New Devices and Technologies for Hemodialysis Vascular Access: A Review

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In the United States, hemodialysis remains the most common treatment modality for kidney failure, chosen by almost 90% of incident patients. A functioning vascular access is key to providing adequate hemodialysis therapy. Recently, major innovations in devices and technology for hemodialysis vascular access care have rapidly changed the landscape. Novel endovascular devices for creation of arteriovenous fistulas may offer a solution to the barriers encountered in initiating maintenance hemodialysis with a permanent vascular access rather than a central venous catheter (CVC). Furthermore, in the prevalent hemodialysis population, the minimally invasive endovascular arteriovenous fistula procedure should help improve long wait times for vascular access creation, which remains a major barrier to reducing CVC dependence. Bioengineered grafts are being developed and may offer another option to polytetrafluoroethylene grafts. Early studies with these biocompatible grafts are promising, as additional studies continue to evaluate their clinical outcomes in comparison to cryopreserved or synthetic options. Prolonging the vascular access patency with appropriate use of devices such as drug-coated balloons and stent grafts may complement the novel techniques of creating arteriovenous access. Finally, innovative solutions to treat stenosed and occluded thoracic central veins can provide an approach to creating a vascular access and allow patients with exhausted vasculature to remain on hemodialysis. The robust developments in hemodialysis vascular access are likely to change practice patterns in the near future.

The US Data Renal System (USRDS) reports that, for 86.9% of all incident patients with kidney failure, hemodialysis remains the chosen treatment modality and that 80% initiate hemodialysis with a dialysis catheter. Although a well-functioning hemodialysis vascular access is a “lifeline,” complications related to vascular access also continue to be a significant reason for increased morbidity and mortality in hemodialysis patients. A multidisciplinary team approach along with improved processes of care are key to creating and maintaining vascular access.

This review provides an overview of the advances in technology relevant to hemodialysis vascular access. The primary focus is on newer devices used to create a minimally invasive arteriovenous fistula (AVF), a promising alternative to synthetic arteriovenous graft (AVG), and devices to bypass a central vein stenosis/occlusion. Advances made to improve the vascular access patency are also discussed (Fig 1).

Vascular Access Burden

The global prevalence of chronic kidney disease (CKD), especially in the elderly population, is expected to grow sharply in the future. Over the past 60 years, hemodialysis vascular access options have largely remained restricted to AVF, AVG, and central venous catheter (CVC). AVF remains the access preferred over AVG because of its lower infection rate, fewer thrombosis events, and higher long-term patency. In 2017, 80% of patients were using a CVC at hemodialysis (HD) initiation, whereas use of AVF at HD initiation rose from 12% to 17% from 2005 to 2017. AVG is used as an alternative access, but it has lower primary 1-year patency (51% for AVG vs 86% for AVF; P < 0.001). The CVC is the least desirable form of vascular access because of its 2- to 3-fold higher risk of morbidity and mortality burden. However, dependence on CVC results from factors that include lack of timely patient education and counseling, surgical delays, financial barriers to creation of permanent predialysis vascular access, high rate of primary AVF failure, poor sustained outcomes with endovascular interventions, and inadequate surgical training.

Dysfunctional vascular access reduces quality of life and worsens patient-centered outcomes. The risk factors for vascular access failure include female sex, advanced age, and multiple comorbidities such as diabetes mellitus, cardiovascular disease, obesity, and frailty. The National Kidney Foundation’s Kidney Disease Outcomes Quality Initiative (KDOQI) 2019 vascular access guideline suggested a patient-centered approach to access selection. Procedures to maintain vascular access may result in missed treatments and repeated hospital admissions, and remain a major burden on the health care system. The total cost to manage maintenance HD patients in the United States was approximately $35 billion in 2015, highlighting the need for innovations in HD vascular access.

Innovations in Access Creation

Endovascular AVF

The 20%-60% primary maturation failure rate observed with AVFs created using the open surgical technique has prompted innovations in creation of an anastomosis with a minimally invasive endovascular technique. The approval of 2 devices by the US Food and Drug Administration (FDA) has paved the way for creating an AVF at a
site in the mid-forearm using an endovascular technique (endoAVF). The dictum of preferentially selecting a distal versus proximal site for AVF creation in the upper extremity is considered standard of care, but often the mid-forearm AVF site (called Gracz fistula) is overlooked due to lack of surgical skills or for the relative ease of creating a more proximal anastomosis at the elbow. The endoAVF offers an opportunity to use the mid-forearm site before considering a more proximal site in the upper arm for future needs.

The approved devices are catheter-based systems used to create a side-to-side anastomosis using the deep vessels in the mid to proximal forearm; the 2 devices are the Ellipsys (Medtronic) and the WavelinQ (Becton, Dickinson and Co.) systems. Both of these FDA-approved systems require prescreening assessment of the forearm vessels with ultrasonography and a multidisciplinary approach to select patients who may be at high risk for distal AVF maturation failure. Every member of the team needs to be well informed about the differences between endoAVF and surgical AVF. Working as a team, the proceduralist and the surgeon can select suitable patients and effectively manage unexpected complications. The nephrologist and the dialysis teams can educate patients and learn the subtle points to assess for endoAVF maturation and cannulation techniques. The eligibility factors for an ideal recipient of an endoAVF include life expectancy of at least 1 year, vessels that are unsuitable to surgically create a distal AVF, a compressible proximal radial/ulnar artery without intimal calcification, an inflow brachial artery ≥2 mm, an outflow cephalic and/or basilic vein ≥2.5 mm, procedural access vessels >2 mm, a perforator ≥2 mm and not tortuous, and an adequate creation site with ulnar and/or radial target vessels >2 mm (Box 1). The access is created between paired ulnar or radial artery and a perforator vein. A physician trained in this technique performs the ultrasound and selects the site for endoAVF. Patient selection is critical to preserve the valuable vasculature for future needs as outlined in the "life-plan" concept in the KDOQI vascular access guideline.

The Ellipsys is a single-catheter system, also called a thermal resistance anastomosis device (TRAD), that uses a single venous catheter placed under ultrasound guidance to create an anastomosis using heat and pressure. An immediate balloon angioplasty of the anastomotic site is performed to prevent stenosis.

The WavelinQ system is a dual-catheter system that involves placing a separate arterial and venous catheter in adjacent vessels using ultrasonographic and fluoroscopic guidance. The catheters are aligned by activating the magnets under fluoroscopic guidance, and an anastomosis is created by using radiofrequency energy. The resulting fistula drains into multiple outflow veins that generally requires additional coil embolization of the brachial vein to direct the blood flow into superficial veins for future cannulation during HD.

The prospective single-arm study using the Ellipsys system enrolled 107 patients, in whom an AVF was created in 105 patients. The primary end points of brachial arterial flow of >500 mL/min and fistula luminal diameter of >4 mm were achieved in 92 of 107 patients (86%). In the pivotal Novel Endovascular Access Trial (NEAT) study published in 2017, the Everlinq (now WavelinQ) system was used to create 59 percutaneous AVFs in 60 patients. A successful AVF was created in 87% of those patients, with a mean brachial arterial flow of 918 mL/min and a mean fistula luminal diameter of 5.2 mm, achieving the KDOQI-suggested target luminal diameter range of 4-6 mm. The primary and cumulative patency rates at 12 months were 69% and 84%, respectively.

![New devices and technologies for hemodialysis vascular access](image)

Figure 1. New devices and technologies for hemodialysis vascular access. Note: an established hybrid device (eg, HeRO (Hemodialysis Reliable Outflow)) has not been included in this review. Image ©2020 Cleveland Clinic Foundation, reproduced with permission of the copyright holder. Abbreviations: AVF, arteriovenous fistula; AVG, arteriovenous graft; EndoAVF, endovascular arteriovenous fistula.
Box 1. Ideal Patient Characteristics for Using an Innovative Device for Hemodialysis Vascular Access

**EndoAVF**
- Minimum life expectancy of 1 year
- Unsuitable vessels to surgically create a distal AVF
- Compressible proximal radial/ulnar artery without intimal calcification
- Luminal diameter of ≥ 2 mm of the artery and adjacent perforating vein
- Patent proximal draining veins

**Bioengineered graft**
- Small veins (<2 mm)
- Individuals with obesity
- Age > 70 years old
- Women with small veins
- Exhausted vasculature from multiple failed accesses
- Minimum life expectancy of 6 months
- Treatment of aneurysm/pseudoaneurysm
- May be as a hybrid with HeRO device

**Early cannulation graft**
- Avoidance of central venous catheter
- Initiating urgent hemodialysis therapy
- As a hybrid with HeRO device
- Age > 70 years old
- Individuals with obesity
- Women with small veins
- Exhausted vasculature from failed multiple accesses but patent artery
- Treatment of aneurysm/pseudoaneurysm

**Inside-out device**
- Total central vein occlusion
- Avoid lower extremity access
- Thoracic outlet syndrome

**Stent grafts**
- Recurrent graft vein stenosis
- Cephalic arch stenosis
- Elastic recoil post balloon angioplasty in noncannulation zone
- Possibly recurrent central vein stenosis

**Drug-coated balloon**
- Further studies needed

**Abbreviations:** AVF, arteriovenous fistula; EndoAVF, endovascular arteriovenous fistula; HeRo, hemodialysis reliable outflow.

The procedure-related complications were low but significantly differed between the 2 systems. The single-catheter device study reported no major procedure-related complications, including vessel perforation, dissection, or distal embolization. Two cases with small hematomas, 1 case resulting in technical failure and 1 case requiring manual compression were the only other adverse events reported. The dual-catheter device–related complications included 1 case of dissection of the brachial artery and 2 cases each with pseudoaneurysm and thrombus formation in the brachial artery. Eight adverse events in 5 patients were attributed to the procedure. Secondary interventions (including transpositions, coil embolizations, and angioplasties) needed to create a functional AVF were required in 99 of 107 patients (92.5%) in the Ellipsys study and 19 of 59 patients (32%) in the NEAT study.

The endoAVF approach requires additional dialysis clinic personnel education and training. The cannulation of an endoAVF can be relatively difficult as the conventional physical examination findings are absent or diminished. A subtle difference in the physical examination findings of endoAVF, such as the absence of surgical scar and softer thrill due to low blood flows (<1,000 mL/min), necessitate learning new cannulation skills. The question as to who will provide this training and how long it will take to learn these new skills become crucial issues during the early planning phase of building an endoAVF program.

Recently, a multicenter retrospective study reported 2-year cumulative patency rates for endoAVFs created in 105 cases, which at 6, 12, and 24 months were 97%, 94%, and 93%, respectively. Even though these results are encouraging, the study failed to provide details on the patient selection process. The high success rate could be attributed to the atypical patient population included in that study, which is younger (mean age, 56 years), leaner (mean body mass index, 31 kg/m²), and with a higher prevalence of White men (74%) than populations with a high maturation failure rate with surgical AVF creation. The study also omits key information on comorbidities such as diabetes, cardiovascular disease, and peripheral arterial disease. Around the same time, Shahverdyan et al published a single-center and single-surgeon experience-based retrospective review comparing endoAVF outcomes in 100 patients using the WavelinQ (n = 35) and the Ellipsys (n = 65) devices. AVF maturation rates at 4 weeks using the WavelinQ and Ellipsys devices were 54.3% and 68.3%, respectively. Twelve-month primary patency rates of 33% and 32% (hazard ratio [HR], 0.92 [95% CI, 0.53–1.59]) and secondary patency rates of 60% and 82% (HR, 0.42 [95% CI, 0.19–0.97]) were reported for the WavelinQ and Ellipsys devices, respectively. Access failure occurred in 37% and 15.4% of patients with the WavelinQ and Ellipsys devices, respectively.

Overall, there are definite advantages to creating an endoAVF compared to an open surgical AVF. The endoAVF can be created in an office-based practice with the patient under conscious sedation using local anesthetics, thereby reducing the scheduling delays and interim dependence on a CVC that are often experienced with a surgical technique. The configuration of the side-to-side anastomosis is believed to support more optimal flow dynamics, reducing shear stress and neointimal hyperplasia, which may ultimately reduce the incidence of stenosis in the juxta (peri)-anastomotic region. Furthermore, an endoAVF avoids surgical dissection, minimizes vessel wall trauma, and eliminates the need to use sutures, thereby reducing local inflammation. An endoAVF may offer the added advantage of avoiding surgical scars and improving aesthetics and acceptance of the procedure by the patient. The high success rate in these early studies is certainly exciting but
warrants long-term randomized controlled studies before endoAVF can become a mainstream option.

**Bioengineered Grafts**

Biosynthetic materials such as bovine arterial grafts and ovine (sheep) collagen grown around a polyester mesh endoskeleton have been used with limited success since the early 1970s. Arterial allografts are plagued by chronic rejection as demonstrated in rat studies showing lymphocyte infiltration in the endothelium, intimal thickening, aneurysmal changes, and thrombi resulting in graft failure. In addition to xenografts, cryopreserved deceased donor cadaveric vascular grafts from the femoral vein and iliac arterial allograft have been used in patients to create a vascular access. Korean investigators harvested aortoiliac arterial allografts from brain death donors and used a liquid nitrogen cryopreservation method to cool the graft to −196°C for storage. When the allograft was needed, it was warmed and placed in the upper arm of patients deemed to have failing or failed nonsalvageable vascular accesses. Complications encountered included early aneurysm formation and high access failure rate (30% in the cryopreserved group vs 18% in the polytetrafluoroethylene [PFTE] group).

There is cautious hope and enthusiasm in the development and clinical application of tissue-engineered vascular conduits in patients with CKD. The potential niche for bioengineered grafts is in patients who would qualify for a synthetic AVG over that of an AVF. The hope is that bioengineered grafts will be more durable and less prone to infection, stenosis, thrombosis, and aneurysms than conventional synthetic grafts. One potential concern is the immunogenic response that may occur with bioengineered grafts as it relates to the integrity of the vascular structure but even more broadly to sensitizing a potential kidney transplant recipient.

In 2016, promising results were published for a phase 2 trial of Humacyl (Humacyte), a completely biologically engineered human acellular vessel (HAV). The HAV is created by obtaining smooth muscle cells harvested from deceased human organs and tissue donors and grown in a nutrient medium. After cell expansion, the cells are seeded on a biological scaffold placed in a bioreactor. The bioreactor provides a pulsatile flow of nutrient-rich fluid to expose cells to shear stress, which promotes cell differentiation. After 8 weeks, the graft is decellularized to remove antigens while leaving behind the non-immunogenic collagen tube (Fig 2). In the phase 2 trial from 2016, a total of 60 patients, 20 from the United States and 40 from Poland, who were deemed unsuitable for AVF creation underwent bioengineered graft insertion. Fifty-nine of the participants received a placement of a brachial artery-to-axillary vein anastomosis and were followed for 16 months. Cannulation was permitted after 8 weeks (n = 50) but was later liberalized to 4 weeks after implantation (n = 10). At 6 and 12 months, the primary patency (intervention-free access survival) rates were 63% and 28%, respectively; primary assisted patency (durability of an intervention until the first episode of thrombosis) rates were 73% and 38%, respectively; and secondary patency (durability of intervention until the access is abandoned) rates were 97% and 89%, respectively. Interventions to maintain patency were required 1.89 times per patient-year. Only 1 vessel became infected, which was corrected with a surgical revision and later used. Investigators analyzed panel-reactive antibodies (major histocompatibility complex I and II), serum immunoglobulin G levels, and biopsied the vessels at 16 weeks, which were negative for CD20 (B-lymphocyte marker) and CD3 (T-lymphocyte marker), confirming the absence of systemic immune or inflammatory response.

One of the most interesting aspects of that study was the identification of CD68 and CD31 cells on the procured sections of the HAV graft near the venous anastomosis site and at previous cannulation sites as early as 16 weeks and also as late as 55 weeks. The histological presence of those cells implies that the HAV graft was being repopulated by surrounding connective tissue cells, resulting in re-endothelialization of the graft and creation of a truly “living tissue” capable of “healing itself” after cannulation. Due to the success of the early trial and with the goal of Humacyl becoming a first-line treatment for HD patients, Humacyte has now completed enrollment of a multicenter, randomized, controlled phase 3 trial comparing HAV to the gold standard AVF in 240 HD patients. The study is expected to be completed in June 2024. The questions that remain unanswered for long-term patency outcome are whether this “living tissue” will heal with fibrosis and result in stenosis, and if so, how often it may need interventions. Also to be determined is whether these problems will be any different from those encountered currently with native AVFs.
Early Cannulation Grafts

Early cannulation grafts have a trilayer design incorporating an elastomeric “self-sealing” membrane that allows cannulation as early as 48–72 hours after the implantation. These grafts offer an option to either skip the use of a CVC or minimize the duration of its use. In a review of 15 studies, several different early cannulation grafts (Flixene [Getinge]; AVflo [Nicast]; Rapidax [Terumo Aortic]; Vectra [Becton, Dickinson and Co.]; and Acuseal [W.L. Gore]) were reported to have equivocal results in patency and complication rates compared to standard PTFE grafts. Twelve-month pooled primary and secondary patency rates ranged between 43.3%–63.7% and 70.5%–85%, respectively. The long-term patency rates for the Vectra graft appear to be more acceptable, although a comparative trial would be required to allow for specific graft recommendation. However, there seems to be a role these grafts can play in reducing the CVC rate in the incident dialysis population.

Catheter-Based Innovations

Central vein stenosis/occlusion is frequently encountered in patients undergoing HD due to prolonged CVC use, multiple CVC insertions, catheter-related thrombosis, and catheter-related bloodstream infection. The development of central vein stenosis/occlusion may prevent the creation of a viable ipsilateral AVF/AVG, unless the stenotic/occluded segment can be bypassed. Total occlusion of the central vein impedes the ability to insert any form of vascular access in the upper extremity. The options are limited to a lower-extremity CVC or arteriovenous access to maintain HD treatment. Recanalization of the occluded central vein using a sharp needle or a wire with radiofrequency energy are the only (high-risk) options. In 2020, the FDA approved the Inside-Out Surface device (Bluegrass Vascular) to create a new track and bypass the occluded thoracic central vein segment on the right side. The newly created track can then be used to insert a CVC or CVC-AVG hybrid device. A multicenter study from Europe enrolled 32 patients with complex central vein occlusions and reported 97% success with achieving central venous access and catheter placement using the Surface device. The early experience from European studies highlights the low complication rate and a new skill that is relatively easy to acquire.

Innovations in Maintaining Vascular Access Patency

The recurrence of stenosis at the juxta-anastomotic and “swing” sites in an arteriovenous access resulting in dysfunction is the “Achilles’ heel” of HD. Timely diagnosis and treatment require a multidisciplinary approach to maintain long-term patency and, hopefully, reduce the risk of access thrombosis. To treat neointimal hyperplasia causing stenosis in an arteriovenous access, the current approach involves performing percutaneous balloon angioplasty. The immediate result is impressive, but 6- and 12-month patency following an angioplasty range from 41%–76% and 31%–45%, respectively. The endothelial injury from forceful dilation of the vessel with balloon angioplasty creates deep fractures in the neointimal tissue and leads to various degrees of inflammatory and proliferative response, which is characterized by a local increase in vascular smooth muscle cell proliferation. The pathologic change at the anastomosis is neointimal hyperplasia, which is characterized by smooth muscle cell proliferation, extracellular matrix production, and angiogenesis. Most patients undergo repeated angioplasties to maintain access patency. Two new innovations are now available that have shown promise in prolonging patency after an intervention (Fig 3).

Drug-Coated Balloons

The idea of local drug delivery technology has been used in coronary and lower limb interventions since the 1990s. The concept is to combine conventional angioplasty with local drug release at the affected area, thus preventing neointimal hyperplasia and recurrence of stenosis. The most commonly used drug in drug-eluting balloons is paclitaxel, which is a cytotoxic agent with hydrophobic-lipophilic properties that facilitate cellular uptake and deliverability of the drug. Once paclitaxel is released, it stops the cell cycle in the M-phase of mitosis, preventing neointimal hyperplasia by causing cellular apoptosis and inhibition of vascular smooth muscle cell migration into the intima.

In 2017, the FDA approved the first drug-coated balloon (DCB) to treat stenosis in a dialysis vascular access. The method of drug delivery is critical, as very slow or very fast delivery could result in subtherapeutic levels, and the desired outcome may not be seen. The use of a DCB is a promising therapy, with recent studies suggesting better outcomes in the short term but inconclusive long-term durable results.

Liao et al studied venous anastomotic stenosis in AVG in 44 patients. The primary end point was target lesion primary patency at 6 months, and secondary end points were target lesion primary patency at 12 months and access circuit primary patency at 6 and 12 months. The DCB group had higher target lesion primary patency (41% vs 9%; P = 0.006) and access circuit primary patency (36% vs 9%; P = 0.019) than the conventional balloon group at 6 months. However, although 1-year target lesion primary patency remained higher in the DCB group than in the conventional balloon group (23% vs 9%; P = 0.019), the access circuit patency was not significantly different (14% vs 9%; P = 0.056).

Trerotola et al compared DCB to conventional balloon in failing native fistulas in 285 patients. The number of interventions needed to maintain target lesion patency were fewer for the DCB group at 6 months (0.31 vs 0.44 per patient; P = 0.03). However, there were no
differences between mean target lesion primary patency (71% ± 4% vs 63% ± 4%; P = 0.06) and access circuit patency (62% ± 4% vs 58% ± 4%; P = 0.25) at 6 months.

The role of DCB to treat access stenosis remains controversial. Two recent meta-analyses reported contradictory findings. A meta-analysis of 17 studies (8 randomized controlled trials, 9 cohort studies) by Yan Wee et al included 1,113 stenoses in AVFs that were treated with DCB (54.7%) versus conventional balloon (45.3%) and concluded that both 6- and 12-month primary patency rates were significantly better in the DCB angioplasty group than in the conventional balloon group (71% vs 49.2% and 44.2% vs 20.6%, respectively). However, more recently, Liao et al compared 11 randomized controlled trials that included 487 patients treated with DCB and 489 patients treated with conventional balloon angioplasty, and found that the 6- and 12-month target lesion primary patency rates were not significantly different (relative risk [RR] of 0.75 [95% CI, 0.56-1.01; P = 0.06] and 0.89 [95% CI, 0.79-1.00; P = 0.06], respectively). The disparity between the meta-analyses could be from the type of studies that were analyzed and the number of patients included. Yan Wee et al included randomized controlled studies and cohort studies that may be subject to selection bias. In addition, the number of censored cases was not provided and were included in the proportion without events, underestimating the number of events. Liao et al took a rigorous approach to calculate early-censored cases, representing a conservative approach to evaluate the device.

In early studies enrolling patients without kidney failure, an increased risk of mortality with paclitaxel-coated balloons was observed, raising concerns for the kidney failure population. However, Trerotola et al achieved a noninferiority safety end point (freedom from local or systemic adverse event) of 95% at 30 days, which was unchanged at 6 months. Long-term safety data are being collected from the same study.

**Stent Grafts**

Endovascular stent grafts are flexible, self-expanding vascular prostheses made of expanded PTFE encapsulating a Nitinol stent framework. Bare metal stents, on the other hand, are made of stainless steel, cobalt chromium, or platinum chromium without a coating. Recurrent lesions at the graft-vein anastomosis in AVG dialysis circuits have been treated conventionally with either angioplasty alone or with a bare metal stent. Several retrospective and observational studies using bare metal stents have shown 6-month patency results from 19%-65%. Haskal et al reported a multicenter, prospective trial randomized patients with AVG who had a venous anastomotic stenosis and underwent either PTA alone or PTA plus placement of the Flair (Becton, Dickinson and Co.) stent graft. The results were reported as primary patency of the target area and of the access circuit. The 6-month patency of the primary target area in the stent graft group versus the balloon angioplasty group was 51% versus 23% (P <0.001). The 6-month primary patency of access circuit was 38% versus 20%, respectively (P <0.008). Subsequently a 12-month patency of access circuit for the stent graft group compared to angioplasty alone was reported as 24.1% versus 10.3%, respectively (P = 0.005), and 24-month access patency was superior in the stent graft group (9.5% vs 5.5%; P <0.01). A second trial compared the Viabahn (W.L. Gore) stent graft to angioplasty alone and reported 6-month target lesion and access circuit patency rates of 53% versus 36% and 43% versus 29%, respectively.
In a recent randomized control trial, Shemesh et al compared a stent graft to a bare metal stent for treating cephalic arch stenosis in brachiocephalic AVF. The study was small (n = 25) but found higher 1-year primary patency with the stent graft than the bare metal stent (HR, 4.09 [95% CI, 1.9-20.3]; P = 0.002) with no differences in secondary patency at 1 year. Interventions for restenosis were significantly fewer with the stent graft than with the bare metal stent (RR, 0.46 [95% CI, 0.22-0.96]).

In our opinion, deployment of the stent graft seems to benefit the patency of target lesion but not necessarily the circuit patency. Stent grafts have been shown to reduce the number of interventions needed to keep the access patent without clearly extending the overall long-term patency. The decision to deploy a stent needs to be judicious, and the stent should be deployed outside the cannulation zone.

**Innovations in the Pipeline**

After relatively little innovation in devices for HD vascular access over the past 5 decades, opportunities for technological advances seem promising in the near future. The global epidemic of CKD and kidney failure has ignited several interesting developments that are in the pipeline. Projects that have progressed to clinical studies include a 1) pneumatic compression device (Fist Assist [Fist Assist Devices, LLC]) to promote AVF maturation; 2) the VasQ (Lamine Medical Technologies) device to improve primary AVF maturation, which regulates blood flow by constraining and shaping the fistula and reinforcing and shielding the perianastomotic vein against high pressure, wall tension, and flow levels; 3) the av-Guardian (Advent Access) vascular access system to guide cannulating needles into the AVF; and 4) BioNanomatrix gel (Endomimetics), designed to prevent intraluminal tissue growth and prevent stenosis in the vein segment of the AVF to promote the AVF maturation process and reduce the primary failure rate.

**Summary**

After several decades of dormancy, innovations in HD vascular access have been reinvigorated. In the right setting, a mature AVF is still considered the most ideal vascular access for long-term maintenance HD. Clinical evidence gathered over the last 2 decades has shifted the dogma from “fistula first” to the “right access” and has given equal importance to alternative types of access. The emphasis is on implementing a patient-centered approach that offers improved patient satisfaction and is aligned with individual goals of care. Additionally, rising health care costs have compelled the dialysis care providers to explore and innovate.

New ideas and innovations are being introduced in clinical practice to simplify the process of creating a vascular access and to improve the patency of currently existing forms of dialysis access (Box 1). The ultimate hope is to improve overall dialysis care and quality of life for our patients who are living longer than ever before.

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**References**


43. Shenem D, Goldin I, Zaghal I, Berlowitz D, Raveh D, Olisha O. Angioplasty with stent graft versus bare stent for recurrent cephalic arch stenosis in autogenous arteriovenous access for


