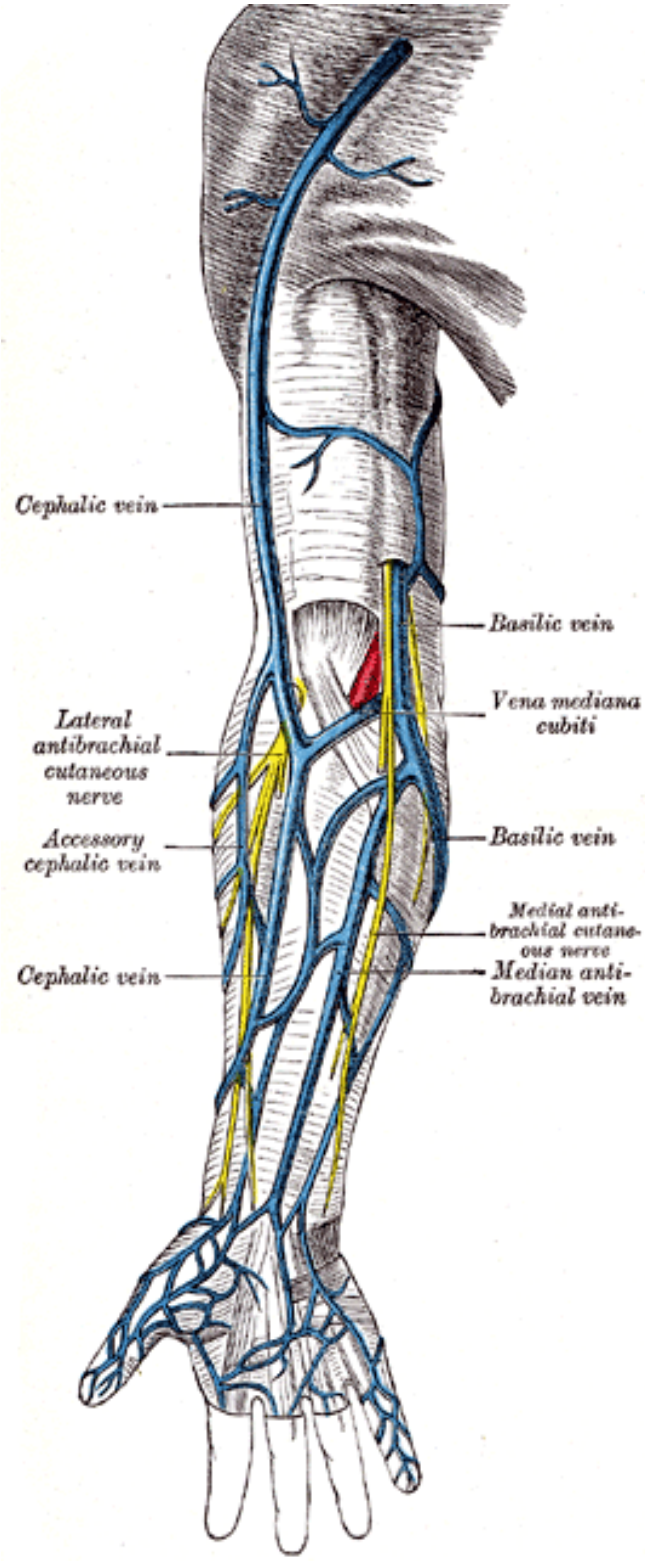


The radial artery is palpable in the distal forearm before it passes under the extensors and abductors of the thumb to anastomose with the ulnar artery via the palmar arch. It is not palpable proximal to the mid forearm, and more difficult to access, as it passes underneath the brachioradialis muscle.



The anatomy of the superficial venous system of the arm is highly variable; one possibility is shown here. The cephalic and basilic veins in the upper arm are constant. A median antecubital vein is often present, connecting to the cephalic vein. The cephalic vein running along the radial side of the forearm is usually present.

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Principles:

There are two possibilities for fistula creation: Arteriovenous fistula, the direct connection of a vein to an artery, and arteriovenous graft, the connection of an artery to a vein by a prosthetic conduit. The prosthetic material, if used, is usually polytetrafluoroethylene (PTFE, various brands.) Fistulas are most commonly connected end-vein to side-artery. Grafts are connected end-graft to side-artery and side-vein. When used, the graft is configured either straight in the forearm or upper arm, or as a loop in the forearm. Infection of the graft mandates removal, but it is unclear whether such infections occur more frequently in resource-limited settings such as ours.

Arteriovenous fistulae are generally placed in four common locations:

- Distal radial-cephalic: the end of the cephalic vein is anastomosed to the side of the radial artery at the wrist. This fistula has perhaps the lowest success rate of all due to the frequently small size of the vein here. However, it can be done under local anesthesia and if it fails, another fistula can be attempted more proximally in the arm. The converse is not true: if a proximal fistula has failed, a more distal one is unlikely to succeed. Another advantage to this fistula is that in >95% of patients, the hand will remain viable even if the radial artery is irreversibly damaged through surgical misadventure, because of the ulnar artery and the palmar arch. Similarly, "steal syndrome," the loss of perfusion to the distal arm due to excessive flow through the fistula, occurs only rarely. Creation of a wrist level AVF is advised if the vein is adequate, as patients on long-term dialysis need as many possible fistula sites preserved as possible.
- Proximal radial-cephalic: the end of the cephalic vein is anastomosed to the side of the radial artery in the forearm. This operation is practical up to the mid-forearm, though the radial artery is deeper than at the wrist. It is a useful option if veins in this area are large, and it does not prevent a fistula based on the brachial artery later. The advantages of radial artery fistula described above also apply here.
- Brachial-cephalic: The end of the cephalic or lateral antebrachial cutaneous vein is attached to the side of the brachial artery. This operation is technically easy to perform; all the vessels involved are relatively large and superficial. The major disadvantage is the potential for steal syndrome. Patients may experience coldness, numbness, or severe pain, either during dialysis or during use of the hand. This complication is best prevented by limiting the size of the arteriotomy to 6mm.
- Brachial-basilic: The end of the basilic vein is attached to the side of the brachial artery. The basilic vein runs deep to the fascia of the upper arm and is therefore unsuitable as a fistula unless it is superficialized. This is commonly done by dissecting it out along its length from the elbow to the axilla, and then transposing it to the anterior midline of the upper arm, where it is more accessible for dialysis. This transposition can be done in one or two stages, as described in the Chapter on this operation.

Decision Making:

The surgeon must evaluate the patient very carefully and select a location where the fistula has the best chance of success. The patient should understand that fistulas are generally not permanent, so part of the planning includes considering future fistula locations and the effect that any present one will have. The following general principles apply:

- Patients will generally prefer a fistula on their non-dominant arm, though the surgeon should prefer this side only if the veins and arteries are of otherwise equal quality on both sides.
- The surgeon should consider the position that the arm will be in during dialysis; even a paralyzed or contracted arm is acceptable as long as a fistula on it can be accessed while the patient is seated comfortably.
- Fistulas will generally have at least a 10% initial failure rate, even if made perfectly with excellent quality vessels. The most meticulous attention to detail is needed to assure the highest chance of success!
- When a distal fistula fails, one can be placed more proximally. However, when a proximal fistula fails, a subsequent more distal one is usually unsuccessful.

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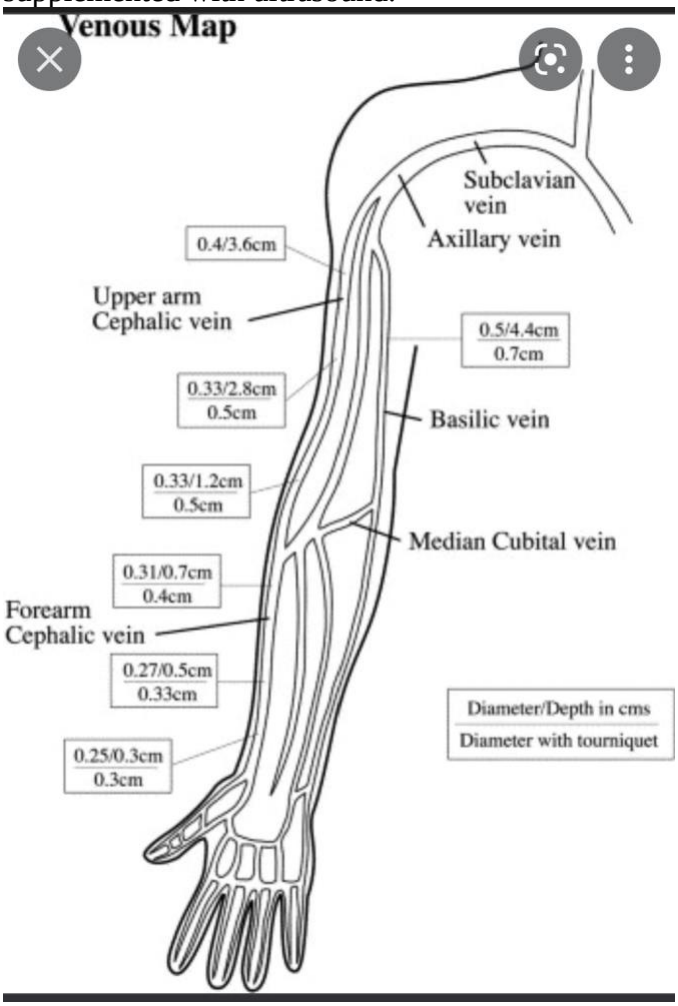
- Fistulas with veins smaller than 2.5mm diameter often fail immediately. Those with veins smaller than 3mm diameter may have prolonged maturation times, even if they remain patent.
- Veins that have been repetitively traumatized are less useful for a durable fistula. Once a fistula site is chosen, the patient should receive no further blood draws or IV's on that side. Once the fistula has been placed, IV's, blood draws, and blood pressure checks on that side are strictly forbidden.

The patient's arterial and venous system are carefully evaluated by physical examination, supplemented with ultrasound.



A venous ultrasonography chart such as this one can be used by the ultrasonography staff to document the sizes and patency of the veins.

The patient's radial and brachial pulses are evaluated. A feeble radial pulse should not be used. A patient with diabetes may have a calcified radial artery, which is hard to the touch. These will be very difficult to use for fistula formation.

A phlebotomy tourniquet is then placed around the upper arm and the arm is allowed to hang below the level of the patient's bed or chair. The superficial venous system can be assessed: patent veins should be palpable but compressible, whereas thrombosed veins will be noncompressible. The patient may squeeze and release their fist, or squeeze a rubber ball, to increase vein distention.

The veins and arterial pulsation can be marked for decision making. The surgeon should assess the superficial veins for the following:

- Compressibility: does the vein in question seem thrombosed, or otherwise in poor shape? Healed scars above the vein may indicate previous trauma. Visible venous valves are a normal finding; the vein can still be used.
- Length: can enough vein be mobilized to reach the arterial pulsation? Are there large branches that must be ligated in order to do so?
- Size: does the vein seem to be at least 3mm in size? Be sure to give the veins a fair assessment: they will consistently get larger the longer that the arm has been hanging off the side of the bed or chair with the tourniquet in place.

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Examination of the radial artery. The surgeon palpates with the index finger, moving up and over the bone into the recess adjacent to it, feeling for the pulsation of the radial artery.

The same right arm (previously marked for surgery,) hanging over the side of the bed, immediately after application of the tourniquet (left) and after two minutes (right.) The longer after the tourniquet has been applied, the more visible the veins will be, so wait a while before concluding that there aren't any usable options.

Resource-Rich Settings

Arteriovenous fistula creation is open surgery in Resource-Rich settings as well. One difference, however, is the availability of percutaneous radiological interventions to salvage a thrombosed fistula, which can extend its lifetime.

Peritoneal dialysis has been used successfully in the short term in resource-limited settings. But it has not been adopted as well in the long term, because of the need for complex dialysis solutions and the severe complications of sclerosing peritonitis.

The biggest difference in Resource-Rich settings is the availability of renal transplantation. In fact, in patients whose renal failure will occur at a predictable time, renal transplantation can be used to avoid dialysis altogether.

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