Review Article on Endovascular and Surgical Interventions in the End Stage Renal Disease Population

The challenging surgical vascular access creation

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Abstract: With the increasing life expectancy of patients with end-stage kidney disease, the creation and maintenance of hemodialysis vascular access are becoming more challenging. A comprehensive patient evaluation including a complete history, physical examination, and ultrasonographic vessel assessment is the foundation of the clinical evaluation. A patient-centered approach acknowledges the myriad of factors that impact the selection of optimal access for the distinct clinical and social circumstance of each patient. An interdisciplinary team approach involving various healthcare providers in all stages of hemodialysis access creation is important and associated with better outcomes. While patency is considered the most important parameter in most vascular reconstructive scenarios, the ultimate determinant of success in vascular access for hemodialysis is a circuit that allows consistent and uninterrupted delivery of the prescribed hemodialysis. The best conduit is one that is superficial, easily identified, straight, and of a large caliber. Individual patient factors and skill level of the cannulating technician also play a crucial role in the initial success and maintenance of vascular access. Special attention should be considered in dealing with more challenging groups such as the elderly population where the newest vascular access guidance from The National Kidney Foundation's Kidney Disease Outcomes Quality Initiative will be transformative. The current guidelines recommend monitoring the vascular access by regular physical and clinical assessments, however, inadequate evidence is available to support routine ultrasonographic surveillance for improving access patency.

Keywords: End-stage kidney disease (ESKD); vascular access; fistula first and catheter last; elderly population

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Introduction

Historical background

In the US and worldwide, intermittent hemodialysis (HD) is the primary therapy utilized to prolong the life of the ESKD patient. Establishing efficient vascular access (VA) with durable long-term outcomes is a life-saving measure. Successfully accomplishing the task may be challenging for multiple reasons. The ideal HD access is one that provides consistent and uninterrupted prescribed treatment with low complication rates and long lifespan. Routes for HD VA include (I) arteriovenous (AV) access (fistula or graft) and (II) central venous catheters (CVC).

The first successful maintenance HD was introduced following the breakthrough AV polytetrafluoroethylene (Teflon) shunt creation by Quinton, Dillard, and Scribner from Seattle in 1960 (1). Following the AV shunt creation, the patient lived for almost 11 years, marking the landmark beginning of maintenance HD. Five years later, Dr. Appel performed the first surgical HD VA. The AV fistula (AVF) was created by constructing a side-to-side anastomosis between the radial artery and the cephalic vein at the level of the wrist (2). In the following years, different surgical approaches were utilized including end-to-end and side-to-

end anastomoses (3,4). Further options became available with the introduction of subclavian vein catheterization by Aubaniac in 1952. A description of central vein catheter use for HD was initially described by Erben *et al.* (5) in their 1969 publication. Despite the subsequent increased popularity of CVC access as a temporary modality over the decades that followed, the use of the subclavian vein has waned in favor of internal jugular access recently (6).

Rationale and knowledge gap

AVFs have higher primary patency (7), lower risk of infection and lower mortality (8-10) when compared with prosthetic AV grafts (AVGs) or venous catheters (7). A meta-analysis by Hajibandeh *et al.* (11) that included 15 comparative studies showed that AVFs are associated with better short- and long-term primary and primary-assisted patency rates compared to AVG. However, high rates of non-maturation are observed in AVFs (20–50%) (12-15), which likely accounts for the fact that at 6 months after initiating HD, 55% of patients continue to be dialyzed with a CVC (16-19). Additionally, contemporary literature suggests that secondary patency for AVGs is similar to that of AVFs, especially over short and midterm follow-up (11). The recent Kidney Disease Outcomes Quality Initiative (KDOQI) guidelines have called into question whether AVFs are the ideal access for every patient, e.g., the elderly patient with limited life expectancy. For these reasons, the successful creation and maintenance of VA remains an ongoing challenge for surgeons and patients alike (7,10,18-20).

The low rates of AVF creation for HD in the United States prompted the Centers for Medicare & Medicaid Services (CMS) and National Vascular Access Improvement Initiative (NVAII) to jointly announce the Fistula First Breakthrough Initiative (FFBI) in 2003 (21). The primary goal of this initiative was to improve the overall care of HD patients by identifying and improving several key clinical areas (16). The initial goal was to achieve AVF creation rates of 50% in incident and 40% in prevalence in the next 5 years (22). In 2009, the FFBI modified the prevalent AVF goal to 66% (23).

The FFBI also set forth a goal of reducing national rates of long-term CVC (>90 days) to less than 10% due to its higher all-cause mortality compared to permanent access (12). Unfortunately, despite the steady decrease in its use, this lofty program goal has not been reached (2003: 28%; 2011: 22%) (23). Therefore, the program's name has been modified to "Fistula First-Catheter Last" Workgroup Coalition in 2015 (24), with a continued emphasis on placement of autogenous fistulas; however, there is increasing acceptance that AVGs have a place in certain patient groups where AVFs are not an option (25,26).

Objective

In view of the KDOQI updated 2019 VA guidelines (27). In the following paragraphs, different aspects of surgical VA creation are discussed. These start from the initial patient evaluation and the multidisciplinary team approach to guidance on the creation of VA access, and highlighting what has been found in the literature on multiple topics, such as the secondary VA and VA in elderly populations.

Patient evaluation

History and physical exam

A detailed history is the foundation of good clinical care. In the context of VA planning, this includes the presence of diabetes, neuropathic symptoms of the upper or lower extremities, carpal tunnel syndrome, lower extremity ulceration, prior ipsilateral lymph node biopsy, prior peripherally inserted central catheter or traditional central catheters, pacemakers, defibrillators and cardiac comorbidities including heart failure or reduced ejection fraction. This list is by no means all-inclusive. Annual mortality for the prevalent ESKD patient cohort is 20% as derived from the United States Renal Data System (28). This statistic has not fluctuated over time and represents this group's severe cardiovascular and cerebrovascular disease burden.

Bedside examination of the extremities with proximal tourniquet occlusion is useful to identify venous targets in the forearm or upper arm and to assess for the stigmata of central vein occlusion. Bilateral brachial cuff pressures are measured for comparison as an indication of subclavian artery stenosis which is more likely to occur on the left side. A thorough lower extremity pulse examination is performed to assess for the presence of peripheral artery disease. High rates of diabetes are present within this population (29) and 85% of lower limb amputations are preceded by diabetic foot ulceration and in this sense preventable (30).

Role of duplex venous ultrasound

Detailed duplex arterial and venous ultrasound (DUS) evaluation of the arms and legs, when performed by a team

that understands the surgical considerations, provides insight into aberrant branching patterns, quantifies and characterizes arterial and venous wall anatomy—both of which dictate incision placement. Although vein diameter is considered a major independent predictor for fistula maturation (31), the recent 2019 KDOGI guidelines (27) did not recommend a minimum vein diameter threshold, however, vessels with diameters of <2 mm should undergo further diagnostic evaluation. This lack of agreement on cutoff diameters is due to wide variation in the reported diameters with optimal outcomes.

Calcified vessels are expected in patients with ESKD. Microcalcifications do not appear to increase the risk of stenosis or immaturity of the AVF (32,33). However grossly visible fibrotic and calcific are associated with non-maturation. The presence of a high brachial artery bifurcation is associated with fistula non-maturation and graft occlusion (34). Corresponding arterial dilation is necessary for vein maturation to occur and likely explains the lower rate of maturation in diabetics with these fibrocalcific vascular changes. When leg access may be a consideration, pulse volume recordings (PVRs) with a toe brachial index are routinely performed to document normal macro- and microvascular perfusion. Low rates of stenosis are seen in non-instrumented central veins, therefore, we do not routinely perform venography in primary VA creation, unless stigmata of central venous disease are identified. When central venous disease is identified, the management strategy remains controversial whether to intervene prospectively/prophylactically prior to VA creation or to undertake an expectant posture and intervene only if symptoms develop following access creation. Carbon dioxide as a contrast agent with or without a small amount of contrast will allow imaging of the central veins to be evaluated for those patients in whom renal replacement therapy has not yet been initiated.

As a complement to DUS vein mapping for secondary access creation in surgical fields that have previously been operated on, venography is routinely performed to evaluate vessel continuity, as DUS is less reliable as a standalone modality (35). For the evaluation and planning of lower extremity procedures, there should be a low threshold for arteriography to evaluate diabetics, particularly if any physical exam pulse abnormality exists. In most instances, we insist upon normal pedal perfusion documented by non-invasive PVR as a condition of proceeding with VA. We have, in limited cases, performed concomitant arterial bypass with proximal femoral artery-based VA for the "no option" patient that will otherwise experience significant catheter-based morbidity if no VA can be created. VA assessment of the lower extremity veins may also require ultrasound, computed tomography or magnetic resonance venography of the iliocaval segments, particularly if there is a history of prior lower extremity catheter usage. When possible, the authors prefer to preserve the lower extremity venous anatomy by utilizing translumbar dialysis catheter placed by our interventional radiology team.

Multidisciplinary team approach

The multidisciplinary approach in initiating and maintaining HD access can be associated with better outcomes. The ideal care of a VA might require the involvement of multiple healthcare personnel such as but not limited to a nephrologist, vascular surgeon, nurse, VA coordinator (VAC), and social worker. For example, VAC may arrange regular follow-up visits for patients and educate them on how to take care of their fistulas and answer any of their questions. One study showed that the presence of VAC was associated with low rates of the access complications such as access failure and infections (36), however, strong evidence is still lacking.

Despite the poor evidence on the impact of the multidisciplinary approach on the rates of AVF and CVC rates (27), KDOQI encourages the use of this approach in taking care of all aspects of HD VA (27). A recent study reported favorable results by comparing the outcomes prior to and following the implementation of the multidisciplinary approach, a significant decrease in the primary patency rate along with better management of failed AVF was noted (37). The value of the multidisciplinary approach was not only limited to the AVF better outcomes, Nguyen *et al.* (38) discussed how this approach may increase the rate of AVF creation. AVF creation rates can be improved through the early referral from the primary care physician, education of patients on the importance of early AVF creation, and involvement of the nephrologist in all aspects of AVF creation process. Furthermore, Wilson *et al.* (39) also showed an increase in the 1-year AVF/AVG rates at the expense of CVC in patients who managed through their newly implemented multidisciplinary approach compared to the usual care.

VA clinical principles and selection of primary access site

Contrary to the normal dictum, the patency of VA is

not the ultimate parameter of clinical success. Anatomic success relies on the "rule of 6s": 6-mm vein diameter, <6 mm below skin, 600 mL/minute flow, and 6-cm length of cannulatable vessel (40). The best conduit is superficial, easily identified, straight, and of large caliber. The ultimate determinant of VA success is whether the conduit can be cannulated (14–16 gauge, 3/5–1.0 in needles). The very nature of cannulation introduces a level of unpredictability that is predicated heavily upon the individual patient and variable skill level of the cannulating technician (26).

The radial artery to cephalic vein (Brescia-Cimino) reconstruction has traditionally been the first site for VA consideration (41). High rates of non-maturation approaching 50% have been reported with this configuration theoretically owing to pre-existing vein sclerosis (41) as well as predisposition to juxta anastomotic stenosis that Shenoy *et al.* (42) have attributed to various flow related factors. A basilic vein to ulnar artery fistula represents an underutilized option (43), particularly as the vein is frequently preserved and free of venipuncture trauma. This circuit must be secondarily transposed to the volar surface and we elect to do this in a staged fashion to facilitate patient comfort during dialysis.

An important point of discussion is that any vein may require superficialization secondarily to facilitate sufficient and reliable cannulation. This may be due to body habitus or the subfascial location of the vein in even an asthenic patient. Various approaches and techniques have been described ranging from superficialization to transposition of the conduit. There are benefits and disadvantages to each approach and the authors have described their technique. It is our practice to perform a two-stage superficialization, which we have found to be of benefit with a relatively higher rate of maturation when done in a single stage. We attribute this to warm ischemia and dissection trauma. We obtain a surveillance ultrasound four weeks following the operation to assess maturation. At that time point, veins that will mature should have a minimum diameter of 5–6 mm and a flow volume of >500 mL/min (27,44). If clinical/ultrasonographic findings of dilatation and increased flow are not noted, the fistula should be examined carefully for presence of any limiting inflow lesions, or competing accessory veins that usually results in difficult to compress fistula with weak discontinuous systolic pulse and reduced thrill. If no lesions are able to be corrected for optimization, the vein has failed to mature and is ligated and converted to a prosthetic bridge graft (27,44). The VA team should have a clear understanding of the threshold and time frame for which to abandon a physiologically optimized but non-maturating fistula and either convert to a graft or proceed to a new site. Poor communication and delayed decision-making contribute to avoidable and prolonged use of CVC, which can lead to increased risk of systemic infection, venous stenosis, and a decreased life expectancy of the dialysis access (9,16).

When forearm autogenous access is not possible, some controversy exists about the next step in VA management. The FFBI, by way of its explicitly stated goals, suggests that the upper arm should be evaluated for autogenous reconstruction (i.e., cephalic, basilic, or brachial veins). However, the most recent KDOQI guidelines (27), with an inherent focus on the "right vascular access, at the right time for each patient" would suggest that consideration be given to a forearm loop bridge graft. Our practice is guided by a complex of factors including the patient age, currently on dialysis or pre-ESKD status, anatomic arterial, antecubital vein and upper arm vein size, gender, age, and body habitus.

We have preferred the two-stage approach to the upper arm fistula construction due to increased patency rates, with the first stage being primary artery to vein anastomosis through a local incision (44). We have found conduits produced by the two-stage approach are larger and due to their arterialized nature, more easily transposed. The larger caliber is associated with reduced rates of infiltration and more durable conduits. However, despite our preference for the two-stage approach, the current literature is still controversial and largely comprised of single-center observational experiences (*Table 1*) (45-47). A large, prospective, randomized and controlled multi-institutional research investigation is necessary to compare outcomes with various approaches.

As a general comment, the brachial artery to cephalic vein upper arm configuration does not require a two-stage approach; however, with the increasing prevalence of obesity in the general population, we have seen an increasing need for superficialization of the cephalic vein to facilitate cannulation. Available evidence suggests that a transposed upper arm fistula will indeed require interventions to maintain patency (48). However, published literature suggests lower rates of thromboses, fewer revisions, and decreased risk of infection when compared with upper arm prosthetic grafts (7,48,49). Comparative multi-center-controlled data are lacking that regarding assisted patency outcomes of prosthetic graft versus autogenous reconstructions.

The recent KDOQI guidelines (27) are non-dispositive

Table 1 Selected comparative studies comparing the outcomes between the one-stage and two-stage brachiobasilic vein arteriovenous fistula creation

Study	Number of fistulas	Patency rates	
		One stage	Two-stage
Kakkos *et al.*, 2021, (45)	16 (one-stage: 9 *vs.* two-stage: 7)	1º: 12 mo, 44%[a]	1º: 12 mo, 57%[a]
		2º: 12 mo, 44%[b]	2º: 12 mo, 86%[b]
Ghaffarian *et al.*, 2018, (46)[c]	131 (one-stage: 57 *vs.* two-stage: 74)	1º: 12 mo, 56%[b]	1º: 12 mo, 72%[b]
		2º: 12 mo, 57%; 24 mo, 44%[b]	2º: 12 mo, 80%; 24 mo, 73%[b]
Sheldrake and Rowlands, 2015, (47)	37 (one-stage: 17 *vs.* two-stage: 20)	Survival proportions: 1 mo, 70.6%; 1 yr, 58.8%; 2 yrs, 51.5%[b]	Survival proportions: 1 mo, 95%; 1 yr, 90%; 2 yrs, 78%[b]

[a], P>0.05; [b], P<0.05; [c], Nonblinded Randomized Controlled Trial. 1º: primary; 2º: secondary. mo, months; yr, year.

regarding the clinical effectiveness of surveillance following VA creation instead taking this thoughtful approach. Clinical surveillance with physical examination and circuit performance metrics is appropriate in all patients and likely to have greater clinical benefit for autogenous reconstructions. Serial ultrasonographic surveillance has an unclear role and prophylactic interventions based upon any positive finding-when performed in the absence of clinical symptoms-likely has no benefit.

For those patients with small venous anatomy (<2.5 mm) in whom autogenous reconstruction would usually not be considered, most recommendations would suggest proceeding with a prosthetic bridge graft. We have found, in this cohort, a subgroup of patients with small axillary venous outflow. These patients understandably experience worse outcomes with creation of primary bridge grafts. We have selected out the "worst of the worst" veins. Thus, our approach has evolved to performing a conditioning brachial artery to brachial vein fistula in these patients. The brachial vein will either mature along the entire upper arm length and can then be transposed or it will mature at the outflow brachial/axillary vein segment, which will yield a much more durable patency when a bridge graft is constructed at a second stage.

Intraprocedurally, ultrasound is performed prior to the surgical incision to confirm the preoperative vein mapping. Careful assessment, not infrequently, demonstrates an alternative conduit that might influence the approach perhaps secondary to patient hydration and/or anesthetic relaxation and vessel dilatation (50).

The ipsilateral axillary artery-axillary vein or chest wall "chandelier" represents a novel and neglected option for patients in whom infraclavicular options are not present (51,52). Because of the high flow arterial and venous flow properties, these constructions are durable. The technique for this approach is described elsewhere (51). The secondary impact of this central reconstruction on patients with pre-existing right heart dysfunction or pulmonary hypertension should be carefully considered. Because "proximalization" is a described treatment for steal syndrome, the iatrogenic development of regional hand ischemia with central access is low (51-53).

Role of anesthesia

The majority of AVFs are usually created under local anesthesia due to the minimal tissue handling and dissection. The regional or general anesthesia options are reserved for more extensive procedures. The KDOQI recommendations suggest that the choice of anesthesia should be at the discretion of the surgeon and based on their clinical judgment (27). The vasodilation-induced anesthetic effects of regional anesthesia may play a role in increasing AVF creation and maturation rates. Researchers from Mayo Clinic (54,55) showed that regional anesthesia may reduce non-maturation rates compared to fistulas created under general anesthesia. The preliminary results of 21 patients in their ongoing prospective study showed a significant increase in the diameters of target veins due to the brachial plexus regional block. Although the approach does not improve the quality of vessels, it changed the surgeon's decision from AVG to AVF creation in 6 (28.5%) cases. Another study investigated the impact of stellate ganglion block on AVF maturation, the results showed that the average maturation time was significantly shorter compared to local anesthesia (41 *vs.* 77 days) (56). Additionally, an National Surgical Quality Improvement Project (NSQIP) database study (57) found that regional

anesthesia is associated with shorter postoperative length of stay and lower reoperation rates compared to the general one. Further prospective, multi-center investigation is necessary to answer this interesting question.

Comparison of forearm and upper arm fistulas

The most recent KDOQI guidelines of 2019 made several salient points (27). The ESKD population is a heterogenous cohort of patients with multiple clinical variables that collectively impact outcomes and presumably should impact VA type selection. That said, outcomes following autogenous reconstructions are variable and for that reason, further investigation must be conducted to determine the population for whom AVFs are most beneficial. The second point, made crystal clear by the use of a third-party evidence quality analytics process, was that the overall quality of evidence available for VA research is low.

The reported literature is evolving to clarify the patency data with alternative fistula configurations. These configurations, which extend far beyond the classic Brescia-Cimino description, were the result of technical ingenuity necessary to accommodate the goals of the fistula first era. It is clear that the FFBI provided the impetus to spur transformation in VA creation. Many of the described configurations involve transposition of either the cephalic, basilic, or brachial venous systems. Moreover, the technical approach to creation of the brachiobasilic AVF creation has been described variously in either a one- or two-stage sequence as we have mentioned earlier (*Table 1*).

However, just as there is heterogeneity in the ESKD patient population, wide variability exists in clinical outcomes. Historical rates of non-maturation for autogenous fistula are reported anywhere from 30–50% (58,59). More recent outcomes for AVF are seen in the PATENCY-2 trial (60) from Proteon Therapeutics where 3-month maturation rate was 55–56% as measured by our very liberal definitions.

Work from Shenoy *et al.* (42) has analyzed both vascular wall biology and technical configuration variables as factors which determine patency, maturation and thus clinical durability. Those local issues are further impacted by arterial wall properties as a function of diabetes and systemic issue such as body habitus including obesity. Here, it is important to recall the definition of AVF maturation as defined by Dixon (61) "*A fistula is mature when it can be routinely cannulated with two needles and deliver a minimum blood flow for the total duration of dialysis*". Unlike the peripheral bypass, the patency of the VA circuit may be preserved while the luminal diameter may be small such that cannulation is difficult and unreliable. To this point, Shenoy (42) has elegantly described the variations in remodeling which impact this clinical end point of vessel dilatation, and ultimately, the clinical outcome is co-determined by consistent, reliable and durable cannulation that allows the prescribed dialysis intervention. Clearly, much work is needed to determine VA outcomes in specific populations.

It is clear that the gold standard for VA durability is the Brescia-Cimino fistula (2). After maturation, especially in young patients, this reconstruction may yield decades of function. The same cannot be expected of transposed reconstructions, which ultimately develop swing point (the anatomic area at the upper arm segment of vein where it transitions to the *in-situ* position) lesions likely caused by flow turbulence and mechanical strain. In fact, although much of the literature suggests that the primary patency of the autogenous fistula is significantly better than a bridge graft (62), the assisted patency benefits of fistulae are questionable because grafts can be more reliably declotted than fistulas (7,20). Transposed vein configurations are durable, although they will usually require multiple percutaneous maintenance interventions, and should be monitored by an organized surveillance program (i.e., physical exam supplement with a flow study) (63,64). That said, the risk of infection with primary fistulae (wound infections aside) has approached zero with the subsequent loss of fistula being extremely uncommon. In contrast, the risk of graft infection is 4% to 5% and almost always leads to site loss. Clearly, the aggregate benefit favors autogenous fistulae over grafts (7).

Secondary VA

VA creation in patients who have yet to be initiated on HD provides the access team ample time to obtain appropriate imaging for VA planning. Moreover, the absence of a CVC or prior access attempts in the arms provides the proceduralist with the best opportunity to succeed. Several publications confirm the patency benefits for patients undergoing VA prior to the need for intermittent HD (IHD) (65,66). Unfortunately, multiple factors including healthcare policy and systems failures, e.g., access to care, insurance status and provider availability are responsible for the fact that less than 20% of patients initiate HD without a CVC (28). To this point, a significant proportion of the

poor VS outcomes present in the dialysis patient population can be directly attributed to a failure of our United States healthcare structure and the inability to effectively deliver prevention, maintenance and early detection services to socioeconomically vulnerable patients.

Published data have reported that prevalence of central vein stenosis can be up to 50% for patients with an indwelling CVC (67,68). As a result, central vein stenosis is a common finding in patients initiated to dialysis with a CVC. When VS is created ipsilateral to a functioning access, symptomatic arm swelling may develop requiring catheter-based intervention with stenting and contralateral re-sighting of the CVC. In the most advanced case when a prior CVC has resulted in endothelial trauma leading to subclavian, innominate or vena cava occlusion, advanced endovascular techniques are necessary to recanalize the central venous system to maintain existing access or optimize the patient for future upper extremity access.

For patients in whom the initial attempt at VA has failed in an extremity, multiple strategic and technical approaches have been described for secondary access. Secondary VA is more decisionally and technically demanding and a multidisciplinary and collaborative team of providers is important to achieve optimal patient outcomes. Consistent with our current KDOQI guidelines, a patient centric approach is important utilizing a Life Plan model (27).

Lower extremity access represents a durable option for patients in whom no additional upper extremity alternative exists. Here again, autogenous reconstruction is more durable and is associated with lower rates of circuit loss due to infection, as a conceptual approach, we infrequently use the great saphenous vein (GSV). We find that the GSV which measure on average is less than 5 mm in most patients, because of its inherent wall thickness, has a low likelihood of diameter maturation of the conduit. For this reason, we use the femoral vein as our preferred lower extremity autogenous conduit option. The femoral vein, with its large caliber, is an excellent conduit. The description for the femoral vein has been described elsewhere and therefore we will forgo reiterating those details (69). The vein must be mobilized to level of the Sartorius to provide sufficient length (70). One technical feature is that consideration should be given to tunneling the transposed vein through an aperture in the sartorius muscle (created with electrocautery to separate the muscle fibers parallel to their natural course). This simple step reduced the likelihood for vessel kinking. To reduce the risk of steal, the vein may be plicated at the arterial anastomosis or occasionally if inadequate length of vein is present, a short interposition of prosthetic may be required. Of course, the patient should have normal pedal perfusion and the arteriotomy size should be controlled to limit steal physiology down the leg. AVGs can be placed in the lower extremity if there are limitations for vein use [e.g., deep vein thrombosis (DVT), short stature, and limited vein length]. The dissection should be performed at least 5 to 7 cm below the cutaneous groin crease to limit the rate of infectious complications.

Several options exist for conduit material when non-autogenous reconstruction is created. Most common is the use of expanded polytetrafluoroethylene (ePTFE) grafts (71). After graft creation, 2 to 3 weeks generally are required before cannulation can be performed. Incorporation involves the graft becoming densely fibrosed to soft tissues so that when needle cannulation is performed there is no potential space for hematoma formation. A new PTFE-based graft includes the Gore Accuseal graft (Newark, DE) that allows needle cannulation within 24 hours by way of a midlayer sealing membrane within a trilayer iteration. This graft is often used preferentially in revision of aneurysmal fistulae that heretofore required a catheter while awaiting incorporation (72). Bovine carotid artery and cadaveric vein graft have also been used as alternative conduits (73,74), although concerns exist about aneurysmal degeneration.

VA in elderly patients

The prevalence of ESKD among elderly adults is consistently increasing (28). The high prevalence of comorbidities among this group makes the decision on the optimal VA more challenging. Inconclusive results were reported on the patient's age as an independent predictor of HD VA outcomes. In a study that included 205 patients (75), age ≥65 years was associated with increased rates of primary fistula failure. The same study found that only 20–30% of AVFs mature in that age group, this low rate can be attributed to normal aging process and poor quality of vessels (75-77). Lok *et al.* (78), however, found that patient age does not significantly affect AVF outcomes, the 1-year fistula survival rate was similar between patients ≥65 years (75.1%) and the younger group (79.7%). Furthermore, Kuningas *et al.* (79) argued the use of age as an independent factor in the decision of creating an AVF, justifying that the age alone does not reflect the general state of health and this should be replaced with more accurate measure such as patient frailty.

The AVF outcomes could also differs according to the creation approach. A systematic review by McGrogan *et al.* (80) found that in elderly patients, the brachiocephalic AVFs have better 1-year primary and secondary patency rates (58.5% *vs.* 49.7%) and (72.7% *vs.* 65.1%), respectively, compared to radiocephalic AVFs. With regards AVF *vs.* AVG, Choi *et al.* (81) study that included 878 elderly patients (age ≥65 years) of a local registry reported that primary patency was comparable between the two groups, however, primary-assisted and secondary patency rates were higher in the AVF group. Similar findings reported by Arhuidese *et al.* (82) except for primary patency was also higher in the AVF group. In that study, the AVF group had lower maturation rate and higher median time to maturation consistent with data on younger group.

Surveillance

The utilization of surveillance for VA is controversial, despite the improvement in patency derived from the surveillance of arterial reconstructions elsewhere in vascular surgery. Cost constraints, patient experience factors and the lack of efficacy data impact the ability to recommend routine surveillance of patients following VA construction. Logistically, the responsible dialysis center should appropriately monitor patients by physical and overall clinical assessment to detect aneurysmal changes, review flow issues, and educate the patient on self-examination (64). Selective referral to the VA clinical team is recommended when abnormal findings are detected. With regard to routine ultrasonographic surveillance to improve access patency, there is inadequate evidence for KDOQI to make suggestions on performing imaging surveillance for both AVFs and AVGs (27).

Conclusions

A comprehensive clinical evaluation prior to the VA creation includes a complete patient history, physical examination, and duplex ultrasound assessment. VA success is ultimately determined by whether the conduit can be cannulated, where the individual patient factors and skill level of the cannulating technician play a crucial role. Secondary VA is decisionally and technically demanding, therefore, an individualized approach based on the VA team's expertise is necessary to achieve patient goals. Special attention should be considered in dealing with more challenging groups such as the elderly population where the newest VA guidance from KDOQI will be transformative. While the current guidelines generally discourage ultrasonography surveillance following AVG and AVF creation, regular physical examinations are recommended.

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