21 Dialysis Access

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Introduction

Although the incidence has largely plateaued, the prevalence of end-stage renal disease (ESRD) in the United States continues to increase. As of December 31, 2011, there were approximately 388,000 patients on hemodialysis (HD), 31,200 patients on peritoneal dialysis (PD), and 185,000 patients with a functioning kidney transplant. Renal transplantation is the preferred treatment for ESRD; however, the number of potential recipients continues to outstrip the number of available kidneys. As of 2013, there were about 98,000 patients on the waiting list for kidney transplant, while only between 16,000–17,000 transplants are performed each year (Organ Procurement and Transplant Network Data, November 2013). The disparity between donors and recipients leads to increasing waiting times for kidney transplant (averaging 5–7 years in some areas) with a concomitant increasing need for renal replacement therapy, both for those waiting for kidney transplant and for those patients who are not candidates. The cost of ESRD is significant, with nearly $50 billion in direct costs in 2011.

Indications for Dialysis

Urgent dialysis can be used to treat sequelae of acute kidney injury including fluid overload, hyperkalemia or acidosis, refractory hypertension, pericarditis, or mental status changes (Fig. 21.1). If the kidneys are expected to recover, a temporary central venous catheter can be inserted either in the internal jugular (IJ) vein or the common femoral vein. The right internal jugular vein is preferred because of the more linear pathway when directing the catheter tip to the cavoatrial junction. Placement of dialysis (or other) catheters in the subclavian veins should be avoided as it may lead to venous sclerosis and occlusion, which can preclude subsequent placement of arteriovenous (AV) fistulas or grafts in the ipsilateral arm.

Chronic renal replacement therapy (RRT) generally is initiated when the patient reaches a glomerular filtration rate (GFR) of 10–15 mL/min/1.73 m^2, when they have symptomatic fluid overload, electrolyte or acid-base imbalance, or significant clinical sequelae such as neurologic changes, uremic pericarditis, or chronic gastrointestinal (GI) symptoms. Of patients beginning renal replacement therapy, more than 90 % of patients beginning chronic RRT begin with hemodialysis (HD). The rest begin peritoneal dialysis (6.5 %) or receive a kidney transplant preemptively (2.5 %). Despite increased emphasis on early diagnosis and referral for nephrology care, in 2011 more than 40 % of patients diagnosed with ESRD had not seen a nephrologist until beginning renal replacement therapy. Ideally, patients should be referred for access placement well in advance of the time of initiation of dialysis to give time for the fistula or graft to mature or to allow the peritoneum to seal around the peritoneal dialysis catheter insertion site.

Because of improved outcomes and decreased costs, there is increasing emphasis on preemptive placement of long-term dialysis access (arteriovenous fistula or graft) as compared to catheter-based dialysis. Of patients without prior access to nephrology care, over half began HD with a catheter, as compared to less than one-third of patients with at least one year of pre-dialysis nephrology follow-up. Many of these patients will subsequently transition to AV fistulas or grafts (for hemodialysis) or peritoneal dialysis. Therefore, consideration of long-term dialysis access is important when placing a temporary (non-cuffed) or tunneled “permanent” cuffed dialysis catheter.

Access Planning

Patients with stage 4 CKD (GFR 15–29 mL/min/1.73 m^2) and those that are expected to require dialysis within 6 months should be referred for access planning. The decision

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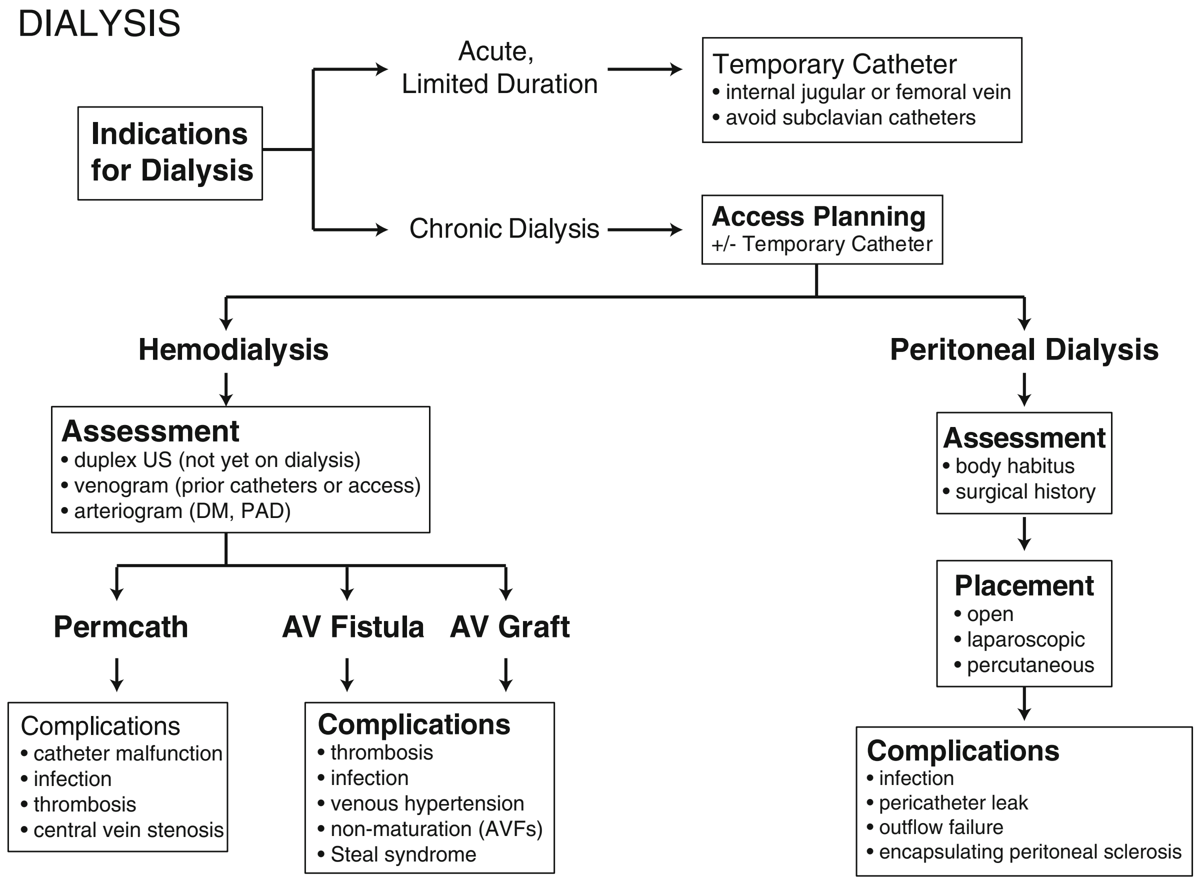

Fig. 21.1 Algorithm for initiating dialysis. *US* ultrasound, *DM* diabetes mellitus, *PAD* peripheral artery disease, *AV* arteriovenous, *AVF* arteriovenous fistula

whether to pursue hemodialysis or peritoneal dialysis should be made with input from the nephrologist and surgeon and based on the patient's preference and the medical and surgical feasibility. The patient also should be referred for evaluation for renal transplantation (preferable when GFR is approaching 20 mL/min/1.73 m^2, which is when they can start accumulating time on the transplant waiting list).

Hemodialysis Access

HD can be performed via a catheter, arteriovenous fistula (AVF), or an arteriovenous graft (AVG). For adequate dialysis, the access must support blood flow rates in excess of 300 mL/min. A fistula is created by anastomosing a native vein to an artery. Over the next several weeks to months, the increased pressure and blood flow in the vein leads to increased diameter and wall thickness, so-called maturation. An AV graft connects the artery and vein by interposition of a synthetic (usually expanded polytetrafluoroethylene [PTFE]) conduit. The National Kidney Foundation's Kidney Disease Outcome Quality Initiative (NKF/KDOQI) recommends AVF use of greater than 50 % in new patients and greater than 40 % in patients already on hemodialysis. This initiative is supported by the Centers of Medicare and Medicaid Services (CMS) through the National Vascular Access Improvement Initiative (Fistula First), because AVFs have higher patency rates and lower incidence of infection, interventions, hospitalization, and death when compared with other types of access.

Preoperative Assessment

Successful placement of an AV fistula or graft requires arterial inflow and venous outflow. For an AVF, an appropriate quality vein is also required. The selected vein must be amenable to percutaneous access, either in its anatomic location or after surgical superficialization or transposition. The patient's medical history should be carefully evaluated to assess fitness for surgery as well as risk factors for central venous occlusion, including:

- Prior central venous catheters; especially subclavian catheters
- Prior central venous stenosis or thrombus

- Unilateral upper-extremity swelling
- Prior fistula placement and cause of failure

The fistula or graft is preferentially placed in the patient's nondominant arm, so that the patient can have the dominant hand free during dialysis.

Apart from the general examination to assess fitness for surgery/anesthesia, emphasis should be placed on examination of the venous and arterial systems. Arterial examination includes assessing skin integrity and perfusion, capillary refill, quality of pulses, and blood pressure and performing an Allen test to ascertain a complete palmar arch. The arm should be examined for any obvious veins; this can be assisted by using a light venous tourniquet above the examined vein.

The size and patency of the veins can be assessed with Doppler ultrasonography (US) or contrast venography. Venous ultrasound provides a good representation of the size, location, and quality of the extremity veins and arteries. It is generally not very useful in assessing the central veins (subclavian, innominate, SVC). Contrast venography is less operator dependent and delineates the central vasculature (and any potential outflow stenosis) better than venous duplex. Carbon dioxide can be used as a contrast agent in patients not yet on dialysis to avoid nephrotoxicity. If the physical exam is inconclusive or if risk factors are present, arterial duplex can be used to evaluate the arterial inflow as well as digital perfusion. This is especially important if an upper arm or brachial artery inflow is planned as they are associated with a higher incidence of distal ischemia. When the distal radial artery is to be used for inflow, the palmar arch should be assessed, either by physical exam (Allen test) or with duplex ultrasound. A careful assessment for arterial insufficiency is mandatory prior to placing any lower-extremity access because of the risk for limb ischemia.

Permanent Catheters

The use of a large-bore tunneled "permcath" in the IJ or femoral vein allows dialysis immediately following catheter placement. Placement with imaging guidance (US/fluoroscopy) is highly recommended, especially in patients with multiple prior catheters who may have central venous stenosis. When compared with an AV fistula or graft, catheters provide lower flow rates, poorer clearance, and more recirculation. When compared with AV fistulas, catheters are associated with a twofold increase in relative rate of death, a nearly sevenfold increase in bacteremic episodes, and higher cost and number of required secondary interventions. Complications of permcaths include catheter malfunction, infection, and central vein stenosis/thrombosis. The latter is particularly damaging as it can lead to loss of the ipsilateral extremity for future HD access.

Autogenous Primary Fistula

Initial evaluation and placement of the AVF should be 3–6 months prior to initiation of dialysis so as to allow time for maturation. A longer lead time may be required if the arterialized vein needs to be superficialized (moved closer to the surface along its anatomic route) or transposed (moved to a more accessible, typically nonanatomic location). Although many veins can be arterialized, some of the more common AVF configurations are listed below. The arterial anastomosis can be done end-(vein)-to-side (artery) or side-to-side. Typically, the later has a slightly higher incidence of steal syndrome:

- *Radiocephalic AVF* – created by connecting the radial artery and the cephalic vein. The anastomosis can be at the level of the anatomic snuff box, at the wrist or at the antecubital fossa. The radiocephalic AVF at the wrist (Brescia-Cimino fistula) is an excellent site because of its high patency rate, longevity, and low incidence of complications.
- *Brachiocephalic AVF* – anastomosis between the distal brachial (or proximal radial or ulnar) artery and the cephalic vein, usually at the antecubital fossa. This AVF also has good long-term patency; however, the cephalic vein may need to be superficialized, especially in obese patients in whom it may be too deep to cannulate.
- *Transposed basilic or brachio-brachial AVF* – can be performed as a single- or two-stage procedure. The first stage involves connection of the distal brachial or proximal radial or ulnar artery to the basilic or the brachial vein just above or (preferably) below the elbow. After adequate maturation (typically when the vein is at least 5 mm in diameter), the vein is transposed to overly the biceps muscle. This fistula also can be created as a single-stage procedure especially if the vein is of good caliber.
- *Forearm basilic vein AVF* – can be transposed as a loop or straight AVF to the proximal or distal radial artery, respectively. This option may be limited by the caliber and length of the forearm basilic vein.

Autogenous Secondary Fistulas

The basilic vein or great saphenous vein (GSV) are harvested and used as grafts in secondary sites in the same patient. Their use is infrequent because the long-term patency rate has been disappointing.

Non-autogenous Grafts

These are used when fistula options have been exhausted, when suitable veins are not available, or in obese patients (especially in the upper arm) where suitable length of autogenous vein is not available to facilitate superficialization or transposition. The most common graft material is polytetrafluoroethylene (PTFE, Gore-Tex®), although multiple materials and configurations have been developed. Grafts should be planned using the same principles as AV fistulas, namely, they should be formed as distal as possible in the upper extremity. Tapered grafts are preferred to limit the arterial inflow and reduce the risk of arterial steal syndrome. Common insertion sites include:

- *Loop forearm graft* – one of the most common form of prosthetic access; it is constructed between the brachial artery or one of its major branches and a vein in the ACF.
- *Straight forearm graft* – usually constructed between the radial artery at the wrist and one of the antecubital veins at the elbow. The patient must have a strong radial flow and a complete palmar arch to ensure adequate graft and digit perfusion.
- *Upper arm arteriovenous grafts (AVG)* – can be used as secondary sites when forearm sites are exhausted or the more-distal arteries are too small. Can be constructed in a straight or looped configuration; usually uses the brachial artery as the inflow. Venous outflow can be to the cephalic, basilic, brachial, or axillary veins.
- *Lower-extremity AVG* – this site is less desirable because of the higher incidence of infection or arterial insufficiency compared with the upper extremity. The most common configuration is looped with inflow from the common femoral artery and outflow via the common femoral vein.
- *Hemodialysis reliable outflow (HeRO) graft* – this is a recent innovation developed to address the problem of central venous occlusion. It consists of an upper-extremity graft connected to a thoracic component (placed like an HD catheter) that extends to the cavoatrial junction. The thoracic component is placed under fluoroscopy, usually after recannulation of central venous stenosis or occlusion.

Complications of Fistulae and Grafts

- *Thrombosis* – most commonly due to outflow stenosis, often as a result of intimal hyperplasia in the outflow vein. AV grafts are more prone to stenosis, although also more amenable to percutaneous or surgical thrombectomy.
- *Infection* – nearly five times more common with PTFE graft than for autogenous vein and accounts for more than one-third of graft losses. Can present as local abscess, bacteremia, or septic emboli. Depending on the extent of infection, can be treated with partial resection (sometimes with immediate reconstitution with a jump graft around the infected area) or complete excision of the infected graft and repair of the arteriotomy.
- *Venous hypertension* – most commonly results from central venous stenosis and may lead to graft loss. Often amenable to percutaneous angioplasty or stent placement.
- *Non-maturation* – AV fistulas can fail to mature (or thrombose) due to poor arterial inflow, venous outflow, or poor quality of the arterialized vein. Most failing AVFs can be identified by physical exam at 4 weeks, and the rate of salvage can be significantly increased if intervention is initiated before the AVF clots. A contrast fistulogram (including evaluation of the arterial inflow as well as the venous outflow) can provide diagnostic information as well as offer therapeutic options such as balloon angioplasty.
- *Steal syndrome* – symptomatic extremity ischemia resulting from diversion of blood flow into the AVF or AVG. The patient may initially present with cool, pale, numb, or painful digits that can progress to nerve damage and distal necrosis. Therapy ranges from narrowing (banding) the access conduit to revascularization procedures such as distal revascularization/interval ligation (DRIL) to ligation of the access.

Peritoneal Dialysis

The prevalence of peritoneal dialysis (PD) in the United States has declined, but it remains popular with selected patients, especially pediatric ESRD patients where it is the modality of choice. The PD catheter has two cuffs, one that is typically placed just superficial to the peritoneal entry point and the other placed in the subcutaneous tunnel.

Preoperative Assessment

The PD catheter should be inserted at least 3–6 weeks before initiation of dialysis to allow adequate sealing of the catheter entry site. Because PD is performed at home, it requires a higher level of patient involvement and a robust support network. Relative contraindications to PD include prior abdominal surgery, ventral hernias, chronic constipation, obesity and inability to obtain sufficient clearance or fluid removal.

Catheter Insertion Techniques

- *Open surgical insertion* – can be performed under local anesthesia in thin patients using a small infraumbilical incision with the catheter entering the peritoneum in the midrectus. Open insertion has the lowest leak rate as the peritoneum can be sutured in a purse-string fashion around the catheter.
- *Laparoscopic insertion* – has the advantage of being able to visualize the peritoneal cavity and take down adhesions in patients who may have had previous abdominal surgery. It may have higher leak rate than the traditional open technique; however, the overall results are comparable in experienced hands.

- *Percutaneous insertion* – wherein the catheter is placed using a Seldinger technique with imaging guidance. This technique is unsuitable for obese patients and those that may have adhesions. It is associated with increased early leaks and there is potential for serious complications like intra-abdominal viscus perforation and hemorrhage.

Complications and Management

- *Infection* – can be localized to the exit site or generalized peritonitis. Patients with tunnel or exit site infections may present with local erythema, tenderness, and purulent discharge and can often be successfully treated with antibiotics. Peritonitis usually presents with generalized abdominal pain, often with systemic symptoms such as fever. The catheter should be aspirated and fluid sent for bacterial and fungal cultures. Empiric antibiotics (systemic or intraperitoneal) are started while waiting for the results of cultures. As a general rule, removal of the catheter is indicated in cases of resistant organisms or fungal peritonitis; the presence of multiple organisms should raise concern for bowel perforation.
- *Pericatheter leak* – presents as dialysis fluid leaking out the exit site and it indicates inadequate sealing of the exit site of the catheter from the peritoneal cavity. It occurs if enough time is not allowed between catheter placement and initiation of PD. A few weeks' hiatus in PD usually resolves the leak; major or persistent leak may require surgical revision.
- *Outflow failure* – retention of instilled dialysate can result from catheter malposition, intraluminal catheter occlusion (often from thrombus or fibrin), or extraluminal catheter obstruction (usually from omentum or adhesions). Malpositioned catheters often can be successfully repositioned using laparoscopy (with the initial pneumoperitoneum obtained via the PD catheter). Other extraluminal obstructions can be addressed with lysis of adhesions or omentopexy or omentectomy. However, eventual loss of peritoneal domain may restrict the long-term use of PD in patients with recurrent adhesion formation or (especially) with recurrent peritonitis.
- *Encapsulating peritoneal sclerosis* – EPS can develop during PD or several weeks or months after catheter removal. The patient typically presents with fever, increased C-reactive protein, and ileus symptoms usually followed by development of ascites. It can progress to peritoneal sclerosis and encapsulation with dense adhesions leading to bowel obstruction. Treatment includes cessation of PD (if ongoing) and steroid pulse. Refractory patients may require TPN. Many patients require enterolysis after the inflammation has subsided.

Pediatric Considerations

Peritoneal dialysis is preferred in the pediatric age group, especially if the patient has strong caregiver support. In ESRD patients weighing less than 10 kg, PD is preferred because it is technically easier to perform than HD, does not require a vascular access (technically challenging in small patients) or venipuncture, and reduces the need for compliance with strict fluid restrictions.