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The native arteriovenous fistula in 2007 Surveillance and monitoring

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ABSTRACT

In the past 5 years, some clinical trials have questioned the value of surveillance in managing vascular accesses. Although prolongation of access life span is an important end point, reduction of thrombotic events reduces patient risks resulting from loss of access patency. Most of the available evidence suggests that detection of stenosis and prevention of thrombosis is valuable. When a test indicates the likely presence of a stenosis, then venography or fistulography should be used to definitively establish the presence and degree of the stenosis. In most but not all cases, angioplasty should be performed if the stenosis is greater than 50% by diameter. The value of routine use of any surveillance technique for detecting anatomic stenosis alone, without concomitant functional assessment by measurement of access flow, venous pressure, recirculation or other physiologic parameters, has not been established. Stenotic lesions should not be repaired merely because they are present. If such correction is performed, then intraprocedural or periprocedural measurement of access flow (Q_A) or intra-access pressure should be conducted to demonstrate a functional improvement with a successful percutaneous transluminal angioplasty.

Key words: *Dialysis, Outcomes, Stenosis, Surveillance, Vascular access*

SCOPE OF THE PROBLEM OF MAINTAINING ACCESS PATENCY

Adequate vascular access function is the most important component determining the success or failure of hemodialytic therapy (1). Access problems are a daily occurrence in busy dialysis units. Low blood flow rates and loss of patency limit dialysis delivery, extend treatment times and result in underdialysis leading to increased morbidity and mortality (2). Maintenance of adequate flow is the chief means of assuring delivery of the prescribed dialysis dose. The reader is referred to the Kidney/Dialysis Outcomes Quality Initiative (K/DOQI) hemodialysis adequacy guidelines (3) for additional information on the importance of achieving the prescribed dialysis dose with regard to mortality. All too often, loss of access patency requires use of cuffed or uncuffed catheters to bridge the interval until the access can be salvaged or a new one established. Between 1991 and 2001, the incidence of vascular access events in patients undergoing hemodialysis rose by 22% (4) with consequences on morbidity and mortality (2, 5). Vascular access–related complications also account for 15% to 24% of hospitalizations among end-stage renal disease (ESRD) patients undergoing hemodialysis (6). Thrombosis, the leading cause of loss of vascular access patency, increases health care spending (7), and adversely affects quality of life (8). In 1997, the National Kidney Foundation (NKF) published the K/DOQI guidelines for the improvement of renal care (9). The 2 major vascular access recommendations that came forth with the initial (9) and the subsequent revisions in 2000 (10) and 2006 (11) were augmentation of the construction of autologous native arteriovenous fistulae (AVFs) and detection of hemodynamically significant stenosis likely to produce dysfunction or thrombosis of the access.

The present review discusses the advantages and limitations of available strategies implemented for monitoring and surveillance of the AVF.

SURVEILLANCE AND MONITORING: DEFINITIONS

The following definitions will be used throughout this paper.

Monitoring (M) - physical examination (inspection, palpation and auscultation) of the vascular access to detect physical signs that suggest the presence of dysfunction (12). In the United States, these basic skills are not used. Rather there is a tendency to emphasize technology, especially methodologies that are built in as "elective" modules into the dialysis delivery system.

Surveillance (S) - periodic evaluation of the vascular access by means of specialized tests that involve special instrumentation. Such tests include access flow, access resistance, intra-access pressure and access recirculation. Measurements such as urea reduction ratio (URR) and Kt/V measure the effect of inadequate access function on the delivery of dialysis. In grafts, these latter measures are poor indicators of access dysfunction or presence of hemodynamically significant stenosis (13). By contrast, in AVFs which remain patent at much lower flows, sequential measurements of these values may indicate the presence of correctible stenosis (14). Duplex Doppler ultrasound (DDU) is unique among the surveillance tests because it is able not only to measure access flow but also to visualize and quantify the severity of any stenoses present (15).

It is important to emphasize that *surveillance* and *monitoring* (S/M) are complementary. Surveillance/monitoring using specific assessments must be combined with regular assessment of clinical parameters of the AVF and dialysis adequacy. These data should be tabulated and tracked within each dialysis center as part of a quality assurance and continuous quality improvement program. Best results are obtained when a multidisciplinary relationship among access surgeons, nephrologists, nurses, and interventional radiologists (vascular access team [VAT]) is developed. *Whatever the VAT's size and composition, its most important function is to work proactively to ensure that the patient's access is ready when needed for dialysis and that thereafter delivery of adequate dialysis dose is achieved by maintaining access function and patency.*

Diagnostic testing - specialized testing that is prompted by some abnormality or other medical indication specifically undertaken to diagnose the cause of the vascular access dysfunction. The current gold standard is angiography, but DDU can be used for this function as well (16). In most cases the individual is sent to a radiologic center where contrast visualization can occur (17). In some cases, intra-access angioscopy and ultrasound can be performed (18). Magnetic resonance angiography (MRA) can also be used to characterize the anatomic presence of stenosis (19-21) as well as to quantitate flow (22).

Intervention - performance of a procedure that dilates a stenosis, stents it, bypasses it or resects it. The most common procedure performed for stenosis is percutaneous transluminal angioplasty (PTA) using high-pressure balloons with burst limits above 30 atmospheres (atm). If the access is thrombosed, a variety of techniques are available to remove the clot. Thrombolytics may or may not be used depending on the type of access and the volume of thrombus.

THE S/M PROCESS AND METHODS OF SURVEILLANCE

Monitoring (the use of physical examination) is an integral process in the evaluation of an AVF. It must be carried out not only in those patients on hemodialysis but also in those with chronic kidney disease (CKD) stage 4-5 in whom an AVF has been created in preparation for dialysis. Many nonmaturing AVFs can be salvaged using percutaneous treatments that include angioplasty and obliteration of competing venous collateral vessels (23-26). Best results are obtained when patients with nonmaturing native fistulae are identified within 1-3 months of creation, permitting referral of patients for fistulography and percutaneous salvage (27). If the physical examination does not clearly indicate the cause for nonmaturation, both DDU (15) (with or without color) or contrast fistulography (using dilute low-volume injection) can be performed without risk of precipitating renal failure in patients with advanced CKD (28).

Lomonte et al (29) used DDU to document the changes in blood flow rate in the brachial artery following construction and maturation of a radiocephalic wrist AVF in 18 incident uremic patients. The internal diameter and blood flow rate of the brachial artery (Q_{BA}) at baseline were 4.3 ± 0.7 mm and 56.1 ± 19.2 ml/min, respectively, and Q_{BA} increased to 438.4 ± 86.0 ml/min at day 7, 720.4 ± 132.8 ml/min (median 750 ml/min, range 480-890 ml/min) at 28 days and 997.6 ± 259.7 ml/min at 258.0 ± 63.0 days after AVF construction in 17 of the AVFs. One failed to mature, with a flow of 88 ml/min at day 28. Thus the most rapid increases occur within the first week (50% of maximum), with progressively smaller increases thereafter. One of the authors (A.B.) has used a similar technique of measuring brachial artery flow to assess the relationship of Q_{BA} to intra-access pressure (30). Given that the brachial artery flow is relatively easy to measure compared with that of the fistula itself, this measure may be helpful in determining which AVFs will probably fail. This screening should aid clinical assessment, thus allowing sound judgment of the level of maturation of an AVF and of its outcome.

With the high maturation rate that exists, surgical technique should also be reviewed. In a multicenter clinical trial, anastomoses created with nonpenetrating interrupted clips showed significant improvement in primary, assisted primary and secondary patencies of AVFs and grafts (31, 32). In addition, both charge and payment calculations indicated financial benefits with the use of clips.

Once an AVF has been constructed and the patient is receiving maintenance hemodialysis, the responsibility for monitoring and surveillance is transferred to the dialysis center. All too often, the responsibility is placed in the hands of 1 individual. It is not feasible for any 1 individual to manage all aspects of access care. The only successful programs that we are aware of have all developed multidisciplinary teams (33, 34) with a designated vascular access coordinator.

In a properly operational program, asymptomatic but functionally significant stenoses in AVFs are detected through a systematic S/M program, referred for study, intervened upon and checked to verify that the hemodynamics or functional abnormality has improved. A functionally significant stenosis is currently defined as a reduction greater than 50% of normal vessel diameter that is accompanied by a hemodynamic or clinical abnormality. Note that the presence of stenosis alone is not sufficient to define access dysfunction; detected stenoses must be accompanied by either clinical or hemodynamic abnormalities that interfere with the delivery of dialysis, produce patient symptoms, impede AVF maturation or are likely to produce thrombosis within several months.

In those in whom the AVF is already being used for hemodialysis, the development of abnormal recirculation values, elevated intra-access pressures, decreased blood flow, swollen extremity, unexplained reduction in Kt/V or elevated negative arterial pre-pump pressures that prevent increases in the delivered blood flow to acceptable blood flow levels heralds the development of a functionally important stenosis (35). Prospective S/M should provide the ability to prolong the use of an AVF, allow salvage of an existing AVF or promote sequential vascular access through planning, coordination of effort and elective corrective intervention rather than urgent procedures or replacement (36).

The current KDOQI vascular access work group has developed explicit guidelines regarding which surveillance tests should be used to evaluate a given access type and when and how to intervene to reduce thrombosis and underdialysis (11). A number of surveillance methods can be used with AVF: sequential access flow, sequential static pressures, recirculation measurements, physical examination and of course combinations of these. According to the Clinical Performance Project of the US Centers for Medicare and Medicaid Services, the dynamic pressure test is still overwhelmingly used in AVFs (37) without correction for the effect of needle gauge used in the initial validation (38). This surveillance technique has no place in AVF (11).

The basic tenet of vascular access monitoring and surveillance is that stenosi(e)s develops over variable intervals in the great majority of AVFs and if detected and corrected, maturation can be promoted, underdialysis minimized or avoided and thrombosis avoided or reduced. The rationale for S/M depends on the "dysfunction" hypothesis: AVF stenosis reduces access flow and alters pressure profiles. An inflow stenosis either prevents maturation of the AVF or in an established AVF, produces dysfunction impairing the delivery of adequate dialysis and often preceding thrombosis. The usefulness of flow or pressure surveillance critically depends on the accuracy of the measurements themselves. Unfortunately, both access flow and pressure vary in patients during and more importantly between dialysis sessions. This arises from needle rotation for cannulation and changes in hemodynamics among dialysis sessions (39). A single measurement is an inaccurate predictor of the presence of stenosis. The *only rational means to detect an evolving lesion* is to perform analysis using multiple repetitive measurements correlated with clinical findings so that inappropriate referrals are not made. Currently there is very little quality assurance of the “success” of an intervention other than anatomical.

Crucial to the interpretation of any S/M technique is knowledge of the “best function” of the AVF with respect to intra-access flow and pressure profile. The pressure drop across the entire AVF system is set by the mean arterial pressure (MAP) less central venous pressure. The useable access flow, Q_A, resulting from this driving force in turn depends on many variables: site of anastomosis (the arterial diameter is larger proximally), presence or absence of disease in the feeding artery, the patient’s ability to augment cardiac output in response to the fistula, health of the vein and its ability to dilate and remodel and the presence of tributaries. Development of stenosis in the AVF circuit will either limit the initial flow increase or after maturation lead to a progressive decrease in Q_A. Intra-access pressure will usually not increase unless there is a downstream stenosis (as from a cephalic arch or central vein stenosis).

It is important to emphasize that the quality and physical dimensions of the artery and vein will determine the initial AVF function. If the artery is healthy, the flow capacity of the AVF will be determined by the characteristics of the vein used in access construction. Too small a vein will limit the flow. In general, arteries at more distal sites have less capacity to deliver flow than more proximal sites. In general, forearm radiocephalic AVFs have flows of 600-1,000 ml/min, whereas elbow level fistulas have flows of 1,000-2,000 ml/min (40, 41). Some AVFs develop flow >3,000 ml/min and are associated with cardiac decompensation (42). Use of calcified or atherosclerotic arteries will yield a lower Q_A than those unaffected by such processes. Unfortunately, arterial disease is not uncommon; access inflow stenosis occurs in one third (and not the 5% that has been traditionally reported (43)) of the graft cases referred to interventional facilities with clinical evidence of venous stenosis or thrombosis (44). This high rate is due to the aging of the population and the progressive calcification of arteries that occurs in many patients over years of dialysis.

A recent study from Spain found a significant frequency of arterial disease in AVF during longitudinal observation (45) of 102 patients, mean age 63.0 ± 13.0 years, mean time on hemodialysis (HD) 31.4 ± 44.0 months; 15.5% with diabetes. Q_A was measured every 4 months for 4 years using the Delta-H method in 116 vascular accesses (AVF 81%) with a mean access use of 28.2 ± 52.9 months. Angiography showed stenosis >50% in 40 of 43 accesses referred for evaluation. Although nearly 70% of AVF showed stenosis in the body of the fistula, stenosis in the feeding radial artery was found in 30.5% with a mean degree of stenosis of 83.5% ± 15.8%. These patients tended to be older (67.5 ± 11.5 years), and their AVF of longer vintage (48.9 ± 76.7 months) since they were on dialysis longer. However, diabetes did not appear to be a factor. Thus the incidence of feeding-artery stenosis in AVFs may be as high as in grafts. The functional results of elective surgery in radial artery stenosis were worse compared with those in vein stenosis.

Although the above study focused on the radial artery, arterial stenosis can occur upstream as well. Duijm et al (46) examined 66 AVFs and found arterial inflow lesions in 10 AVFs of which 7 were radiocephalic and 3 were brachiocephalic. Arterial lesions were located in the subclavian artery in 5 cases, axillary artery in 1 case and radial artery in 4. They recommend that radiologic evaluation comprise assessment of the complete arterial inflow not just that in immediate proximity to the anastomoses.

The relationship between Q_A and intra-access pressure in an AVF as a stenosis develops depends on the location of lesions. If an outflow stenosis develops and increases resistance, pressure will increase and flow decrease. The increase in pressure will affect the post-needle bleeding time and may contribute to aneurysmal dilation. Since the stenotic process progresses variably with time, its detection requires sequential measurements of flow, pressure or both to detect a threshold at which action should be taken. The frequency of measurements depends on the rate of progression. With an inflow stenosis, venous pressures usually do not change or decrease (14). However, such inflow lesions are usually easily detected by physical examination because they occur in the first several centimeters distal to the anastomosis. Paradoxically, a high basal intra-access pressure can occasionally be observed in an AVF in the absence of stenosis, when the flow delivered by a healthy artery is in excess of the venous system’s initial capacitance to accommodate to the flow. Because of all of the above confounders, there is little if any correlation between a single measurement of flow and intra-access pressure.

Thus, serial repeated measurements of pressure or flow within each patient’s AVF correlated with findings of routine physical examination are more valuable in detecting a stenosis than any isolated measurements of absolute intra-access pressure, normalized ratio or access flow. It is our opinion that the frequently cited criterion that uses an “isolated” decrease in Q_A of approximately 25%-30% (47) from some “preceding value” leads to too many interventional referrals and performance of some angioplasties that are not needed and that increase risk to the patient. It is my opinion that access flow measurements performed at greater than monthly intervals provide insufficient data on the “stability of flow” to make timely decisions in AVF. Accumulation of monthly data and statistical analysis of trends allows detection of a true progressive reduction of flow that can affect the delivery of dialysis dose.

Regular assessment of physical findings (monitoring) is, I believe, a crucial part of any S/M program of AVFs and enhances an organized surveillance program to detect access dysfunction. Specific findings predictive of venous stenosis include: edema of the access extremity, prolonged bleeding postvenipuncture (in the absence of excessive anticoagulation) and changes in the physical characteristics of the thrill in the AVF (12). An AVF that does not collapse or become less distended on arm elevation is likely to be harboring an outflow stenosis. Physical examination (augmentation test) is a useful screening tool to exclude low flow (<450 mL/min). Attention also has to be paid to the ratio of blood pump flow to pre-pump negative pressure. Normally this ratio is >1.6 mL min/mm Hg. A progressively decreasing value may reflect inflow problems in the AVF. To use this test correctly, one should set the pre-pump pressure consistently to the same values, for instance between -200 and -250 mm Hg, and trend the blood flow achieved.

The utility of dynamic venous pressure (DVP) at flows of 150-225 ml/min to predict presence of stenosis or occurrence of thrombosis is quite limited (48). There are no direct studies of its sensitivity or specificity to detect hemodynamically significant stenosis in AVFs. As a result, the method is not currently recommended as a surveillance technique (11). By contrast, flow measurements by a variety of techniques (11, 36) – DDU assessment for stenosis (49-51) and static pressure measurements (direct or indirect) (52) – can detect hemodynamically significant stenosis in native fistulae. Although the location of stenosis in fistulae (inflow) favors Q_A over some form of static pressure measurement, no direct comparisons have been made of the 2 techniques using DDU anatomical imaging or contrast angiography to determine the accuracy of the techniques in AVF for detection of functionally important stenosis.

If the prescribed Kt/V is consistently not delivered in a patient who is using a native fistula, measurement of access recirculation, using the recommended urea-based method (table CPG 4-6 (11)) or one of the nonurea methods (53-55), should be conducted. Recirculation is a relatively late predictor of access dysfunction but because of other factors the test is less sensitive and less specific for detecting low flow access dysfunction. Flow in AV fistulae, unlike in AV grafts, can decrease to a level less than the prescribed blood pump flow (i.e., less than 300 to 500 ml/min), while still maintaining access patency (30, 56). Thus measurement of recirculation is a more useful screening tool in AV fistulae compared with AV grafts; in my experience (A.B.), an increase in recirculation >5% was found in over 30% of AVFs evaluated for dysfunction (13, 14).

Flow measurements performed by dilution ultrasound (DUS, Transonic (57)) and other techniques (11, 37) can be done online during dialysis, providing rapid feedback. The same applies for static pressures (54). Flow and pressure techniques can be combined to provide even more hemodynamic information (58). Measuring venous pressure is the least expensive method of surveillance for stenosis (59). Online access flow measurements (60) are available but require further improvements in accuracy and replicability or frequency of measurements to be effective.

The current K/DOQI work group feels that there is insufficient literature evidence to prefer 1 surveillance technique from those listed in the guidelines (11). Although Doppler ultrasound (DDU) studies are predictive of access stenosis and the likelihood for failure (61), frequency of measurement is limited by expense and operator skill (62). Doppler ultrasound may be useful in AVF despite its increased cost (63). Variation in the internal software used for calculating Doppler flow measurements by different manufacturers prevents standardization. Magnetic resonance flow is accurate but expensive (46, 64). Both Doppler flow and magnetic resonance are difficult to perform during dialysis sessions.

In native AVFs, inadequate flow through the access is the primary functional defect that produces underdialysis and increases the probability of thrombosis. It is currently unknown whether indirect measures of flow such as static venous dialysis pressure are less predictive of thrombosis and access failure than flow measurements in AV fistulae. However, combining sequential static measurements with pre-pump pressures to assess for changes in adequacy of inflow may be as effective as flow measurements (A.B., personal observations). In the context of proper needle position, an elevated negative arterial pre-pump pressure that prevents increasing the blood flow rate to the prescribed level is predictive of arterial inflow stenoses.

ISSUES IN THE EFFICACY/VALUE OF S/M IN AQVF

The usefulness of S/M depends on accurate prediction of AVF dysfunction so that problems producing underdialysis are corrected expeditiously and interventions to correct anatomical stenosis are completed within a reasonable interval of time. A dysfunctional access is a very real concern to patients, as almost 60% of patients cite thrombosis of the access as one of the most feared problems associated with hemodialysis, ranking it second only to pain (65). As summarized in Table I, loss of access patency affects the treating staff as well. A body of evidence indicates that prospective S/M to detect stenosis reduces the rate of access failure and/or thrombosis in grafts, although at the expense of increased procedures (11, 38, 66-70). Although it is also agreed that Q_A identifies stenosis in patients with native vessel AVFs, the threshold for intervention is debated. Practice guidelines recommend performing angiography when Q_A is <500 ml/min in an AVF. This value was supported by Tonelli et al (71) who constructed receiver operating characteristic (ROC) curves examining the relationship between different threshold values of Q_A and stenosis in 340 patients with AVFs. The area under the curve for the composite definition of stenosis was 0.86. The small gain in sensitivity associated with a <600 ml/min threshold was outweighed by reduced specificity compared with <500 ml/min. Q_A measurements seemed to predict stenosis or incipient access failure equally well in groups defined by diabetic status, gender and AVF location. Somewhat higher thresholds were found by an Italian group (16) in a group of 120 patients who all underwent fistulography, and 54 of whom were found to have a stenosis of 50% by diameter. A Q_A <700-1,000 ml/min and/or a reduction in Q_A >25% were found to be optimal predictors for stenosis (91% efficiency) and a Q_A <300 ml/min for incipient thrombosis for wrist AVF. A higher value of 1,000 ml/min was noted for stenosis detection in AVFs constructed in the mid-forearm. In their study, correction for systemic blood pressure did not improve performance – similar to the findings in a Canadian study (66). A change in flow did, however, increase the sensitivity of Q_A in predicting the presence of stenosis. Note that flows of 600-1,000 ml/min in AVFs may be associated with the presence of stenosis but at these flow levels, intervention might not be necessary as the access can still deliver adequate flow and has a low risk for thrombosis.

Another study followed 52 randomly selected patients whose accesses were followed for 4 years clinically, in whom Q_A measurements were made only annually, and intervention prohibited unless the AVF failed due to thrombosis or failed to deliver adequate dialysis (72). All failures were due to thrombosis. ROC analysis revealed a Q_A of <700 ml/min as the best predictor of failure over a *period of years*, with a sensitivity of 89%, but a specificity of only 69%. Four-year actuarial survival was 74% in those with Q_A >700 ml/min and only 21% in those with flow <700 ml/min. It should be noted that of the 24 AVFs that remained patent throughout 4 years, 5 had a Q_A consistently less than <500 ml/min.

Thus, a single Q_A threshold for angiography in all patients is too simplistic in my opinion. The optimal threshold might vary by patient subgroup and the best function ever attained by the AVF. This is supported by a retrospective study of 294 incident and prevalent hemodialysis patients treated at a single institution, all of whom had a functioning AVF during the study period (73). Q_A was measured twice a month using ultrasound dilution; a total of 4,084 Q_A measurements were made. Univariate analysis found that younger patient age, non-diabetic status, higher SBP, DBP, MAP (all at the time of Q_A measurement), upper arm AVF location and overweight status (BMI ≥25) were significantly associated with Q_A. SBP was more strongly associated with Q_A than DBP or MAP. In a multivariate model, SBP, overweight status and diabetic status were independently associated with Q_A. The strong association

TABLE I

A THROMBOSED VASCULAR ACCESS IS A MAJOR PROBLEM

For dialysis staff
- Assist patient in coping
- Arrange for transportation
- Interface between patient and physicians
- Rearrange dialysis schedule
For the nephrologist
- Console unhappy patient and family
- Arrange for logistics to resolve AVF failure
For the patient
- Cope with discomfort, pain, anxiety and fear
- Delay of dialysis
- Concerns about K+ and fluid
- Disruption·to schedule
- Decreased quality of life

between SBP and Q_A suggests that adjusting Q_A for SBP may improve the specificity of access screening.

One study that used an ultrafiltration method which changes hematocrit as the indicator signal also established the value of Q_A surveillance in AVFs; the positive predictive value, negative predictive value, sensitivity and specificity of this Q_A method for detecting VA stenosis were 84.2%, 93.5%, 84.2% and 93.5%, respectively (74). However, a study from Australia found less benefit of Q_A surveillance (75): 67 and 68 patients were assigned to the control (usual treatment) and Q_A surveillance groups, respectively. The area under the ROC curve demonstrated, at best, a moderate prediction of (>50%) AVF stenosis (0.78; 95% confidence interval, 0.63-0.94). Thus, unlike the Canadian and Italian groups, these clinicians felt that the addition of AVF Q_A monitoring to clinical screening for AVF stenosis resulted in a nonsignificant doubling in the detection of angiographically significant AVF stenosis. What produces these differences among populations is unclear, but I speculate that the clinical ability of dialysis staff to evaluate AVF might be crucial. In the United States, where the clinical skills are lacking, Q_A surveillance could make a huge difference.

Accuracy of measurement is important in surveillance. Several studies have assessed the degree of variability of Q_A among and within dialysis sessions. Polkinghorne et al (76) measured Q_A and MAP multiple times (at 30, 60, 120, 210, and 240 minutes) during 3 consecutive dialysis treatments. They noted a significant reduction in Q_A and MAP throughout the dialysis treatment, with Q_A decreasing by 5% and 10% in the middle and last third of the treatment compared with the first third. Q_A could be as much as -30.6% from baseline during the last hour of dialysis. MAP influenced Q_A more in radiocephalic (r^2=0.55) than in brachiocephalic fistulae (r^2=0.06). Similar results were found by Huisman et al (77), who measured access flow predialysis using DDU and flow during dialysis using DUS in 2 successive treatments in 24 accesses of which 11 were brachiocephalic and 10 were radiocephalic. Although the mean value was unchanged, the mean coefficient of variation (CV) was large at 16.4%. Within-session CV was smaller at 7%. Variation was larger between sessions if the needle orientation was altered in direction. The data suggested higher variance at higher flows, usually associated with elbow level AVFs.

From the perspective of the patient, the focus on whether AVF access patency is maintained longer is inappropriate. This writer (A.B.) believes that *prevention of thrombosis without prolongation of overall longevity is a worthy outcome*. The objective of access surveillance is the early recognition of dysfunction in order to be able to correct the stenosis by angioplasty or surgery. A retrospective analysis of an incident cohort of 88 hemodialysis patients, demonstrated a 24% primary access failure rate due to complications (8). A total of 2.43 inpatient days and 1.05 outpatient encounters per patient-year-at-risk were directly attributed to such access complications. Improvement in access patency can only come from better treatments of the lesions found. Pharmacologic, cellular and molecular engineering approaches are needed for preventing or producing regression of the lesion of neointimal hyperplasia.

Several studies have been performed evaluating Q_A surveillance and AVF outcomes. Results of prospective surveillance in native AVFs in Spain with measurements made 4 months apart have been positive. The AVF thrombosis rate in 50 patients followed with Q_A surveillance was lower (2/50 or 4%) than in 94 patients not followed with flow measurements (6/94 or 17%; p=0.024) (78). Similarly, a study by Tessitore et al (79) evaluated the effect of PTA on functioning AVF survival. In a prospective controlled open trial, they evaluated whether prophylactic PTA of stenosis not associated with access dysfunction improved survival in native, virgin, radiocephalic forearm AVFs. Sixty-two patients with stenotic, functioning AVFs (able to provide adequate dialysis) were enrolled in the study: 30 controls and 32 to prophylactic PTA. Kaplan-Meier analysis showed that PTA significantly (p=0.012) improved AVF functional failure-free survival rates with a 4-fold increase in median survival and a 2.87-fold decrease in risk of failure. A Cox proportional hazard model identified PTA as the only variable associated with outcome (p=0.012). PTA induced an increase in Q_A by 323 ml/min (range 236-445 ml/min; p<0.001), suggesting that improved AVF survival resulted from increased Q_A. Prophylactic PTA was also associated with a halving of the risk of hospitalization, central venous catheterization and thrombectomy (p<0.05).

A follow-up study by the same group reported on their 5-year randomized controlled open trial of blood flow surveillance and preemptive repair of subclinical stenoses (angioplasty alone or/and open surgery) with standard monitoring and intervention based upon clinical criteria alone (80). Surveillance with blood pump flow (Q_b) monitoring during dialysis sessions and quarterly Q_A or recirculation measurements identified 79 AVFs with angiographically proven, anatomically significant (>50% diameter) stenosis that were then randomized either to a control group (intervention done in response to a decline in the delivered dialysis dose or thrombosis; n=36) or to a preemptive treatment group (n=43). Kaplan-Meier analysis showed that preemptive treatment reduced the failure rate with statistical significance (p=0.003) and the Cox hazards model identified treatment (p=0.009) and higher baseline Q_A (p=0.001) as the only variables associated with a favorable outcome. Access survival was significantly higher in preemptively treated than in control AVFs (p=0.050). This study provides evidence that active blood flow surveillance and preemptive repair of subclinical stenosis reduce the thrombosis rate and prolong the functional life of mature forearm AVFs and that a Q_A >350 ml/min prior to intervention portends a superior outcome with preemptive action in AVFs.

An important aspect of care is the degree of improvement in flow and the durability of the increase in Q_A following intervention. As found by Tessitore et al (80), higher postintervention Q_A was the only variable associated with improved access longevity (p=0.044). In a study by Roca-Tey et al (78), elective intervention was successful in 88% of treated accesses (15/17) with mean Q_A increasing from 563.8 ± 115.4 ml/min just before intervention, to 975.7 ± 351.8 ml/min just after intervention. The latter did not differ from the highest recorded mean Q_A before intervention, 877.7 ± 415.4 ml/min (p=0.25). Access thrombosis during the follow-up period (354.4 ± 293.1 days) occurred in 3 of 17. Five accesses restenosed and 2 of them (40%) underwent reintervention by surgery.

A closer examination of changes in access flow was carried out by van der Linden et al (81). Mean Q_A in AVFs increased from 304 ± 24 ml/min to 638 ± 51 ml/min as degrees of stenosis fell from 72% ± 5% to 23% ± 7%. Q_A values before PTA and the increase in QA postintervention correlated with long-term outcomes, whereas angiographic results did not. The data from this study as well as that from the literature suggest that there is an optimal timing for PTA, and we need more studies on this aspect.

The technique of PTA is too complex to describe here. Trerotola et al (82) collected data prospectively for 102 PTA procedures (66 prophylactic PTA procedures and 36 PTA procedures performed during access thrombectomy). Outcomes data other than residual stenosis were not collected, but the end point for all interventions was a thrill in the access. A total of 230 lesions were treated. Only 2 (1%) could not be successfully treated with PTA despite the use of "ultra-high" pressure. Overall, 55% of lesions required pressures greater than 15 atm to efface the waist. More lesions in AVFs than in grafts (20% vs. 9%) required very high pressure (>20 atm) to efface the waist (p=0.02). Residual stenosis was positively correlated with severity of initial stenosis and negatively correlated with duration of inflation. Thus conventional angioplasty balloons are often inadequate for the treatment of most hemodialysis access stenosis, pressures >15 atm are commonly needed for PTA in hemodialysis access, and importantly very high pressures of >20 atm are often needed in native fistulae.

The overall conclusion from the above studies is that prophylactic PTA of stenosis in functioning forearm AVFs improves access survival and decreases access-related morbidity. They also strongly support a surveillance program for early detection of stenosis. However, the urge to intervene with PTA to prevent thrombosis must be balanced with the observations that PTA almost invariably triggers a repeated need for the same procedure. The optimal care of such patients requires individualization and not rigid application of protocols.

The main controversy that has arisen is whether Q_A surveillance produces benefits in terms of cost and which methodology to use. Lok et al (66) concluded that the functional information provided by low flows was predictive of thrombosis, whereas stenosis detection alone was poorly predictive of incipient thrombosis. Mann et al (83) collected cost data on all incident patients (n=239) between July 1, 1999, and November 1, 2001. During the first year, 18.4% of all admissions were for vascular access–related complications. As expected AVFs had the lowest total cost, but in all cases vascular access care consumed a significant portion of the health care costs in the first year of dialysis. Several studies have examined the trade-offs of vascular access flow surveillance. Wijnen et al (84) noted that access-related costs during a 3-period of surveillance tended to be lower than during the preceding 3-year period without monitoring; an increase in angioplasty interventions was offset by decreased hospitalization for thrombectomy. However, the benefit was seen with grafts and not AVFs, because grafts are more prone to stenosis and thrombosis. The results echo those from half a decade ago by McCarley et al (85). They also noted significant improvement in catheter placement and in missed outpatient treatments.

Finally, Tonelli et al (86) examined the cost-effectiveness of performing angiography in AVFs when Q_A is <500 ml/min, even though a Q_A threshold of <750 ml/min is more sensitive for stenosis. Notably, screening strategies did not reduce expected access-related costs under any clinically plausible scenario. The cost to prevent 1 episode of AVF failure appeared to be approximately Can $8,000-$10,000 over 5 years for both screening strategies, compared with no screening. However the analysis also pointed out that Q_A surveillance might be worthwhile if reduced exposure to central catheters produces morbidity or mortality benefits or a change in quality of life for the patient. Obviously, if the vascular access assessment cost could be reduced by design or labor components, surveillance might become cost-effective even from the heath purchaser's point of view.

Perhaps the use of more than 1 modality needs to be evaluated. Some authors advocate the use of DDU in addition to dilutional flow methods alone to guide PTA (50). The DDU procedure is a known effective method for the diagnosis of vascular access stenosis, and according to Bacchini et al (49), it could improve stenosis screening by avoiding the risks of exposure to ionizing radiation in those without stenosis but low flow, and of adverse reactions to contrast media.

Conclusions

Most of the available evidence suggests that detection of stenosis and prevention of thrombosis in AVF is valuable. When a test indicates the likely presence of a functionally significant stenosis, venography or fistulography should be used to definitively establish the presence and degree of the stenosis. In most cases, angioplasty should be performed if the stenosis is greater than 50% by diameter. Stenotic lesions should not be repaired merely because they are present.

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