Surgical creation of upper extremity arteriovenous fistula and grafts: a narrative review

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Background and Objective: Surgical creation of arteriovenous fistulas (AVF) and grafts (AVG) continues to be the mainstay access for hemodialysis (HD). Avoidance of dependence on dialysis catheters continues to be a worldwide mission in dialysis access. Importantly, there is no one-size-fits-all approach to hemodialysis access and each patient should undergo access creation that is patient-centered. The aim of this paper is to review the literature, current guidelines, and discuss the common types of upper extremity hemodialysis access and their reported outcomes. We will also share our institutional experience regarding the surgical creation of upper extremity hemodialysis access.

Methods: The literature review incorporates twenty-seven relevant articles from 1997 to present and one case report series from 1966. Sources were gathered from electronic databases including PubMed, EMBASE, Medline, and Google Scholar. Only articles written in the English language were considered and study designs varied from current clinical guidelines, systematic and meta-analyses, randomized controlled trials, observational studies, and two main vascular surgery textbooks.

Key Content and Findings: This review exclusively focuses on the surgical creation of upper extremity hemodialysis accesses. Creating a graft versus fistula ultimately is decided by the existing anatomy, and is centered around the need of the patient. Preoperatively, the patient should undergo a thorough history and physical exam, with special attention to any previous central venous access, as well as, delineating the vascular anatomy with ultrasound imaging. The major tenets of access creation are choosing the most distal site of the non-dominant upper extremity whenever possible; and ideally creation of an autogenous access is preferred over a prosthetic graft. Described in this review are multiple surgical approaches for upper extremity hemodialysis access creation and associated institutional practices performed by the surgeon author. In the postoperative period, follow up care and surveillance are imperative to preserve a functioning access.

Conclusions: The most recent guidelines regarding hemodialysis access still favor arteriovenous fistula as the primary goal for patients with suitable anatomy. Preoperative evaluation including patient education, intraoperative ultrasound assessment, meticulous technique, and careful postoperative management are all paramount for successful access surgery. Dialysis access remains quite challenging, but with diligence the great majority of patients can be dialyzed without catheter dependence.

Keywords: Arteriovenous fistula (AVF); arteriovenous graft (AVG); ultrasound; end stage renal disease

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Introduction

Since the invention of the Scribner arteriovenous shunt in 1960, hemodialysis access has seen a rise and fall in the popularity of both arteriovenous grafts and central venous catheters. Over the past two decades the Fistula First Breakthrough Initiative, published by the National Kidney Foundation, and subsequent guidelines have produced a shift toward more judicious access planning (1). More recently, the initiative has been re-introduced as "Fistula First, Catheter Last" to emphasize the importance of prioritizing autogenous hemodialysis access creation and discouraging central venous catheters as a terminal solution, with prosthetic grafts bridging the gap for patients without adequate venous conduit (1). However, because fistula maturation can take up to 6 weeks or longer, one practical advantage of tunneled venous dialysis catheters is afforded to patients awaiting fistula maturation as these catheters can be used immediately after placement for hemodialysis (2). The Society for Vascular Surgery (SVS) advocates for surgeons to pursue distal, autogenous arteriovenous targets in non-dominant extremities whenever possible. This is influenced by the dogma that proximal dialysis targets be preserved for future access creation. The cephalic vein is preferred because it is more superficial than the basilic vein, and outflow is the most important factor for long-term patency (1). The Kidney Disease Outcome Quality Initiative (KDOQI) also advocates for the preservation of proximal vessels while incorporating a patient-first focus to end-stage kidney disease life planning regarding vascular access choice (3). Although not explicitly discussed in this review, the 2018 clinical practice guidelines of the European Society for Vascular Surgery regarding vascular access echo many of the same sentiments as both the SVS and KDOQI. The purpose of this paper is to provide a review of the surgical creation of upper extremity AVF and AVG and discuss the preoperative patient assessment, intraoperative considerations, and postoperative surveillance of patients with renal impairment preparing to undergo future hemodialysis treatments. In addition, the patency outcomes of different vascular access types will be discussed, as well as, our institutional experience regarding the surgical creation of upper extremity hemodialysis access. We present the following article in accordance with the Narrative Review reporting checklist (available at https://cdt.amegroups.com/article/view/10.21037/cdt-21-565/rc).

Methods

Our review of the literature incorporated twenty-seven relevant articles from 1997 to present, with only one case report series describing the historic inception of the radiocephalic fistula written in 1966. Sources gathered were searched in electronic databases including PubMed, EMBASE, Medline, and Google Scholar. This review article considered literature written in the English language only and combined papers with varied study designs including current clinical guidelines, systematic and meta-analyses, randomized controlled trials, observational studies, and two main vascular surgery textbooks (*Table 1*).

Preoperative assessment

The planning of a surgically created vascular access begins with a thorough history and physical exam. In particular, the patient's history should include knowledge of any previous central and/or peripherally inserted central (PICC) lines, previous vascular access procedures, presence of transvenous pacemakers/defibrillators, medical comorbidities, and a list of current medications. On physical exam, both the dominant and non-dominant upper extremity vasculature should be evaluated. An Allen test should be performed to evaluate whether the radial or ulnar artery is the dominant blood supply to the hand. On inspection, the superficial venous system is assessed, as well as, paying attention to any signs of central venous stenosis such as venous collaterals and edema (4). Preoperative imaging usually consists of vascular mapping study, including both arteries and veins. Arteries of at least 2.0 mm in diameter are desirable while a minimum of 2.5 mm is the suitable size for a vein (4). According to the KDOQI recommendations, vein mapping studies should be performed in all patients prior to access placement and venous conduits less than 2.0 mm should be carefully evaluated for feasibility and quality (size, distensibility, and flow) of the vein to create a functional AVF (3). A more in-depth review of preoperative imaging will be reviewed in a future section of this journal series.

Although some literature fails to support the routine use of venous mapping as a preoperative imaging modality, there are some proponents of using intraoperative duplex ultrasound given this allows the identification of additional access options not seen on physical exam (5). This approach is thought to provide the end-stage renal disease (ESRD)

Table 1 The search strategy summary

Items	Specification
Date of search	May 2021–June 2021
Databases and other sources searched	PubMed, EMBASE, Medline, Google Scholar
Search terms used	Free text search terms:
	-End stage renal disease
	-Hemodialysis practice guidelines
	-Arteriovenous fistula creation
	-Upper extremity fistula versus graft creation
	-Upper extremity vein mapping
	-Prosthetic vascular access
	-Regional anesthesia
	-Vascular access outcomes
	-Anticoagulation effects on fistula patency
	-Arm exercise and hemodialysis
	-Fistula superficialization
	-Brachial vein transposition
Timeframe	1966, 1997–2021
Inclusion and exclusion criteria	Exclusion criteria: non-English language
	Inclusion criteria: peer reviewed articles only
Selection process	Article selection was divided equally among writers

patient more fistula options and a longer access lifespan (6). For this reason, we believe that surgeon-driven ultrasound mapping is a critical tool for the access surgeon to implement intraoperatively and prior to incision, as it is not uncommon to find subtle anatomic variations from the ultrasound report which could impact the vascular access created for a patient. Historically, there has been a push to create an autogenous AVF over an AVG, however, it is important to consider creation of an AVG in the correct patient population. Though very few randomized prospective trials comparing short-term patency, long-term patency or postoperative complications exist, many retrospective reviews and multiple meta-analyses have demonstrated the superiority of autogenous arteriovenous access over prosthetic access creation. A large systematic review and meta-analysis of the topic found autogenous access to be superior with a significant reduction in risk of death and access site infection (7). Complication-related lengths of hospitalizations were shorter for patients with autogenous vein conduit compared to those with prosthetic grafts. The meta-analyses also found that patency rates of autogenous access were significantly superior to prosthetic access when comparing both primary patency at 12 months and secondary patency at 36 months (7). Overall, the vascular access of choice will ultimately be anatomically driven and should take into account the surgeon's experience.

Because patients who are on the cusp of needing HD typically have multiple related comorbidities (i.e., hypertension, diabetes, coronary artery disease, peripheral arterial disease, etc.), it is prudent that careful preoperative anesthesia planning is carried out. Traditionally, AVF and AVG creation was performed under general anesthesia, however, regional nerve blocks or sedation combined with local anesthetic have grown in popularity in many centers. Although more rapid recovery, decrease in hemodynamic instability, and venodilation from regional anesthesia have all contributed to its rise in favor, it still represents a minority of analgesic selection for arteriovenous access creation nationwide. One retrospective review of National Surgical Quality Improvement Project data from 2007–2010 found that 85.2% of new arteriovenous fistula creations entered into the database over the period were performed under general anesthesia versus 11.9% of cases performed under regional anesthesia, and only 2.9% created under sedation with local anesthetic (8). Outcomes between general and regional anesthesia are similar. One large retrospective review of the Vascular Quality Initiative database found that patients with access creation under regional anesthesia had a 3.2% absolute increase in early failure rate within 120 days than those created under general anesthesia. However, perioperative complications such as infection and bleeding may be lessened in these patients with the use of regional anesthesia (9). Conversely, a single-center retrospective study found an improvement in failure rates with access created under regional anesthesia instead of general anesthesia (10). Our practice is regional anesthesia which has decreased the need for vasoconstrictor use and perioperative cardiac events, as well as, increased our fistula creation rates. In the past three years, our institution has had the opportunity of performing over 2,500 arteriovenous fistula and grafts, consisting of over 200 basilic vein transposition, 1,772 direct site creations, and over 500 graft placements.

It is important to educate patients on the natural history of vascular access creation and emphasize that it is not uncommon that AVFs may malfunction initially or require additional interventions to help the fistula maturation process and to maintain functional access. It has been reported that AVF primary failure rates vary anywhere from 20–60% (11). It is of utmost importance that patients be educated preoperatively on the expectations of AVF maturation and possible failure. Setting the expectation that secondary procedures may in fact be required, changes the perspective of the patients and other healthcare team members. If that education has been done properly, secondary maturation procedures can be viewed as a normal part of the access creation process, which otherwise can be viewed as unexpected failures which lead to frustration, doubt, and dissatisfaction. Also important in preoperative counseling is discussion about scars and superficial nerve injury symptoms, both of which are much better accepted if discussed beforehand.

Intraoperative considerations

Two adjuncts for the surgical procedure include the use of regional anesthesia and intraoperative vessel mapping. Regional anesthesia has many benefits including less stress than general anesthesia for physiologically frail patients with ESRD, good pain relief, and improved venodilation. There have been two meta-analyses showing superior outcomes compared to local anesthesia and increases in the numbers of distal fistulas created (12,13). The only downside to regional anesthesia is the potential for delayed recognition of significant early steal syndrome. Similarly, intraoperative vessel mapping by the surgeon, particularly after regional anesthesia, has the great potential to maximally optimize choice of access, reducing graft placements and increasing distal fistula creation (6). It is the strong opinion of the senior author that use of ultrasound by the access surgeon greatly improves outcomes of dialysis access creation and perioperative assessments.

The surgical creation of different arteriovenous access types requires the application of key principles in vascular surgery. For example, the use of the non-dominant upper extremity should be used first when both arms have equally suitable vessels; creation of vascular access should begin with the most distal suitable blood vessels; and autogenous AVF should be attempted before a prosthetic AVG if anatomically suitable (4). The autogenous AVF should follow in this order: direct AV anastomosis, venous transpositions, and venous translocations. Keeping the above principles in mind, the preferred vascular access in the upper extremity should typically proceed in the following order: radial-cephalic AVF (RCF), brachial-cephalic AVF (BCF) vs proximal radial artery-based fistula, brachial-basilic AVF (BBF), forearm AVG, and upper arm AVG (4). Less common procedures such as forearm basilic vein and brachial vein transpositions, however should be considered.

The autogenous radial-cephalic AVF (RCF) is one of the first dialysis access procedures described by Cimino and remains the access of choice in anatomically suitable patients (14). This access has the benefits of a superficial vein, multiple outflow pathways at the antecubital area, and a low incidence of steal or high flow due to its distal arterial inflow source. It is established by anastomosing the end of the cephalic vein directly to the side of the radial artery over other descriptions of side-to-side configuration. The most common anatomy allows for a single incision technique given the proximity of the blood vessels (1). Although this fistula is traditionally known to be located at the level of the wrist, our practice is to make the anastomosis more proximal to the wrist, roughly a quarter of the way up from the wrist to the elbow. Intraoperative mapping follows the vein down the forearm from the antecubital area. The caliber of the vein can be visualized and not uncommonly there is a significant caliber change at a confluence of tributaries in the distal forearm, which is where we most commonly choose to make our anastomosis. There are several branches of the superficial radial nerve in the area which should be preserved, if possible, to avoid sensory changes over the wrist and dorsal aspects of the hand and thumb. Pitfalls of the RCF include the few patients who are radial artery dominant, small calcified radial arteries, and development of juxta-anastomotic stenosis.

The autogenous brachial-cephalic AVF (BCF) is the connection of the end of the cephalic vein to the brachial artery at the level of the antecubital fossa. A single transverse incision is made when the blood vessels are close in proximity, however, the cephalic vein may require tunneling to the brachial artery to perform a tension-free anastomosis. If the proximal radial artery is suitable for inflow, then performing a proximal radial artery-cephalic fistula provides a viable option with less risk for steal syndrome (1). In a meta-analysis by Almasri *et al.*, the cumulative primary and secondary patency rates of BCFs are reported to be 52.6% at 130 weeks and 57.3% at 104.5 weeks, respectively (15). One challenge of the BCF is that it is the most common access that leads to high flow volumes, aneurysms, and steal. Care should be taken to keep the arteriotomy size limited in BCFs and if possible, use the proximal radial artery preferentially for inflow. The median cephalic vein is often too short to reach the radial artery. The perforator vein extends to the lateral radial vein and can be used for the venous connection if the quality is good and anatomically suitable, otherwise the proximal portion of the median antecubital vein can be used to reach down to the radial artery. The lateral antebrachial cutaneous nerve is just lateral to the median cephalic and perforator veins and care should be taken to avoid injury to it to avoid numbness and pain along its distribution.

The brachial-basilic AVF (BBF) is a good alternative in the upper arm if the cephalic vein cannot be used. However, given its deep and medial location with overlying medial antebrachial cutaneous nerve branches, transposition or superficialization is almost always necessary for all vascular accesses using the basilic vein (1). One or two-stage transposition procedures can be performed with no consistent finding of superiority of one technique over the other in the published literature. Cooper *et al.* found no significant difference in failure rates or 1-year primary patency between single and two-stage transposition after a review and meta-analysis of 97 studies (16). Our preference is to perform a staged transposition unless the vein is large (>4 mm throughout its length). We find if there are early failures, it is more commonly after a small incision for the first stage and at the second stage, any juxta-anastomotic stenoses can be excised and a new anastomosis created. We feel that, if possible, the vein should be transposed anteriorly and laterally to make accessing the AVF easier, but care must be taken at the transition from the tunnel back into the axilla to avoid tension or torsion which can lead to a so-called "swing point" stenoses. The reported cumulative primary and secondary patency rates of BBFs are 58.2% at 104 weeks and 72.2% at 91 weeks, respectively (15). Care should be taken to preserve as many of the median antebrachial cutaneous nerve branches to avoid the irritating medial forearm sensory changes.

AVGs are typically only performed after all autogenous arteriovenous access in the arm has been exhausted. Previously, forearm grafts would have been performed prior to moving to the upper arm fistulas, but this practice is no longer common. Historically, forearm grafts were anastomosed to the median cubital and median cephalic veins, but those are now more commonly used for upper arm fistulas. Thus in most patients, only the brachial vein at the antecubital region is left for grafts and frequently the brachial veins in this location are small and paired and not adequate for graft placement which has led to a fall in numbers of forearm graft placements. Mapping studies suggest that a 4 mm vein is needed for adequate outflow for grafts (17). Forearm graft configuration is almost always in a loop from proximal radial artery or brachial artery to the outflow vein. Per Almasri *et al.*, the primary and secondary patency rates, from their meta-analysis, of a forearm graft are 33.2% at 104 weeks and 46.3% at 84 weeks, respectively; and the overall infection rate is reported to be approximately 11% (15). The upper arm AVG is commonly formed between the distal brachial artery and the brachial vein in the axilla with two incisions. This technique however does not utilize the brachial vein between the antecubital region and the axilla. Therefore, our most common approach is to use the mid-upper arm brachial vein as outflow with a single incision to expose both the artery and vein and tunnel the graft around in a loop. The more proximal vein can then be conserved for future graft placement. The aggregate primary and secondary patency rates of upper arm AVGs are 44.1% at 88.5 weeks and 39.1% at 104 weeks, respectively (15). The overall infection rate Is similar to forearm AVGs and occurs in about 11%

of upper arm AVGs (15). Of note, there are no randomized controlled studies that convincingly prove that one graft type is better than another.

Another viable option for patients who have exhausted all upper extremity superficial veins is a brachial vein transposition. This vascular access type can be performed as a single-stage or a two-stage procedure. It is reported that the two-staged procedure is often more recommended whereby the AV anastomosis is created first to allow the vein to arterialize, and then after 4–6 weeks the vein transposition is performed which requires mobilization of the entire brachial vein (18). This fistula is considerably more tedious than other access procedures because of multiple small tributaries between veins, the brachial vein is more thin-walled and fragile than the basilic and cephalic veins, and the proximity to the median nerve. Favorable anatomic characteristics are those where the medial brachial vein is dominant with good caliber and does not spiral around the artery and nerve. The overall primary and secondary patency rates of brachial vein transpositions have been shown to be 52.0% and 92.4% at 1-year and 46.2% and 92.4% at 2-year, respectively (15).

Not to be forgotten is the forearm basilic vein transposition. The forearm basilic vein is medial and dorsal and often spared from previous venipuncture and intravenous cannulation. It has considerably more tributaries than the other described fistulas and needs transposition both to reach a suitable inflow artery and to facilitate punctures. Both a long single incision or skip incisions can be utilized and the surgeon needs to be mindful that the vein is very superficial. After harvesting the vein, anastomosis is most commonly performed to the distal radial artery after tunneling but can be tunneled to the ulnar artery or looped around to the antecubital region depending on the best inflow site. The number of tributaries requiring ligation and uniform need for transposition along with its location make this fistula less commonly performed than others, but remains a good autogenous option.

Brachial artery superficialization has been described as a technique for challenging dialysis patients but has not gained traction in the US because of unfamiliarity and concerns of aneurysmal degeneration and possibility of ischemic complications (19).

Postoperative assessment and secondary procedures

Post-operative assessment within the first month of access creation is important. Hand/arm exercises have been shown to assist with fistula maturation/usability and given no significant risk, should be recommended routinely (20,21). Many accesses however, will need maturation procedures, evidenced by an unassisted AVF maturation failure rate of roughly 60% in the DAC trial (22). Careful assessment of fistulas after creation is paramount to successful cannulation and helping patients avoid catheter dependence. Ignoring this crucial step leads to infiltrations with missed cannulation attempts and dissatisfaction among patients and dialysis workers. Having a palpable thrill is not the same as having a usable fistula. Bedside assessment has been found to be a strong predictor of fistula usability, as shown by Robbin *et al.* where experienced dialysis nurses were able to accurately predict, via clinical exam, the utility of the fistula for dialysis in 80% of patients (23). Physical examination should be of the strength of the thrill, how easy it is to distinctly palpate the fistula, keeping in mind that punctures of fistulas in the United States are almost universally done by palpation alone with no ultrasound guidance. If not clear on examination, a simple bedside ultrasound assessment with a sweep of the fistula from the anastomosis to the next joint can be very informative. Size, depth, and tortuosity can all be readily determined. If unclear still, a formal duplex study can be performed looking for the above criteria in addition to volume flow and areas of stenosis. Although several criteria have been proposed, the senior author prefers the original DOQI definition of 600 cc/min, 6 mm in diameter, and less than 6 mm from the skin (National Kidney Foundation), determined at 4–6 weeks postoperatively (24). Postoperative duplex ultrasound surveillance for autogenous arteriovenous dialysis access creation has been growing in adoption and may assist in maturation rates and long-term patency. One center instituted an early duplex ultrasound surveillance protocol 4 to 8 weeks postoperatively and offered either open surgical or endovascular intervention for positive ultrasound findings, which included peak systolic velocities greater than 375 cm/s or evidence of greater than 50% stenosis with distal flow impairment. The study found that prophylactic intervention improves AVF maturation among patients with a positive doppler ultrasound study indicative of early failure of maturation, with 70% receiving an intervention going on to maturation versus 25% of those that did not receive intervention (11).

Secondary interventions should be targeted at clinically significant findings including angioplasty or revision for flow-limiting stenoses and superficialization procedures for fistulas that are too deep. Minimally incision superficialization technique (MIST) has proven to be one such method for AVF creations with a deep outflow vein no suitable needle access segment (25). In addition, Bourquelot *et al.* revealed that Lipectomy is a safe, effective, and durable approach to make deep arterialized forearm veins accessible for routine cannulation for hemodialysis in obese patients (26). With these fairly simple procedures, many fistulas can be accessed successfully.

Routine use of antithrombotic agents has not been adopted in our practice as it is associated with bleeding complications and no benefit in terms of AVF patency. A randomized control trial published by Dember *et al.* demonstrated evidence that clopidogrel in the postoperative period reduces the frequency of early thrombosis but the small improvement in thrombosis was overshadowed by the much greater problem of fistula non-maturation (22). Additionally, according to the most recent KDOQI guidelines, use of pharmaceutical anti-thrombotics in the early postoperative period (<30 days) is relatively contraindicated due to the associated bleeding risk (22).

Long-term surveillance of fistulas remains a controversial topic since many arteriovenous fistulas and grafts have stenoses within the circuit that are not clinically meaningful and their treatment has not resulted in improved cumulative patency (27). Clinical assessment is recommended with physical examination including quality of the thrill/bruit, pulsatility and trends noted at the dialysis unit such as dialysis derived volume flows, arterial and venous pressure alarming, and prolonged bleeding (3).

Conclusions

The recommended initial vascular access for patients who will start hemodialysis is an autogenous AVF, assuming anatomic suitability. Careful preoperative consideration should include studying the blood vessel anatomy and physiology using doppler ultrasound. The practice of surgeon driven intraoperative ultrasound mapping often leads to the identification of additional vascular access options thereby increasing a patient's access lifespan. The traditional concepts of autogenous over prosthetic, upper extremity over lower extremity, and working from distal to proximal hold true in modern times. Many AV access options exist and should be familiar to invested access surgeons and proceduralists. Postoperative evaluation is nearly as critical as the surgical procedure itself as many patients will require adjunctive procedures for fistula maturation. Percutaneous fistula creation techniques continue to be explored and their position in algorithms remains to be determined. Although not part of this review, consideration of peritoneal dialysis and encouraging pursuit of renal transplantation should be part of the evaluation for arteriovenous access in suitable patients. Through careful planning and surgery, the great majority of patients can be maintained on hemodialysis with a functional AV access and avoid catheter dependence.

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Footnote

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