Venous Access for Patients with Chronic Kidney Disease

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Abbreviation: PICC = peripherally inserted central catheters

ESTABLISHING and maintaining reliable intravenous access for patients with chronic renal failure or end-stage renal disease presents special considerations unique to this patient population. These patients often present with complicated medical conditions requiring intravenous medical therapies; at the same time, there is a critical need to preserve the peripheral and central veins for future hemodialysis access.

The native arteriovenous fistula is the preferred form of vascular access for hemodialysis, delivering superior patency with lower morbidity, hospitalization, and cost relative to synthetic grafts or venous catheters (1). For these reasons, the nephrology community has implemented a nationwide agenda to increase the creation of native fistulas in our hemodialysis patients. The National Kidney Foundation Dialysis Outcomes Quality Initiative (NKF-DOQI) was published in 1997, with specific guidelines relative to creation and management of hemodialysis vascular access (2). More recently, the Centers for Medicare and Medicaid Services along with the regional ESRD Networks and the clinical nephrology community have developed and promoted the National Vascular Access Improvement Initiative (NVAII), with the specific goal of promoting more native arteriovenous fistulas in United States hemodialysis patients (3). Ultimately, however, our ability to create functional fistulas is critically dependent on the availability and condition of the patient's peripheral veins. Frequent venipuncture and the indiscriminate use of peripherally inserted central catheters (PICCs) or central venous catheters can damage veins and jeopardize future fistula construction. Therefore, it is of paramount importance that patients who have or are at risk for renal failure are identified and their venous access be restricted to preserve peripheral veins for future vascular access construction. This important concept has been emphasized in editorials by Trerotola related to the publication of the original DOQI vascular access guidelines (4,5), and more recently in updated NKF-K/DOQI guidelines (6).

VASCULAR ACCESS FOR HEMODIALYSIS

Hemodialysis treatment requires reliable vascular access capable of delivering blood flow rates up to 500 mL/min. This can be achieved with a central venous catheter or a surgically created vascular access constructed of either native blood vessels or synthetic graft material.

Because of its excellent long-term durability and low complication rate the native arteriovenous fistula is the preferred vascular access for hemodialysis. The classic configuration, the Brescia-Cimino fistula, is constructed at the wrist with an end-to-side anastamosis of the forearm cephalic vein to the radial artery (7). Another common fistula configuration is created with the brachial artery and cephalic vein just above the elbow. However, with increasing numbers of elderly, obese, and diabetic patients, alternative vascular configurations have become more common. In many of these alternative constructions, especially those using the upper-arm basilic vein (8), the native vein is too deep to be accessed by dialysis needles and surgical transposition of the vein is required to bring it closer to the skin surface. Ironically, in obese patients, these relatively deep upper arm basilic or cephalic veins may be well preserved because they are not easily accessed for routine venipuncture. If these veins are identified and properly used, fistula success rates are similar in obese and nonobese patients (9).

To develop into a functional vascular access, an arteriovenous fistula must undergo a "maturation" process, a physiologic change in the blood vessels that occurs over a 1 month period (10,11). Creation of an arteriovenous fistula decreases the peripheral vascular resistance in the extremity resulting in a substantial increase in blood flow through the artery and vein. In response to this greater blood flow there is adaptive vessel wall remodeling resulting in increased diameter

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(12). These physiologic changes are advantageous in that they allow easier and safer cannulation of the fistula for hemodialysis treatment. Therefore, it is recommended that native fistulas not be accessed until at least 1 month, and preferably 3 to 4 months after creation (13). Practice patterns for first cannulation of native fistulas vary considerably at different programs and internationally, but typically range from 1 to 3 months (14). Any injury or damage to the peripheral veins, either before or after fistula creation, has potential to incite endothelial scarring that may interfere with this maturation process. It is for this reason that the nephrology community strongly advocates early protection of all peripheral veins in patients at risk for end-stage renal disease.

A hemodialysis graft is created with a synthetic conduit inserted into the patient's nondominant arm, close to the skin surface, and interposed between an artery and peripheral vein. The vein must be of sufficient caliber to construct the graft-vein anastomosis and support the substantial blood flow through the vascular access. Hemodialysis grafts typically require a 2 to 3 week healing period to allow the graft material to become incorporated into the surrounding tissue prior to needle cannulation (13).

Arteriovenous fistulas and synthetic grafts both require a brachial artery capable of delivering substantial blood flow (>800 mL/min) and good quality peripheral and central veins which can provide an uninterrupted pathway to the right atrium. Venous stenosis or thrombosis in either the peripheral or central veins may render the limb unsuitable for either form of vascular access.

Central venous catheters are the least desirable vascular access for hemodialysis. Catheters deliver suboptimal blood flow and result in more complications when compared with fistulas or synthetic grafts (15). Nevertheless, hemodialysis catheters continue to be heavily used, with up to 26% of incident patients and 19% of prevalent patients undergoing hemodialysis treatment with a central venous catheter in the United States (16). There are a number of factors that contribute to this unacceptably high rate of catheter use. A fundamental problem is that primary care physicians often delay in referring patients with deteriorating renal function to a nephrology specialist (17). All too often the patient presents to the nephrologist in need of immediate renal replacement therapy. Unfortunately, because of the necessary healing or maturation time for either a graft or fistula, the patient requires a central venous catheter to initiate hemodialysis treatment. Paradoxically, although the arteriovenous fistula is the preferred vascular access, the extended maturation time (3–6 months) of a fistula will often result in prolonged use of a hemodialysis catheter. This is one short-sighted rationalization for use of a synthetic graft that can usually be safely accessed within 3 weeks, instead of an arteriovenous fistula.

It is important to understand that the critical issue of vein preservation does not "go away" when the patient has functional vascular access. This is especially true for patients with synthetic grafts but also applies to those with native fistulas, because any arteriovenous access is at risk for eventual failure (12). The same applies to patients with alternative forms of renal replacement therapy, including peritoneal dialysis catheter or renal transplant. Peritoneal dialysis patients, who do not require immediate vascular access, have a substantial risk of failure due to infection, membrane failure, leaks, or other mechanical problems (18). Failure of peritoneal dialysis requiring conversion to hemodialysis occurs at a rate of 20% to 30% per year (19). Although transplant survival has been improving over the past two decades, there remains a significant rate of long-term allograft failure necessitating return to hemodialysis (20). Some medical centers rank transplant failure as one of the most common reasons for initiation of dialysis (21). Therefore, vein preservation continues to be an important issue for all patients with end-stage renal disease. Every patient starts with only four superficial upper extremity veins with potential to become a native arteriovenous fistula, the cephalic and the basilic vein in each arm. Frequently one or more of these are already damaged or unsuitable by the time dialysis is required. Therefore, the loss of any of these veins represents a significant morbidity that should be strenuously avoided. No peripheral vein should ever be considered "expendable" in this high-risk population.

CATHETER-RELATED VENOUS INJURY

The injurious effects of venous catheters, including venous stenosis, thrombosis, and infection, are well known. However, the true incidence of catheter-related venous stenosis and thrombosis remains illusive. Vascular injury is considered a primary initiating event for catheter-related thrombosis (22). Vascular damage may occur early, at the time of catheter insertion, or the injury may be progressive if the catheter remains in the vein for an extended period. In a small autopsy study, Forauer and Theoharis (23) showed early intimal injury associated with focal endothelial denudation with short-term central venous catheters. With long-term catheter use, there was vein wall thickening, increased smooth muscle cells, and focal catheter attachments to the vein wall with thrombus and collagen.

Early thrombosis may be caused by an acute venous injury sustained at the time of catheter insertion. Standard venous access techniques, with the use of vascular dilators or an introducer sheath, can cause significant damage to the venous entry site. Ducatman et al (24) performed an autopsy study of 141 patients with central venous catheters and reported that 32% had pericatheter thrombus in the brachiocephalic veins or superior vena cava within 2 weeks after catheter insertion.

In the majority of previously published studies, including the classic study of PICCs by Grove and Pevec (25), follow-up imaging studies were only performed in symptomatic patients. A more accurate assessment of venous injury would require thorough venographic imaging both before and after placement of the venous catheter. Allen et al (26) used contrast venography at the time of initial PICC placement, and then again when a subsequent PICC was placed in the same patient. These investigators reported that 23.3% of patients developed venous thrombosis after initial PICC placement. When all subsequent PICC placements were included for patients who underwent multiple PICC insertion procedures, the rate of thrombosis increased to 38%. In this study, the rate of thrombosis in the cephalic vein was particularly high with 57% of patients developing thrombosis after PICC placement. In a similar study, Gonsalves et al (27) reviewed venographic studies that were performed both before and after insertion of PICCs in 150 patients to determine the incidence of central venous stenosis or occlusion. These investigators reported that 7.5% of patients with previously normal central venograms developed subsequent venographic abnormalities after PICC placement; 4.8% developed central venous stenosis and 2.7% had central venous occlusion.

It is now well recognized that large diameter central venous catheters inserted into the subclavian vein can cause stenosis and thrombosis. Hernandez et al (28) used serial venographic studies to evaluate the long-term effects of subclavian vein catheters in 42 patients. At the time of catheter removal, 45% of patients had stenoses and 7% had total thrombosis of the subclavian vein. Interestingly, the follow-up venographic studies revealed that 45% of these patients had at least some resolution of these abnormalities during the 3 month period after catheter removal.

In a retrospective study of 279 central venous catheters in 238 patients, Trerotola et al (29) reported that catheter-related venous thrombosis occurred in 13% of patients with subclavian vein catheters, compared with 3% of patients with internal jugular vein catheters. The mean time to thrombosis was 36 days for subclavian catheters and 142 days for internal jugular vein catheters. Similarly, Bambauer (30) reported an incidence of thrombosis or stenosis of 8% in patients receiving subclavian vein catheters and only 0.3% in patients with internal jugular vein catheters.

It is abundantly clear that both peripheral and central venous catheters can cause substantial venous injuries which may preclude use of the vein for future vascular access construction. Therefore, the use of venous catheters must be minimized in patients who have or are at-risk for developing chronic renal failure.

IDENTIFYING AT-RISK PATIENTS

Patients with any degree of renal impairment can progress to end-stage renal disease and are potential candidates for future vascular access construction. In young patients with relatively mild renal insufficiency, a slow deterioration of renal function over many years may ultimately result in advanced renal failure. Diabetic patients are at particular risk for progression of renal disease. Diabetic patients with overt proteinuria (>150 mg for 24 hours) or any degree of creatinine elevation are at greater risk of renal disease when compared with similar patients with nondiabetic renal disease. For all of these patients, at all stages of their chronic renal disease, vein preservation is a critical issue. It is imperative that all at-risk patients are identified early and appropriate management plans for venous access are disseminated to the patient and to all members of the health care team.

It is essential to establish criteria for the identification of patients with significant established renal failure, or those at risk for progressive renal failure. Although the glomerular filtration rate is considered to be the most accurate measure of renal function, it is rarely measured in patients with chronic renal failure. Renal creatinine clearance is widely accepted as a surrogate measurement for glomerular filtration. Direct measurement of creatinine clearance with 24 hour urine collection is cumbersome and prone to multiple errors in collection and/or measurement, so is largely avoided. Therefore, creatinine clearance is typically estimated with formulas based on the serum creatinine. The most widely used formula for estimating creatinine clearance is the Cockroft-Gault equation: $CrCl = [(140 - age) \times wt_{kg}] \div (PCr \times 72)$; this is multiplied by 0.85 for women (31). Although any degree of renal impairment may be important, a measured or estimated creatinine clearance less than 50 mL/min/1.73 m^2 is indicative of significant renal failure. Other formulas have been derived in attempts to increase the accuracy of this estimation by incorporating additional patient variables (32). However for most clinical purposes, these have not been shown to be superior to the widely used Cockroft-Gault equation (33).

Simple serum creatinine measurement is the most readily available and widely used means of assessing renal function; it is also the least accurate, with wide variations based on age, gender, race, body habitus, nutritional status, and other comorbid factors. However, when these factors are taken into consideration the serum creatinine value can provide insight into the patient's renal function. Guideline 7(B) of the K/DOQI Guidelines recommends that a serum creatinine value greater than 3 mg/dL should be used to identify patients with chronic renal disease which is sufficiently advanced to warrant heightened awareness for preservation of peripheral veins (6).

VENOUS ACCESS FOR PATIENTS WITH CHRONIC RENAL DISEASE

An important factor in developing a hospital-wide policy for management of venous access in patients with chronic renal disease is collaboration between interested parties. Primary referral physicians, nephrologist, interventionalists, advanced practice nurses, and hospital administrators should be encouraged to work together to develop local policies to address this issue. Venous access is frequently a limiting factor for hospital discharge, introducing a powerful influence in an era where hospital "length of stay" is paramount.

As with all medical decisions, there is no protocol that can entirely substitute for good medical judgment; individualized decisions need to be made by the physicians most knowledgeable about the patient and their renal disease. Patients with no further arteriovenous access options in a limb may have a venous catheter placed in that arm without affecting future dialysis access. A PICC may be appropriate for some very elderly or terminal patients who are not anticipated to require hemodialysis for an extended period of time. Vascular access planning for each patient, including alternative management strategies, should be carefully considered and discussed by all members of the health care team.

The administrative policies in many hospitals forbid the use of an existing hemodialysis catheter for any application other than hemodialysis treatment. These policies are based on the premise that frequent use of a hemodialysis catheter by nondialysis staff may lead to an increased incidence of infection, although there is no published evidence to support this conclusion. This potential risk must be weighed against the potential long-term consequences associated with the insertion of a second venous catheter. In some instances, particularly for patients with limited venous access, it may be prudent to use the existing hemodialysis catheter for other needs. Meticulous catheter care combined with a concerted effort to minimize use of the catheter can make this a viable option. Routine blood samples can be obtained when the catheter is accessed for hemodialysis. In patients with renal failure, the delayed elimination of certain antibiotics can be used to our advantage. In particular, vancomycin (34), aminoglycosides, quinolones, and most cephalosporins (35) can be dosed to maintain effective levels when administered 3 times per week at each hemodialysis treatment. The selection of one of these antibiotics, when medically appropriate, can obviate the need for a separate venous access. Certain antibiotics, most notably penicillin and its derivatives, require more frequent dosing intervals and may require placement of alternative venous access.

Hospitalized patients who need a temporary hemodialysis catheter plus another route for venous access are good candidates for a triple lumen hemodialysis catheter (36). These unique catheters have two large lumens for hemodialysis and a third smaller lumen which can be used for blood draws and the administration of medications. These temporary catheters can be used for up to 3 weeks duration. Triple lumen, long-term (tunneled) hemodialysis catheters are currently being developed by several manufacturers.

Our experience is that the physicians who routinely order PICCs are actually requesting any suitable form of reliable, minimally invasive, long-term venous access. There should be an understanding that this order can be translated by the operating physician so that the most appropriate vascular access can be used.

The preferred routes for insertion of a venous catheter into patients at-risk for renal disease are the internal and external jugular veins. For many patients with poor peripheral veins a catheter inserted into the internal jugular vein is easier, faster, and potentially less traumatic than attempting to insert a catheter into a deep, diminutive, peripheral vein. However, jugular vein catheters appear to be associated with a higher incidence of infection when compared with subclavian vein catheters (37,38). CDC recommends avoidance of jugular vein catheters for this reason (39). Tunneling the catheter along the anterior chest wall may reduce infection rates and improve patient acceptance of this route (40). In their paper addressing alternative venous access for patients with chronic renal failure, Sasadeusz et al (41) reported successful placement of 43 small bore catheters, with short subcutaneous tunnels, into the internal or external jugular veins. These investigators reported one catheter-related infection (0.17 per 100 catheter days) and one catheter-related thrombosis. As with all venous access sites there is a risk for the subsequent development of stenosis or venous thrombosis which may complicate future vascular access placement. However, with the use of soft, small caliber catheters the damage to these large veins may be minimized.

RECOMMENDATIONS FOR VENOUS ACCESS IN PATIENTS WITH CHRONIC RENAL FAILURE

1. Educate patients, physicians, and nurses about the requirement for peripheral vein preservation in chronic renal disease. Offer patients medical alert bracelets to wear on the arm to be preferentially protected from venipuncture (6) and state, "No subclavian or PICC."
2. Always consider alternative therapeutic strategies that will accomplish the treatment goal without requiring the use of venipuncture or intravenous catheters. Whenever possible, take advantage of the delayed elimination of certain drugs to allow dosing on the hemodialysis schedule.
3. Identify patients who have established chronic renal failure, or are at higher risk for developing end-stage renal disease.
   Suggested criteria:
   Serum creatinine > 3.0 mg/dL
   Estimated creatinine clearance $<$ 50 mL/min
   Diabetic patients with proteinuria (> 150 mg/day)
4. As recommended by NKF-K/DOQI Guideline 7 (6), "Arm veins suitable for placement of vascular access should be preserved regardless of arm dominance. Arm veins, particularly the cephalic veins of the nondominant arm, should not be used for venipuncture or intravenous catheters. The dorsum of the hand should be used for intravenous lines in patients with chronic kidney disease."
5. Offer alternative venous access for patients with renal disease, particularly tunneled jugular vein catheters. Develop the skills and techniques necessary to achieve safe, secure, comfortable, and cosmetically acceptable jugular insertions.
6. Develop and implement written hospital venous access protocols that reflect these recommendations.

Vascular access is one of the most critical factors in the management of hemodialysis patients, and accounts for substantial morbidity, hospitalization, and expense. Preservation of any and all veins that might be required for arteriovenous hemodialysis access is warranted at all stages of progressive renal failure. The importance of this issue to the nephrology community and dialysis patients cannot be overemphasized.

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