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Best Vascular Access in the Elderly: Time for Innovation?

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Abstract
Background: Conflicting data continue to surround the optimal dialysis access for the elderly. Many propose that catheters are the best option for this population; others emphasize the creation of an arteriovenous fistula. ***Summary:*** While an arteriovenous access is the best available access, it has a high early failure rate, particularly in the elderly. However, significant differences exist in forearm (men ≥65 years ~70%; women ≥65 years ~80%) versus upper arm (men ≥65 years ~40%; women ≥65 years ~38%) fistula failure rates in the elderly, with upper arm having much lower failure rates. Two percutaneous innovative techniques that successfully establish fistulas at the upper arm using proximal radial/ulnar artery as the inflow have been recently introduced. These procedures have been successfully performed in the elderly. Importantly, these techniques bypass the open surgical exploration and as such avoid the surgical manipulation of the juxta-anastomotic region (a common cause for the development of juxta-anastomotic stenosis and early fistula failure). ***Key Message:*** This article discusses the arteriovenous fistula creation in the elderly, highlights the factors necessary for successful fistula creation, and describes the 2 innovative techniques that can be used to provide a robust platform for successful fistula creation in this population.

For the most part, a mature arteriovenous fistula is the best available access for an end stage renal disease patient maintained on long-term hemodialysis. However, many fistulas fail to achieve maturation [1]. These fistulas frequently require interventions to achieve maturation and some thrombose with or without an intervention [1]. Elderly (>65 years) end stage renal disease patients are a challenging population. It has been documented that nearly 70–80% of the fistulas in the elderly fail to mature [2]. This rather high incidence of early fistula failure in this population is disturbing. These data indicate that only 20–30% of the fistulas mature in the elderly population. While the high failure rate is a reality, recent data have emphasized lower rates of hospitalization secondary to all-cause infection and bacteremia in the elderly patients with arteriovenous fistulas [3]. Elderly patients with fistulas had a lower risk of death compared to the

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patients with a graft (HR 0.76; 95% CI 0.73–0.80) [3]. Fistulas offered a better survival in the elderly compared to those with grafts.

In term of fistula survival, a study of 196 elderly patients (>65 years) documented that cumulative survival of fistulas at 1 and 5 years was 75.1 and 64.7%, respectively [4]. In contrast, younger patients (<65 years) demonstrated a survival of 79.7 and 71.4% at 1 and 5 years, respectively [4]. It is important to mention that the relative risk of fistula failure was 1.7 in the elderly [4]. There was no difference in the intervention rates between the older (>65 years) versus the younger (<65 years) patients. The study documented that age alone should not be the primary limiting factor when contemplating fistula placement in end stage renal disease patients [4]. Because mature fistulas offer a better survival, it is important to find avenues to improve the placement of successful fistulas.

The role of surgical expertise is a critical one and the one that is often ignored. Data from Dialysis Outcomes Practice Patterns Study has emphasized the importance of surgical training in arteriovenous fistula creation [5]. It has been demonstrated that the risk of early fistula failure was 34% lower (relative risk 0.66) when fistulas were created by surgeons with more experience (surgeons who created more than 25 fistulas) compared to surgeons with less experience (surgeons who created fewer than 25 fistulas) during their training [5]. Others have also demonstrated that surgeon's experience in creating arteriovenous fistulas is critically important [6]. The surgeon's commitment and experience in creating fistulas result in lowering the incidence of early arteriovenous fistula failure and leads to functional fistulas. In recent years, nephrologists have initiated the creation of fistulas in the United States [7]. This approach has demonstrated that fistulas can be created safely, successfully, and with good maturation rates by nephrologists.

Preoperative vascular mapping is critical in fistula creation and must be considered in the elderly patients undergoing an arteriovenous fistula placement [8–11]. Both the assessment of arteries and venous system are required for fistula creation. Physical examination, ultrasound assessment, and venography are all important techniques that can used to conduct mapping. During physical examination a tourniquet is placed around the upper arm and veins of the extremity are inspected. A simple ruler can be used to measure venous diameter as the length of the veins. Chest wall must be examined for a catheter scar or the presence of a catheter. A scar/catheter can indicate the presence of central venous stenosis. Simple pulse examination, differential blood pressure measurement along with the Allen test can be effective means to assess the arterial system. While physical examination is one of the simplest means of performing vascular mapping, its utility in the eventual creation of an arteriovenous fistula is less than optimal [12]. In contrast, ultrasound is an objective assessment and allows for accurate measurements of extremity veins as well as arteries [8–10]. Many investigators have demonstrated a marked improvement in fistula placement with the use of vascular mapping [8–11]. In one study, a dramatic increase in fistula placement was documented when preoperative ultrasound was performed compared to the simple physical examination (preoperative physical examination = 34%, preoperative ultrasound mapping = 64%; $p < 0.001$) [10]. Furthermore, the study revealed doubling of the patients dialyzing successfully with a fistula (preoperative physical examination = 16%, preoperative ultrasound mapping = 34%; $p < 0.001$) [10]. Another study demonstrated an improvement in fistula creation (from 14 to 63%), a reduction in graft placement (from 62 to 30%), and a reduction in catheter placement (from 24 to 7%) when preoperative ultrasonography was performed [8]. Arterial narrowing and calcification are relatively common particularly in the elderly, hypertensive, and diabetic patients [1]. The presence of calcification can also limit the creation of a successful fistula. Ultrasonography can recognize this condition and guide a surgeon to a successful fistula. Angiography can also be used to conduct vessel mapping [11]. In this technique, a vein on the dorsum of the hand is cannulated and a small amount (10–20 mL) of iodinated contrast material is injected into the veins. Fluoroscopy is performed, and images are recorded from the wrist veins to the right atrium [11]. The technique is important as it allows for direct visualization of the peripheral and the central veins. Any stenosis in the central veins can be easily seen [11]. Both, venography and ultrasonography provide an objective analysis of the veins and the arteries and provide vital information to create a fistula. Therefore, preoperative mapping must be considered prior to the creation of an arteriovenous fistula [12, 13].

Finally, two innovative percutaneous endovascular minimally invasive techniques have been recently described that may have a positive impact on fistula creation in the elderly [14–17]. In one study, Lok et al. [14] documented the creation of an arteriovenous fistula using a percutaneous intervention (mean patient age = 60 ± 13 years). In their study, an innovative technique that used radiofrequency energy and catheter-based endovascular technology was employed to create a percutaneous arteriovenous fistula. The steps of creating a

percutaneous fistula are rather simple. However, expert interventional radiologists as well as surgeons created arteriovenous fistulas in the study. Simple percutaneous cannulation tools were used to enter the brachial artery and vein in an antegrade direction. Through these vessels magnetic catheters were navigated down into the ulnar artery and the vein. Magnets in the ulnar artery and vein attracting each other then held the ulnar artery and ulnar vein together and radiofrequency electrode in the ulnar vein created a side-to-side anastomosis between the two vessels. The brachial vein entrance can be embolized to direct flow to the superficial veins. In this study, preoperative mapping was performed to identify vessels that were most suitable for fistula creation. Fifty-nine arteriovenous fistulas were created percutaneously in 60 patients (98%). Importantly, with a diameter of 5.2 mm and a robust brachial artery flow of 918 mL/min, 87% of these fistulas were available to provide dialysis therapy. At a follow-up period of 12 months, these fistulas demonstrated excellent primary (69%) and cumulative (84%) patency rates. Very recently, another technique of percutaneous creation of an arteriovenous fistula has been reported. In this approach, a thermal resistance anastomosis device (TRAD) is employed for the creation of a fistula [15–17]. The technique uses pressure and thermal resistance energy which is used to create an anastomosis between an artery and a vein. The anastomotic site can subsequently be dilated using percutaneous balloon angioplasty to increase the flow into the fistula, if needed. The procedure is rather easy to perform [16]. Under ultrasound guidance, a micropuncture needle is inserted into the cubital or brachial vein and navigated into the proximal radial artery. A guidewire is passed into the radial artery followed by sheath insertion. The TRAD device is then inserted which captures the walls of the artery and the vein and creates an anastomosis. Similar to the previous technique, percutaneous balloon angioplasty can be performed to increase flow into the fistula [16]. In a prospective study, 102 TRAD fistulas were successfully created in 107 patients (mean patient age = 56 ± 12 years). A great majority of patients (77/107) required balloon angioplasty and coil embolization procedures [16]. No major device-related adverse events were encountered. The cumulative patency was found to be 91.6, 89.3, and 86.7%, at 90, 180, and 360 days, respectively. Importantly, successful (2-needle dialysis) was achieved in 88% (n = 71) of the 81 patients on hemodialysis. The TRAD technique has also been successfully employed by other investigators [17]. In a recent study, 33 fistulas with a robust flow (956 mL/min) were established in 34 patients (technical success 97%) [17]. All fistulas were available for dialysis except for one, which required lipectomy (superficialization) procedure to provide dialysis therapy.

The elderly population with end stage renal disease requiring dialysis is rapidly increasing and the optimal vascular access for these patients is a major challenge [18]. The percutaneous innovation to create an arteriovenous fistula is a significant advance. Both studies included elderly patients and fistulas were created successfully. The two techniques described above are relatively simple. Surgeons, interventional radiologists, and interventional nephrologists can all perform the steps involved in creating these fistulas. Importantly, percutaneous fistulas do not require general anesthesia, which is a major plus in the elderly population. The procedure can be performed under sedation, local anesthesia, and regional block on an outpatient basis. A critically important point is that these fistulas are created at the elbow. By definition, it is an upper arm fistula; however, the inflow to the fistula is the proximal radial/ulnar artery. The use of proximal radial/ulnar artery as the inflow reduces the risk of hand ischemia, as brachial artery is not used to create the fistula. By creating an upper arm fistula, this site offers another advantage to the elderly. While early fistula failure rates for forearm fistulas in the elderly population is very high (men ≥65 years ~70%; women ≥65 years ~80%), the upper arm failure rates have been reported to be much lower (men ≥65 years ~40%; women ≥65 years ~38%) [2]. Fistulas created percutaneously by the techniques described above may have similar low failure rates presented above and reported previously for upper arm fistulas in the elderly [2]. Additionally, this technique avoids open surgical exploration and thereby surgical manipulation of the juxta-anastomotic area, which has been implicated in the development of juxta-anastomotic stenosis and eventual immaturity of the fistula. It is conceivable that this innovation can provide better outcomes for fistulas in the elderly by bypassing this factor. Finally, because proximal radial/ulnar artery is used as the inflow, there is less chance of high output heart failure that can be associated with brachial artery-based arteriovenous fistula.

Conclusion

In general, mature fistulas are still the best vascular access for end stage renal disease patients maintained on long-term dialysis including the elderly. Surgical exper-

tise is a very important factor. Arteriovenous fistulas created by surgeons with limited experience and numbers/year have high failure rates. The innovative techniques of percutaneous fistula creation described above are simple, offer multiple advantages, can be performed on an outpatient basis, and without general anesthesia. Preoperative mapping is critically important and must be considered in the elderly population prior to fistula creation. It is anticipated that the percutaneous techniques will gain popularity and provide a platform to successfully establish fistulas in the elderly population.

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