Essentials of Vascular Access for Home Hemodialysis

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Hemodialysis (HD) at home has gained increasing popularity in recent years because of regulatory and financial issues. Creation and maintenance of a well-functioning, cannulatable vascular access is essential for performance of home HD (HHD). A vascular access team-based approach to creation, maintenance, and troubleshooting of vascular access can facilitate removing barriers to cannulation at home related to fear of pain and bleeding associated with large bore needles. Frequent cannulation of HD access is associated with more frequent access complications, especially infections. Thus, proper cannulation of arteriovenous access requires careful training of rope ladder and buttonhole techniques to avoid infectious and traumatic complications that can lead to dire consequences. Development of better methods of creating buttonholes and single needles for dialysis can facilitate HHD. A culture of self-cannulation at dialysis centers can also promote HHD.

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Hemodialysis (HD) is the most common type of dialysis modality, both in the United States and across the globe, with most of the patients dialyzing in dialysis centers. While there is an emphasis on increasing the overall number of patients using home therapies, only 7% of patients with end-stage kidney disease (ESKD) were using either peritoneal dialysis or HD, and only 2% were using home HD (HHD) in 2016.[1] As the number of patients undergoing incident dialysis using home therapies and kidney transplant in the "Advancing American Kidney Health" initiative is desired to be much higher at 80% by the year 2025, significant efforts by stakeholders to increase this number are underway. Furthermore, the current Coronavirus Disease 2019 (COVID-19) pandemic has highlighted the need of alternative models of ESKD management to avoid exposure to crowded settings such as in-center HD to "going home" instead. Performance of HHD would require a sustainable vascular access at home that is consistently cannulatable by the patient or the care provider.

IDEAL VASCULAR ACCESS FOR HHD: THE CHOICE

An ideal vascular access for any modality of HD would be easy to create and maintain. It would also provide consistent and adequate HD and be free of complications. There are several characteristics that differentiate arteriovenous (AV) accesses and central venous catheters.[2,3] AV fistulae (AVF), when mature, are generally able to provide adequate blood flow rates for performance of HD and have the best patency rates. However, AVF have poor maturation rates. AV grafts (AVGs) are often used when AVF sites are depleted or when veins are too small for a successful AVF creation. However, AVGs are more prone to thrombosis and infection. Central vein catheters are considered the least optimal choice because of a much higher rate of infection, thrombosis, and venous damage, and there also seems to be a better survival and lower cost associated with AVF and AVG than with catheters. However, these reported outcomes may be associated with a high likelihood of bias.

Even though AVF and AVG are considered superior to a tunneled dialysis catheter (TDC), catheters remain the primary access in nearly 80% of the patients undergoing incident HD in the United States, and TDC continue to be used in 20% of the prevalent patients.

A patient considering HHD should be able to make a choice of vascular access that would be most suitable and long lasting, while being easy to cannulate. Owing to the unique circumstances at home, patient-specific factors would dictate the best individualized choice as the responsibility of cannulation and connection to the dialysis machine would lie solely upon the patient or the care provider, not a technically experienced cannulator as in the case of at a dialysis center. As the access will need to be used 4-6 times a week at home, it would be challenging to achieve consistent dialysis because of the potential for cannulation failure and provider fatigue.

VASCULAR ACCESS MANAGEMENT PLAN FOR HHD

ESKD Life-Plan is a strategy for living with ESKD, ideally formulated by the patient and a multidisciplinary team (coordinated chronic kidney disease management team). A patient-centered approach to HD vascular access should consider multiple aspects including a patient's needs, access eligibility, current and future life goals, preferences, social support, functional status, and logistic and other practical feasibilities.[4] An access management team should be multidisciplinary and should include nephrologist, access surgeon, radiologist, nurse, social worker, and patient family member or another supporter. A vascular access coordinator is usually the key member of this team who not only coordinates and schedules the

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procedures but also educates patients about the pros and cons of access choice, addresses any concerns, and facilitates appropriate use of the vascular access. Without diligent coordination, a predefined strategy for patient's "life plan," essential steps in access planning can be easily overlooked during the hectic transition of one's life during initiation of dialysis. Having a patient-centered and mutually discussed plan for appropriate access that includes AV access and catheters makes it easier to individualize the access for the patient's setting, preferences, and life plan. Depending on the choice of access, vessel mapping can be requested before access creation. It is also important for the patient and caregiver to be educated for cannulation and taking care of access appropriately before transitioning to home setting.

Both an AV access and a TDC are acceptable access depending on a patient's ESKD life plan.[4] In appropriate scenarios, such as in a patient with no or poorly maturing AV access, multiple comorbidities, or fear of needles, a catheter may be an appropriate choice, either as an initial, or as a permanent vascular access for the patient to go home. In addition to considering the ESKD life plan, the HHD as a modality should not be out of reach beause of the restricted access considerations based on reported outcomes or cost.

CLINICAL SUMMARY

- Creation and maintenance of a well-functioning, cannulatable vascular access is essential for performance of home hemodialysis and may utilize emerging technologies.
- A patient-centered approach should enable the patient on home hemodialysis to make a choice of vascular access that would be most suitable and long lasting, while being easy to cannulate.
- AV access cannulation is the rate-limiting step for transition to home hemodialysis, and diligent teaching of cannulation technique to include audiovisual aids and hands-on training can mitigate potential risks of infection and bleeding.
- Outcomes of vascular access and patients on home hemodialysis can be improved by proper training and monitoring of access.

PLANNING THE TRANSITION TO HOME: ACCESS CANNULATION

Education and process of transition to HHD should be initiated simultaneously with access creation plan. Cannulation training of the patient or caregiver needs to be implemented after access creation. AV access cannulation is the rate-limiting step for transition to HHD, other than actual dialysis training. There is a natural fear of cannulation that needs to be alleviated to avoid complications that lead to pain, failure to cannulate, infiltration, bleeding, trauma, aneurysm formation, access thrombosis, and eventual access loss. The use of hands-on training, audiovisual aids, and support groups may help acceptance of self-care. There are several available resources regarding training methods and videos that have been discussed elsewhere.[5]

CANNULATION TECHNIQUE AND NEEDLE SIZE

For successful cannulation, it is important to choose a correct needle size according to dialysis prescription. Too small or too large needle gauge can either provide inadequate dialysis or lead to access trauma, respectively. If a patient is unable to use a larger gauge needle, sometimes the dialysis prescription can be adjusted to achieve adequate HD.

Choice of AVF cannulation technique is also the key in achieving successful cannulation without causing access trauma. A rotating site technique commonly known as the "rope-ladder" technique is the most used technique in dialysis centers. This technique can be used by patients and caregivers for HHD. However, a constant site technique, commonly known as the buttonhole technique, is an alternative that is sometimes easier for the patients.[6] A third technique that cannulates access repeatedly in the same general area, known as "area" cannulation, is only being mentioned to warn against its use. This technique can damage the fistula and lead to aneurysm formation and potentially life-threatening bleeding.

The choice of cannulation technique depends on specific characteristics of AVF. To rotate sites, it is essential that there is an adequately long available segment of AVF which can be cannulated with a sharp needle every time. However, when a limited length of AVF is available for cannulation, buttonhole technique can be useful. This is especially important if the patient is self-cannulating and can only cannulate a certain part of AVF. Buttonholes, when fully developed, would allow cannulation with blunt needles which may be perceived as an advantage by the patient or the caregiver.

Development and the use of buttonholes require a meticulous and diligent technique.[7,8] The use of a constant site, angle, depth, and direction of a sharp needle are essential when creating a buttonhole. It is recommended that a single operator should create a buttonhole using a constant position of the arm and tourniquet placement.[5] For the patient, it is important that the track is compatible with one-handed cannulation by the opposite hand. Generally, 8-10 initial sharp cannulations are required for adequate development of the track that would accommodate the blunt needle. Recently, a polycarbonate peg (eg, BioHole Plug [Nipro], Supercath [Togo Medikit]) has been used to create a buttonhole, with its dull version used later to cannulate for performance of HD.[9] Often, a second set of buttonholes is recommended, but without regular use, it can close spontaneously.

Another important aspect of cannulation of buttonhole is removal of the scab with a *separate* needle before blunt needle cannulation. Scab removal techniques vary among different operators, but having a protocol would help maintain consistency. Using the same blunt needle for removal of scab and subsequent cannulation is sure to introduce bacteria into the blood stream.

Both techniques of cannulation have their pros and cons. The RL technique requires accurate cannulation with a sharp needle, with a lesser risk of infection. Buttonholes are easier to cannulate and use blunt needles but come with an elevated risk of local and systemic infections if correct technique is not adhered to. Stenosis of AVF at the site of buttonholes has been noted as well.

RISK OF INFECTION IN BUTTONHOLE CANNULATION

Both observational and randomized controlled studies have examined the risk of infection as well as the benefits of using buttonhole cannulation technique. Retrospective studies and reviews of cannulation technique have demonstrated a higher rate of infection in buttonholes.[10-12] Two recent studies have also shown higher incidence of infections with buttonhole, leading to the recommendation by some to abandon the use of buttonholes.[13,14] On the other hand, small observational studies of buttonhole cannulation have shown a decrease in hematoma and aneurysm formation.[15] A prospective observational study from South Korea showed improved hemostasis time, cannulation pain, and nursing stress.[16] Considering the preponderance of infection risk in most studies, it is perhaps reasonable to consider RL technique for most patients, but it would be interesting to compare both techniques in patients with limited available cannulation sites doing dialysis at home.

Infection risks in buttonhole can be minimized through the use of aseptic precautions and use of topical antimicrobials such as mupirocin.[17,18] However, there is a risk of development of bacterial resistance with the use of mupirocin.[19] Approaches to reduction of infection risk in buttonhole cannulation include decolonization of *Staphylococcus aureus* from the track, prevention of bacterial invasion of track through proper removal of scab, and control of bacterial growth in buttonhole track by disinfection with povidone iodine.[5,7,20]

PATIENT PREFERENCE AND EMPOWERMENT

Patients on HHD have already made an important choice for independence. Ability to cannulate successfully is important for their empowerment, although it is often the rate-limiting step in going home. The context of patient convenience, preference, and feasibility of cannulation should be considered when comparing the 2 techniques for HHD. Often, buttonhole cannulation is used when RL is not practical for the patient. Furthermore, adherence to a strict protocol of buttonhole cannulation by a single operator at home may render results different from those when different operators use variable techniques in dialysis centers. If HHD must be abandoned based on the preference for one or the other technique, that would not serve the patient-oriented care and individual choice.[21] Thus, the use of population-based studies should not be the basis of selection of the cannulation technique for an individual with peculiar anatomy, personal choice, and cannulator comfort to be able to go home. Those with deep, tortuous AVF, with limited available length of AVF for cannulation, are likely better suited for buttonhole cannulation. The use of a strict protocol for access cannulation, care, and novel methods of buttonhole creation may result in better outcomes in future.

Some contraindications to buttonhole cannulation should also be considered. These include cannulators with poor vision and hand tremors, who may not be able to follow the needle track with consistency. Also, buttonhole cannulation can pose a risk of bacteremia, and RL cannulation should be preferred for those with an indwelling prosthesis.

It is to be remembered that the buttonhole cannulation only applies to AVF, not AVG. AVG can be cannulated with relative ease with sharp needles in rotating fashion. The use of angiocatheters with plastic cannula (rather than metallic needles) is currently practiced outside the United States and may improve comfort during dialysis.[22] It is unclear if these catheters can provide blood flow during HD as practiced in the United States.

PSYCHOSOCIAL ASPECTS OF VASCULAR ACCESS FOR HHD

Similar to new operators in unsupervised environment, the patient and caregiver lack the experience despite intense physical training. There still is trypanophobia (fear of needles) and hemophobia (fear of blood) that may hinder with successful cannulation for HHD. On the contrary, the HD at home allows familiarity, freedom, and flexibility that allow comfort and quality of life to the patient and family. A successful HHD program should promote self-cannulation and staff support, and the use of local anesthetic creams can help alleviate these fears.[23,24]

It is important to remember that prevalent in-center HD patients can be a prospective candidate for HHD. After identification of potential candidates, efforts should be made by the HD staff to address the barriers to the culture of self-cannulation. Current environment of remote monitoring related to COVID-19 pandemic may, in fact, help convincing patients to do HHD.

MAINTENANCE OF VASCULAR ACCESS IN HHD

Despite training and experience, repeated and frequent cannulation can be complicated by usual access complications. It is important to have a protocol for frequent and regular access evaluation including history taking and examination, either physically or virtually, at the time of monthly visits or when there is difficulty in using the access. The examination of access should include inspection, palpation, and auscultation which can reveal clues to the presence of abnormalities causing dysfunction.[25,26] Presence of excessive bleeding after removing dialysis needle, poor dialysis adequacy, swelling of ipsilateral arm, enlarged veins and aneurysms, failure to collapse on elevation, and a systolic bruit in a fistula usually indicate presence of outflow stenosis. On the other hand, poor access flow and poor augmentation on compression of AVF indicate poor inflow. Detection of stenosis (inflow or outflow) associated with poor adequacy requires intervention to enable or restore performance of adequate dialysis. Such intervention is coordinated via the management team. Presence of a large aneurysm with shiny and ulcerated

overlying skin requires emergent repair to prevent exsanguination. Detection of large accessory veins preventing maturation of AVF need surgical or endovascular occlusion.

It is also important to review and reemphasize hygienic protocols to maintain sterile technique to avoid infectious complications. Usual surveillance of access with flow, access pressures, and adequacy of HD should be continued. It may be necessary to bring the patient for on-site duplex and Doppler evaluation of access. If complications are detected, the patient should be promptly referred for intervention which can be performed as an outpatient most of the times. There is no current established preventive therapy (such as the use of anticoagulation or antiplatelet agents) to improve longevity or patency of AV accesses.

Infection of vascular access and failure of cannulation are the most important barriers to use of access at home. Undergoing an HHD cannulation, its review, and frequent periodic reinforcement in patients can prevent infections. The protocol should include correct aseptic technique, the use of personal protective equipment, site cleansing, scab removal for buttonholes, and the use of antimicrobial prophylaxis of the site.

TDCs FOR HHD

Catheters remain an important and significant access for HD and may be an acceptable access to initiate HHD while AV access planning, creation, and cannulation training are in process. Catheters may also have to be used during periods of AV access complications for continuation of HD. As usual, it is preferable to avoid subclavian vein catheters because of a high incidence of central vein stenosis, and internal jugular vein is the preferred site for a TDC. A catheter may be used as a suitable permanent access in selected cases if an AV access is not feasible logistically or per patient preference.

As in the case of AV access, catheters need a strict protocol and checklist to use PPE, catheter hub–cleansing protocol, and a catheter lock protocol to maintain patency and avoid infection. A transparent dressing and the use of antimicrobial ointment (eg, polysporin, mupirocin, medihoney, povidone-iodine) at the exit site should be a part of the catheter care protocol. Patient should be advised not to swim and cover the catheter meticulously if a shower bath is desired.

TDC are commonly complicated by infection and thrombosis. A catheter monitoring and management program should be in place for quick recognition and resolution of these problems. The catheter exit site and tunnel need to be examined by the patient and provider routinely. Prompt recognition and reporting of the signs of systemic infection should be taught.

Exit site infection should be treated with topical antibiotics. Presence of tunnel infection would need removal of catheter and change of tunnel. Systemic infections require the use of systemic antibiotics, catheter lock solutions, and removal and replacement of catheter according to clinical need. Closed catheter connector devices are frequently used to prevent catheter-associated infection (Tego Needlefree Connector [icumedical], Curos Caps [3M]). These devices can also reduce risk of bleeding and air embolism in HHD.

A catheter thrombosis management protocol should be established depending on local resources and regulations. It should include the use of forced flushing with saline and/or use of tissue plasminogen activator instillation in ports. While it may be easier for in-center patients to receive these interventions almost immediately, the patients at home usually need to call the access coordinator and travel to the dialysis center for tissue plasminogen activator instillation. If these interventions do not restore patency, further interventions will need to be scheduled by the vascular access management team. Presence of a fibrin sheath requires disruption of sheath with angioplasty and exchange of catheter. Central vein stenosis as a complication of TDC can render the ipsilateral extremity unsuitable for an AV access in future. TDC should be avoided and removed at the earliest when an AV access can be achieved. A radiograph may be required to diagnose mechanical complications (kinking or displacement) of catheter.

PREVENTION OF BLEEDING FROM VASCULAR ACCESS IN HHD

Although uncommon, bleeding can occur during HHD because of needle dislodgement or misthreading of the arterial tubing to the dialyzer.[27] These catastrophes can be avoided by following a strict technical protocol of needle taping and taping of tube to the shoulder to avoid life-threatening bleeding. Proper technique of taping the needles requires placing an initial strip of tape over the needle, crisscrossing another strip of tape, and covering with yet another strip. It is also safer to tape the tubing near the shoulder to prevent accidental needle dislodgement.[8,28,29] The use of wet alarms placed under the dialysis machine, dialyzer, as well as the access arm can detect blood loss quickly. Access aneurysms with thin or ulcerated skin require emergent repair.

OUTCOMES OF VASCULAR ACCESS IN HHD AND FREQUENT HD

Outcomes of vascular access vary between less and more frequent HD. AVF has been used for HHD for a long time.[30] Several studies in the past have shown better outcomes with the use of AVF, being associated with a lower risk of mortality and hospitalization.[31,32] Frequent HD is associated with a higher risk of vascular access complications, mainly infection.[33] Bacteremia rates in HHD were lower in a retrospective study from Canada in AV access group than those in the TDC.[34] Coagulase negative *Staphylococcus* (51.4%) were the most common organisms isolated followed by *Staphylococcus aureus* (20.3%). An observational study incorporating data from the US Renal Data System demonstrated a hazard ratio (HR) of 1.01 for all-cause admission, 0.89 for cardiovascular disease, 1.18 for infection, 1.02 for vascular access dysfunction, and 1.39 for vascular access infection in HHD patients ($n = 348035$) as compared to in-center patients ($n = 17,400$).[35] A systematic review of 12 studies noted no apparent increase in access complications in patients

on daily HD, as compared to those undergoing HD 3 times a week.[36] However, a randomized trial of 120 patients undergoing HD conventionally 3 times per week and 125 patients on 6 times per week noted more (95 interventions) in the frequent HD group than in the conventional HD group (65 interventions).[37] At least one procedure was required in 47% of the frequent HD cohort but only in 29% in the thrice-weekly HD group. Another observational study of 87 patients with ESKD showed worse vascular access outcomes in the frequent HD (6 times per week) group as compared to the conventional (three times a week in-center) group.[38] A 4-year prospective observational study of 77 subjects doing 6 vs 3 HD sessions per week recorded total access procedures (fistulagram, thrombectomy, access revision).[39] There were 543.2 procedures per 1000 person-years in conventional HD vs 400.8 procedures per 1000 person-years in the daily HD group. There was no difference in time to first access revision between the daily and the conventional HD groups. Consequently, this study concluded that daily HD was not associated with increased access complications or increased access failure rates.

Complications of vascular access were examined with frequent HD in 2 recent separate randomized controlled trials that compared 198 patients with AVF or AVG and 47 patients with TDC receiving 6 days per week of in-center HD vs 3 days per week of conventional HD; another subgroup of 87 patients received 6 nights per week of home nocturnal HD or 3 days per week of HHD for 12 months.[40] The overall risk for a first access event was 76% higher with frequent HD than with conventional HD (HR: 1.76) with no difference in loss of AV access between groups. More total AV access procedures were needed in frequent HD (both home and in-center) patients than in patients on less-frequent, conventional HD and 55% of all interventions involved thrombectomies and surgical revisions. There were 33 repairs and 15 losses in the frequent HD group as compared to 17 repairs, 11 losses, and 1 hospitalization in the conventional group. The HR for time to first access repair, loss, or access-related hospitalization was 1.9 in patients with AVF or AVG in the frequent HD cohort as compared to that in the conventional group, while it was 2.7 in those with central venous catheters. A meta-analysis of 15 studies analyzing vascular access outcomes included 1540 access-years for frequent HD and 2284 access-years for conventional HD.[41] There were higher vascular access event rates in the frequent HD group than those in the conventional HD group (difference of 6.7 events per 100 patient-years). AVG and central venous catheters had higher event rates than AVF. AVF had relatively better outcomes in both frequent and conventional HD.

UPCOMING ADVANCES IN HHD

A double-lumen single needle may have survival advantage for frequent access cannulation as it will reduce number of cannulations in half.[42,43] There may also be less risk of accidental needle dislodgements. Single needle may, however, reduce dose of dialysis by decreasing effective dialysis time and increasing access recirculation. Training for single-needle cannulation will also be important to avoid risk of infiltration if not fully inserted. Single needles for HD are in development. Newer techniques of creating buttonholes may improve buttonhole results. The use of nonmetal angiocaths is expected to improve comfort during dialysis.

In summary, appropriate vascular access that can be cannulated with ease and safety is the best access for performance of HHD. The choice of HHD vascular access is crucial and needs individualization. Training to properly cannulate an access that avoids infection and traumatic complications and its periodic auditing are very important. Methods of cannulation are important but should consider ease of cannulation and risk of infection. A vascular access team approach is essential for creation, maintenance, and troubleshooting of vascular access to allow safe and effective HHD.

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