JNEPHROL 2007; 20: 399-405

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Interventional nephrology: from episodic to coordinated vascular access care

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ABSTRACT

In recent years, nephrologists have taken the initiative of performing vascular access–related procedures themselves. Because of their unique clinical perspective on dialysis access and better understanding of the intricacies of renal replacement therapy, nephrologists are ideally suited for this activity. This approach has minimized delays, decreased hospitalizations and decreased the use of temporary catheters, thereby improving medical care, decreasing costs and increasing patient convenience. Vascular access interventions commonly employed by nephrologists include vascular access education, vascular mapping, percutaneous balloon angioplasty, thrombectomy, intravascular coil and stent insertion and tunneled hemodialysis catheter–related procedures. While the performance of these procedures by nephrologists offers many advantages, appropriate training to develop the necessary procedural skills is critical. Recent data have emphasized that a nephrologist can be successfully trained to become a competent interventionalist. In addition to documenting excellent outcome data, multiple reports have demonstrated the safety and success of an interventional nephrology approach. The last decade has been a period of significant advances in this new field. This has been driven in part by the formation of the American Society of Diagnostic and Interventional Nephrology (ASDIN), whose mission includes training, quality assurance and certification. Recently, the ASDIN has published guidelines for training in nephrology-related procedures and has begun certifying physicians in specific procedures related to chronic kidney disease. It is anticipated that this will promote the skillful performance of these procedures by nephrologists and lead to substantial improvements in the care of renal patients. Challenges for the future include awareness of this subspecialty and development of training programs at academic centers on a larger scale.

Key words: *Hemodialysis access, Interventional nephrology, Percutaneous balloon angioplasty, Thrombectomy, Tunneled hemodialysis catheter*

INTRODUCTION

Over the past decade, significant advances have been made by nephrologists in the performance of hemodialysis access–related procedures (1-16). Because of their training and experience, nephrologists have a unique clinical perspective on vascular access–related issues, renal disease and renal replacement therapy and dialysis outcomes. This perspective makes nephrologists ideally suited to perform vascular access–related procedures. Recent data have emphasized that nephrologists can assume a greater role in the procedural aspects of vascular access and do so with effectiveness, efficiency and safety (2-18).

Vascular access always has been the Achilles' heel of extracorporeal dialysis. Historically, nephrologists took the lead in the development and clinical application of innovations in vascular access. However, surgeons and radiologists have become the clinicians who perform most vascular access–related procedures and, perhaps by default, have become the clinicians who have made most of the decisions regarding access planning and placement. As a result, vascular access options available to nephrologists caring for hemodialysis patients typically have been limited by the diagnostic and percutaneous technologies offered by their radiology colleagues and by the repertoire of their surgical colleagues. The terrain is changing in those medical communities where interventional nephrology has emerged and widened the horizons of both diagnostic and procedural options available for nephrologists to offer their hemodialysis patients. A consequence is the resurgence of nephrologists again in assuming a leadership role in clinical decision-making regarding vascular access planning, placement and maintenance.

Vascular access education

At our center, interventional nephrologists have spurred the dialogue regarding vascular access. There is a flurry of enthusiasm for learning about vascular access that extends from the senior through the junior faculty to the fellows and beyond to embrace the house staff and medical students. The clinical staffs of our dialysis units have a new enthusiasm and commitment to access surveillance, management and maintenance. In this context, vascular access care is moving from an episodic event to coordinated patient care.

These changes have resulted from the direct involvement of interventional nephrologists in patient care, working together with other physicians and other members of the health care team in clinical settings. New dialysis patients are more expeditiously examined for purposes of access planning. Clinical problems in prevalent hemodialysis patients such as reduced access flow rates, swollen arms and steal syndromes are assessed on a regular basis in the dialysis clinics. Physical examination techniques are demonstrated and whenever possible correlated with vascular radiographic images. Results of diagnostic and therapeutic interventions are shared with the patient's care team through reports and direct communication.

Interventional nephrologists are having a very positive impact on the educational environment and importantly are raising the level of concern about vascular-access health care and positively influencing access outcomes at all levels. One of the most important effects has been to stimulate early referral of patients for vascular access evaluation, planning and placement. Perhaps just as important has been the positive impact on patient education and awareness of vascular access issues discussed below.

Vascular access planning

The National Kidney Foundation Dialysis Outcomes Quality Initiative (K/DOQI) recommends that prospective end-stage renal disease (ESRD) patients, as well as prevalent dialysis patients, should be clinically evaluated by history and physical examination to determine the most suitable type and location of vascular access (1). When clinical evaluation by history and physical examination reveals potential problems known to be associated with vascular impairment, diagnostic evaluation by venography and/or vascular ultrasound is recommended to detect underlying defects in vascular structure and flow. Such problems include edema, collateral veins, prior subclavian vein cannulation, a transvenous pacemaker, prior trauma or surgery in the area of venous drainage, multiple previous accesses and diminished arterial pulses. Venography is cited as most useful for vein assessment, especially central veins, while ultrasonography may be particularly useful for vascular evaluation when contrast agents are to be avoided (1). A major goal is to foster the placement of arteriovenous fistulae (AVFs) while minimizing the placement of arteriovenous grafts (AVGs) and limiting tunneled dialysis catheters (TDCs) to short-term use as bridge accesses while the preferred AVF accesses mature. Indeed, vascular mapping prior to any vascular surgery procedure has proven to be essential for achieving this goal.

Vascular mapping

One of the most important impacts of the interventional nephrology team has been to demonstrate the importance of vascular mapping prior to any surgical procedures. This experience has confirmed that physical examination is not adequate to demonstrate either the presence or absence of suitable veins for creation of an AVF. The final outcome has been the identification of vessels suitable for an AVF in patients previously thought to be candidates only for grafts or for consignment to permanent use of catheters.

It is unimportant where the preoperative access evaluation takes place as long as the information is available to the individual constructing the access and the individual performing the evaluation (Doppler ultrasound or venography) has received sufficient training in the techniques and can perform an ample volume of procedures to maintain and improve his/her skills. In an ideal setting the evaluator and the "surgeon" are the same individual, but this is not mandatory, as long as the information is shared. At some centers, interventional nephrologists do the majority of mapping and endovascular interventions; at others, it is the radiologist; at still others it is the vascular access surgeon. Collaboration is the key, particularly in those cases where the evaluation indicates a challenging anatomy or the need for "innovative" solutions.

It has become routine at our medical center for all patients needing vascular access surgery to be referred to interventional nephrology for preoperative venography (3, 18). Our interventional nephrology team has elected to evaluate vessels for access placement by using venography rather than sonography (3, 18). However, this approach has the drawback of not evaluating the arterial supply. There have

not been any randomized studies to determine whether venography is superior to sonography for evaluation of the venous vasculature prior to access surgery. Venography offers the clear advantage of directly imaging central veins instead of indirect assessment provided by Doppler evaluation. By contrast, Doppler ultrasound offers the advantage of noninvasive arterial evaluation. Regardless, preoperative vascular assessment utilizing ultrasonography or venography has been demonstrated to be superior to physical examination (inspection of veins by the naked eye using a tourniquet placed on the upper arm) in evaluating vessels suitable for AVF creation (19-22). Relying on physical examination to assess the vascular system may exclude patients in whom venography or vessel mapping would demonstrate adequate vessels for AVF creation.

Upon conclusion of vascular mapping, patients are educated about a possible site(s) for fistula creation using simple lay terminology. We have found that this is an opportune time to educate patients regarding vascular access types and their associated complications, including the risks of morbidity and mortality. The AVF is highlighted as the best available access with the lowest incidence of complications and best associated patient survival. Patients are encouraged to request the creation of an AVF at their appointment with the surgeon, and this is further reinforced through a written communication. It is entirely proper to make such a request to the surgeon, and if an AVF is not possible, the reasons should be explicitly documented in the communications between members of the access team.

The value of vascular mapping in fostering creation of AVFs is illustrated in 2 case series we recently have reported (3) (see also Asif et al. Maximizing fistula creation in prevalent hemodialysis population. American Society of Diagnostic and Interventional Nephrology meeting. Phoenix, Arizona, USA, 2005 [abstract]). In the first instance (3), among 86 patients originally consigned to permanent catheter use, vascular mapping demonstrated that 94% of patients with no prior arteriovenous accesses (64 of 66) had suitable veins for arteriovenous access placement and 90% of patients with previously failed arteriovenous accesses (18 of 20) had suitable veins, all basilic veins in the latter cases. Seventy-two of these 86 patients agreed to proceed to vascular access surgery; fistulae were created in 68 of 72 patients (94%), the other 4 patients required AVG placement due to a lack of a suitable vein in proximity to an adequate artery for inflow (for example, no usable basilic or cephalic vein). These findings clearly demonstrate the value of vascular mapping in detecting vessels suitable for arteriovenous access placement, even in patients previously consigned to percutaneous catheters because of prior vascular access failures. The most striking outcome of this experience was that AVFs comprised 94% of the arteriovenous accesses created. Indeed, these results virtually mandate the search for patent veins suitable for arteriovenous access placement in every patient dialyzing with a percutaneous catheter.

The second series (see Asif et al. Maximizing fistula creation in prevalent hemodialysis population. American Society of Diagnostic and Interventional Nephrology meeting. Phoenix, Arizona, USA, 2005 [abstract]) of patients comprised 10 patients referred to interventional nephrology with problematic arteriovenous accesses: 5 patients with AVGs that were either thrombosed or had poor flow due to venous stenosis, 3 patients who had mega-fistulae with thin-walled aneurysms and outflow stenosis, 1 patient with inadequate arterial flow to an AVF and a final patient with multiple thromboses of an AVF related to prior stent placement. Management options for thrombosed AVGs and stenotic lesions traditionally have included thrombectomy, angioplasty, stent placement and, when these fail, placement of a “jump” AVG. Similarly, the treatment of “serpentine” mega-AVFs, after resection, has generally been replacement by an AVG. The end result regretfully has been an AVG. During the interventional procedures for access problems in these 10 patients, vascular anatomy suitable for creation of AVFs was identified, and all 10 patients had successful creation of secondary AVFs. Our experience with these patients again demonstrates that secondary AVFs, rather than “jump” AVGs, often can be placed successfully in patients with problematic arteriovenous accesses. As recommended by K/DOQI guidelines (1), we recommend that during percutaneous interventions, patients should routinely be evaluated for vessels suitable for creation of secondary AVFs.

These 2 clinical experiences illustrate how a dedicated interventional nephrology team can be effective in optimizing the vascular access health status of dialysis patients by minimizing AVG use and maximizing creation of AVFs.

INTERVENTIONS

Interventions can be done in dedicated free-standing vascular access centers within or outside of hospitals. Small dialysis centers may not have adequate volume to sustain “independent” programs, but the needs of several geographically close dialysis units can be met by 1 Interventional vascular access unit. In general, about 500

dialysis patients are needed to support an endovascular vascular access suite wherein a wide variety of procedures can be performed. This requires mutual cooperation to build a regional team that will support the required personnel and staff.

Percutaneous balloon angioplasty

Both arteriovenous grafts and fistulae may develop vascular stenosis. The pathophysiologic mechanisms of stenosis are complex; however, neointimal hyperplasia appears to play a pivotal role (23, 24). Traditionally, it has been highlighted that stenosis in grafts occurs most frequently at the venous anastomosis (about 60%). Recent information from our center, however, has emphasized that lesions may occur anywhere within the access system and can coexist as single or multiple (7). Regardless of the location of the stenosis, percutaneous balloon angioplasty has become a standard treatment for the management of arteriovenous dialysis access (grafts or fistulae) stenosis (4-8).

For both types of permanent accesses, access stenosis should be treated if the stenosis is 50% or greater and is associated with clinical or physiologic abnormalities (1). The abnormal clinical parameters used to suspect the presence of stenosis should return to within acceptable limits following intervention. In a series of 1,120 cases of venous stenosis treated by angioplasty at multiple access centers, Beathard (25), reported the initial success rate when performed by interventional nephrologists/surgeons to be 94%. Primary (unassisted) patency determined by life table analysis was as follows: 1 month - 87.4%, 2 months - 84.8%, 3 months - 77.2%, 6 months - 66.4%, 1 year - 44.5%. These results are comparable to those reported by interventional radiology (26, 27).

A significant number (10%-40%) of AVFs do not adequately develop and fail to sustain dialysis therapy. Recent data have classified fistulae failure into early and late failure (8). Early failure refers to fistulae that never develop to the point where they can be used or that fail within 3 months of successful usage. In contrast, late failure denotes failure after 3 months of successful usage. Traditionally, these undeveloped fistulae were abandoned. Recently, Beathard et al (8) provided invaluable information regarding how to improve the function of an AVF that is not developing properly. In this prospective observational study, 100 patients with early failure underwent evaluation and treatment at 6 free-standing outpatient vascular access centers. Vascular stenosis and the presence of a significant accessory vein (an accessory vein is described as a branch coming off the main venous channel that comprised the fistula) alone or in combination were found to be the culprits. Venous stenosis was present in 78% of the cases. Nearly a majority of these lesions (48%) were found to be close to the anastomosis (juxta-anastomotic lesion). A significant accessory vein was present in 46% of the cases. Percutaneous balloon angioplasty and accessory vein obliteration using any of the 3 techniques (percutaneous ligation using 3/0 nylon, venous cutdown or coil insertion) were used to salvage the failed fistulae. Angioplasty was performed with a 98% and vein obliteration with a 100% success rate. Postintervention, it was possible to initiate dialysis using the fistula in 92% of cases. Actuarial life table analysis showed that 84% were functional at 3 months, 72% at 6 months and 68% at 12 months.

A nephrologist can effectively establish a surveillance program to monitor vascular access function, identify the failing access and perform percutaneous intervention to correct stenosis and maintain a healthy vascular access and avoid access failure. By use of an aggressive approach and employment of 2 basic techniques, balloon angioplasty and vein obliteration, nephrologists can successfully salvage and subsequently utilize an otherwise failed fistula. A recent study from northern Italy indicates that screening for stenosis was uniformly used and in many cases used both clinical examination and surrogates for access flow. Angiography and Doppler were used in equal proportions for imaging, with nephrologists acting preemptively on 57% of "well-functioning" AVF (28).

Thrombectomy procedure for access thrombosis

Nephrologists are routinely performing thrombectomy procedures for a thrombosed arteriovenous graft and fistula (5, 6, 9, 10). Both mechanical and pharmacomechanical thrombolysis for the treatment of thrombosed dialysis access can be successfully performed by nephrologists (6, 9, 10). Although the initial success rate (95%) is similar to that for the angioplasty procedure, primary patency rates after thrombectomy of a clotted vascular access are markedly reduced when compared with the primary patency following angioplasty of access stenosis.

Thrombosis leading to access failure is a major issue. It often causes unnecessary hospitalization, missed dialysis, frustration on the part of the dialysis staff and patients and exposes the patient to temporary catheters. Ideally, this

complication should be managed rapidly, under local anesthesia and on an outpatient basis. Recent data have clearly shown that such care is being delivered successfully by nephrologists at many centers on an outpatient basis (4-6, 10). Nevertheless, aggressive detection and early correction of hemodialysis access stenosis is of utmost importance to decrease graft thrombosis and improve access survival.

TUNNELED HEMODIALYSIS CATHETER PROCEDURES

Hemodialysis cuffed tunneled catheters are commonly used as a bridge access to allow time for placement or maturation of a permanent vascular access (AVF or AVG). In addition, they may be used as a temporary access for hemodialysis for patients with acute renal failure. Finally, tunneled catheters may also be used as a permanent vascular access for patients who have exhausted all other options to receive hemodialysis. Traditionally, these catheters were placed by surgeons and less frequently by interventional radiologists (29). However, many nephrologists are now performing this procedure routinely both on an inpatient as well as outpatient basis (11, 13-15). In addition to the catheter insertion, catheter exchange and removal procedures, nephrologists are also engaged in developing optimal catheter design to achieve adequate blood flow to sustain dialysis treatment (15).

Tunneled catheters play a major role in the delivery of hemodialysis therapy to a large portion of the dialysis population. However, their use is associated with many complications (1, 16). In addition to catheter-related infection, fibroepithelial sheath formation is associated with these catheters and leads to catheter malfunction and occlusion (16, 30). A recent study (30) evaluating 947 cases of catheter dysfunction (inability to sustain a blood flow greater than 300 ml/min) documented that fibrin was detected in 368 cases (38.8%). The presence of a fibrin sheath was determined at the time of exchange using radiocontrast material administered through the venous port of the old catheter. In this study, an angioplasty balloon catheter was inserted over a guidewire through the catheter tunnel, and thereby through the lumen of the fibrin sheath, and was then inflated to disrupt the fibroepithelial sheath. The investigators used an 8-mm balloon diameter with a 100% success rate. Removal of the sheath was confirmed by a repeat radiocontrast injection at the time of insertion of the new catheter over the guidewire. Catheter blood flow rates sufficient for dialysis were achieved in 99%. The presence of a fibrin sheath is a relatively common cause of tunneled catheter dysfunction (16, 30). Nephrologists can successfully manage this complication on an outpatient basis by using percutaneous balloon angioplasty and over the wire catheter exchange techniques.

COMPLICATIONS OF PERCUTANEOUS INTERVENTIONS BY NEPHROLOGISTS

Recently, in the largest prospective series published to date (n=14,047), Beathard and Litchfield reported the complications of endovascular procedures performed by interventional nephrologists (17). In this report, data on basic hemodialysis procedures (tunneled hemodialysis catheter [THC] insertion and exchange, percutaneous transluminal angioplasty [PTA] of grafts and fistulae, and thrombectomy of both grafts and fistulae) were analyzed for safety and effectiveness.

In 5,121 PTA procedures (fistulae, n=1,561; grafts, n=3,560), the complication rate in cases of fistulae and grafts included 3.35% and 0.76% grade 1 hematomas (stable, does not affect flow), 0.4% and 0.11% grade 2 hematomas (stable, slows or stops flow) and 0.19% and 0.05% grade 3 hematomas (represents a complete vascular rupture, expands rapidly and leads to access loss), respectively (17). These results are far superior to those reported previously (1.7%-6.6%) (31-34).

Among 4,899 thrombectomy cases (fistulae, n=228; grafts, n=4,671), the complication rate in cases of fistulae and grafts included 5.7% and 3.32% grade 1 hematomas (stable, does not affect flow), 0.88% and 0.83% grade 2 hematomas (stable, slows or stops flow) and 0.43% and 0.41% grade 3 hematomas (represents a complete vascular rupture, expands rapidly, leads to access loss), respectively (17). Peripheral artery embolism occurred in 0.38% of cases. These complication rates are lower than those reported previously (10%-16%) (27, 35, 36).

A total of 4,027 THC-related procedures were evaluated for complications (17). In the THC insertion procedure group (n=4,027), complications included minor oozing at the cannulation and exit site (0.36%) and major adverse events such as pneumothorax (0.06%). In contrast, both the surgical and radiological literature have documented a much higher incidence rate of complications including pneumothorax (2.5%) (29), hemothorax (0-0.6%), bleeding requiring exploration and/or transfusion (0-4.7%) and

recurrent laryngeal nerve palsy (0-1.6%) (37-39). When cases with THC exchange were analyzed (n=2,262), only 1.41% had minor complications, and there were no major complications identified (17).

Conclusion

As nephrologists, we bear the ultimate responsibility for the outcomes of our patients. The data are clearly there to indicate safety, success, quality and excellent outcomes when vascular access–related procedures are performed by nephrologists. In addition, the all-too-frequent delays are minimized and procedural care more efficiently delivered by a nephrologist trained in hemodialysis vascular access procedures. Nephrologists must play a more proactive role in the planning and procedural management of hemodialysis access. Finally, the specialty of interventional nephrology can result in more nephrologists asking pertinent clinical questions and then attempting to answer them with well-planned studies.

Acknowledgements

Pietro Ravani held a young investigator award from the Italian Society of Nephrology for the year 2005-2006 and received funding from the EU (Marie Curie Actions-OIF, proposal #021676) for the year 2006-2007. Prabir Roy-Chaudhury is supported by grants from the National Institutes of Health and Satellite Dialysis.

Conflict of interest statement: None declared.

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