Considerations in Access Cannulation: Traditional and Evolving Approaches

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Needle cannulation of hemodialysis access is the soft underbelly of hemodialysis access care that has remained unchanged for a long time. Cannulation error results in complications such as infiltration, hematoma, subsequent revision procedures, and potential loss of hard-earned access. The "best" cannulation method is contingent upon access type and characteristics along with local expertise. The rope ladder technique of cannulation, characterized by successive rotation of puncture sites with each hemodialysis session, permits sufficient time for healing of prior cannulation sites, and reduction in complications such as bleeding, infection, and aneurysm development. A steeper needle angle, higher blood flow rates, and deep needle tip can lead to wall stress on the posterior wall and up to 10 cm from the needle cannulation site. Plastic cannulas provide a viable alternative to metallic needles; they have lower complications and a favorable cost-benefit ratio. There is lack of evidence to support an optimal arterial needle direction configuration. Needle injury may promote intimal thickening, but its effect on access outcomes is currently unknown. Percutaneous creation of arteriovenous fistula presents new challenges in dialysis access cannulation. Point-of-care ultrasound-guided cannulation will likely lead to a paradigm shift in access cannulation. Novel care delivery using cannulation stations is a promising development.

Key Words: Hemodialysis vascular access, Cannulation, Buttonhole cannulation, Dialysis needle, EndoAVF

Vascular access (VA) is the most vulnerable aspect of hemodialysis (HD) delivery to a patient with end-stage renal disease. The present day HD delivery was made possible by the advent of arteriovenous fistula (AVF) and the subsequent development of polytetrafluorethylene, a synthetic fluoropolymer of the tetrafluoroethylene-based arteriovenous graft (AVG). The acceptance of AVF as the "holy grail" of HD VA prompted an increase in the creation of AVF. With the plateauing of AVF rates, VA planning has now moved toward individualized access planning. Advances in surveillance, referral process using VA coordinators, interventions with balloon angioplasty, stent grafts, and endovascular AVF (endoAVF) creation are other notable developments in VA care.

Needle cannulation continues to be the soft underbelly of HD access care. Cannulation is a delicate skill. Cannulation errors result in complications such as infiltration and hematoma development, with subsequent interventions and a high risk of losing access.[1] Similar to many other phases in VA care, optimal cannulation method has stalled owing to inconsistent evidence and, at times, bewildering outcomes. For a long time, the question of what is the best cannulation method to improve access outcome has persisted. Access types and local staff expertise dictate the "best" cannulation method. Selection bias secondary to access traits and personnel skill affects research studies that evaluate cannulation and access outcome. This predicament is further exaggerated by the advent of endoAVF creations. This review aims to address many of these puzzles.

HISTORICAL ASPECTS OF DIALYSIS ACCESS CANNULATION

Physicians cannulated the VA in the early developmental phase of HD therapies. Even now, the Center for Medicare and Medicaid Services "Conditions for Coverage for End-Stage Renal Disease Facilities" considers nephrologists to be primarily responsible for VA management.[2] In the 1960s, there were notable advancements in HD machine technology and adoption of the Cimino-Brescia AV fistula. Nephrologists started to oversee dialysis prescription rather than perform routine dialysis tasks. The dialysis delivery tasks were then delegated to the registered nurses and subsequently to HD biomedical/patient care technicians. In 1972, the United States government enacted the End Stage Renal Disease (ESRD) Program under Medicare, which recognized the role of patient care technicians in increasing cost efficiency and the spread of HD within the United States.

Metal needles with wings soon became the preferred devices for dialysis access cannulation. Nephrology nurses developed cannulation policies and procedures. In the United States, the dialysis facility medical director oversees the nursing policy and procedures. The role of the registered nurse has expanded to include supervision of the care provided by the patient care technicians. In the United States, patient care technicians perform most of the incenter HD cannulations. In other countries, the use of patient care technicians is much less prevalent, and the main cannulators are still registered nurses. Table 1 and Fig 1 provide a historical understanding of the evolution of dialysis and access cannulation over the years.

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CANNULATION METHODS

There are 3 commonly used cannulation practices. They are "site rotation" or "rope ladder" (RL), "area cannulation," and "buttonhole" (BH). Although there is limited literature on the merits and demerits of the RL technique, it is probably the most widely recommended cannulation method. RL involves a successive rotation of puncture sites with each HD session, hoping to provide sufficient time for healing, likely leading to a reduction in complications, such as prolonged bleeding, infection, and aneurysm development. In 2012, Parisotto and colleagues[11] surveyed 7058 patients who were receiving care in 9 different counties. They found that the RL method was used only in 28% of patients. Area cannulation was used the most (65.8%), and BH cannulation was the least used technique (6%).

Area cannulation involves the repeated cannulation of a small area. This weakened segment of the fistula wall could develop into aneurysms. A limited cannulation segment or deep access pushes cannulators toward area cannulation for convenience. It is critical to note that area puncture is not an acceptable cannulation technique because it increases the risk for vessel damage or graft degradation.

In 1979, Twardowski described a novel method developed by a patient with a limited cannulation segment based on the reuse of the same needle sites.[8] Kronung rechristened the "constant site" method as the BH technique.[12] The BH technique involves the use of a sharp needle for tract formation, followed by blunt-tip needles, inserted at the same angle, depth, and location to form a fibrous track. The critical step in the BH technique is needle track development. Ideally, "the same cannulators" should perform the cannulation until the track is established. It can take between 8-12 cannulations for the track to develop.[13] BH cannulation is suitable in patients with a limited cannulation segment. The widespread adoption of BH cannulation is not advocated owing to the high rate of infection, with risks as high as 78%.[14] BH tracks are known to have transient or sustained colonization of bacteria such as *Staphylococcus aureus,* and asymptomatic bacteremia is common.[15] Despite education and strict infection prevention practices, the rate of infection in BH approaches that of central venous catheters.[16] The perceived benefits of BH, whether in terms of improved cannulation-related pain or fistula survival, have not outweighed the infection risks.[17] A detailed analysis of the strengths and weaknesses of BH are well published in the literature.

CLINICAL SUMMARY

- Cannulation of dialysis access is a delicate skill, and errors may result in serious complications.
- Infection rates of buttonhole cannulation can be as high as central venous catheters negating any perceived benefits.
- Ultrasound-guided cannulation of an endovascular-created arteriovenous fistula is preferred.

EFFECTS OF NEEDLE CANNULATION ON VASCULAR ACCESS BIOLOGY

Neointimal hyperplasia is a well-recognized cause of dialysis VA dysfunction. The pathophysiology involves cells originating from the tunica adventitia and smooth muscle cell migration from the tunica media to the tunica intima. Adverse inward remodeling infringes into the vessel lumen, leading to stenosis and dysfunction. The effect of frequent cannulation on access outcomes were described by the Frequent Hemodialysis Trial Network in their two trials: Nocturnal Trial and Daily Trial.[18] While the increased frequency of needle cannulation may result in direct vessel damage, stenosis development may be an indirect consequence. Authors from the Frequent Hemodialysis Trial Network hypothesized that repeated trauma at venipuncture sites and associated turbulent blood flow influences profibrotic cytokine production and local inflammation, culminating in neointimal proliferation.[19,20] Ultrasound findings of changes in the intimal layer from venipuncture were reported by a study from Hsiao and colleagues[21] Increased intimal thickness without luminal stenosis was noted in about 40% of patients using BH along with consistent vascular dilation. It would be naïve to assume that mechanical injury from needles would not initiate a sterile inflammatory response. Studies evaluating biochemical responses leading to inflammatory process from repeated venipuncture are sorely needed.

Juxta anastomosis stenosis in AVF typifies how wall shear stress leads to adverse endothelial remodeling and eventual failure. The pulsatile jet from the dialysis needle creates localized turbulence and changes in shear pressure, but its effect on neointimal hyperplasia is currently unknown. The adverse shear stress could be instigated by the direction of the venous needle, access depth, angle of penetration, access blood flow rate, the distance between the arterial and venous needles, the number of side holes located in the needle, and needle geometry. A three-dimensional computational model study evaluated the angle of insertion, needle flow, needle tip position in relation to the lumen, and localized hemodynamic changes noted at the site of needle cannulation.[22] A steeper needle angle, higher flow rates, and increased depth of the needle tip result in higher wall stress, mainly affecting the posterior wall of the access and up to 10 cm from the needle cannulation site. Higher access blood flow rate could help in dissipating some of the wall shear stress by the admixing of access blood flow with the needle jet stream. Low wall shear stress at the anterior wall, behind the needle jet stream, and turbulent downstream are all known to propagate intimal hyperplasia. The study also noted use of shallow needle angles, a blood flow rate of approximately 300 mL/min, and placement of the needle tip away from the walls of the vein may help mitigate this risk. Internationally, blood flow rates range from 250 mL/min to 350 mL/min, whereas standard prescriptions in the United States might be around 400-500 mL/min. These findings could suggest that the current dialysis practice in the United States with an average blood flow rate higher than 400 mL and

Table 1. History of Cannulation Methods for Hemodialysis

Year	Hemodialysis and Cannulation Advancements
1914	Rudimentary cannulas were placed into the animal's artery and vein.[3]
1915	George Haas added a simple blood pump to the dialysis circuit as blood pressure from the artery cannula was insufficient to move the blood into a series of multiple dialyzers.[4]
1940	Willem Kolff used a single blood access cannula with a burette that was raised and lowered to allow blood to enter and return from the rotating drum Kolff artificial kidney device.[4]
Mid 1940s 1948	The Alwall System used a stationary drum dialyzer incorporating a blood pump to move the blood through the extracorporeal circuit. Alwall also described the use of a cannula to access the patient's blood vessels.[4]
Early 1950s	George Jernstedt developed the Westinghouse kidney with a built-in blood pump and pressure monitoring technology.[4]
1960	Dr. Paul Teschan used heparin to lock cannulas for the first time allowing repeated use of the same blood access sites. This enabled chronic dialysis.[5]
1960	Clyde Shields had a Quinton-Scribner shunt inserted into his arm. The shunt tubing was the first to use PTEF tubing, decreasing the clotting risk.[4]
Early 1960s	Self-care home dialysis was pioneered by Dr. Stanley Shaldon, including vascular access care.[4]
1966	Dr. Kenneth Appel was the first to anastomose an artery to a vein creating an internal AV fistula (Cimino-Brescia internal fistula).[6]
Mid 1960s	Development of metal AV fistula needles without wings for cannulation.[7] Cannulation methods included rope ladder, area puncture, and constant site method (buttonhole).[8]
Mid 1990s	Plastic cannula utilization for AV Fistula cannulation with wide adoption in Japan.[9,10]
2012-present	Plastic cannula utilization for AV Fistula cannulation with wide adoption in many countries in Europe, Asia, and Canada. No device currently FDA cleared in the United states.

Abbreviations: AV, arteriovenous; FDA, Food and Drug Administration; PTEF, polytetrafluoroethylene.

increasing prevalence of deep accesses owing to obesity might be contributing to access dysfunction. The in vitro studies with stationary access such as this fail to mimic in vivo conditions involving patient mobility during dialysis. Pragmatic in vivo studies evaluating the needle cannulation parameters and development of neointimal hyperplasia are genuinely needed.

NEEDLE TYPES

Conventionally, dialysis needles are metallic with a bevel edge and back eyehole at the tip of the needle. The metal is typically stainless steel with siliconized coating for easy insertion and low flow profile. The length of the needle shaft and the luminal diameter determine the average blood flow. New AVFs are cannulated with smaller profile needles, ie, 17G, and progressively increased to as high as 14G. Moreover, metallic needles are rigid, and mobility during dialysis leads to infiltration.

Plastic cannulas are gaining prominence as an alternative to metallic needles. A biocompatible material with flexibility and a blunt tip makes it an optimal choice for restless patients, children, older frail patients, nocturnal HD, and tortuous veins.[23] Each plastic cannula is delivered with an introducer metal needle. It has been reported to be used effectively in early AVF cannulation. The learning curve could be steep with nearly 12-18 months training before the staff becomes proficient and benefits are reaped. Ultrasound guidance is frequently advocated to be used in cannulation with plastic cannula. The jet flow characteristics that emanate from the needles are also different. The mean Doppler velocities of the blood flow were higher for the metal needles than for the plastic cannulas.[24]

Another randomized study from Canada reported on the complication rates between the plastic cannula and the metal needles.[25] Thirty-three patients were randomized to either metal needles or plastic cannula, with 5 trained registered nurses providing ultrasound-guided cannulation. Procedures to treat complications along the cannulation segments increased in the metal group (0.41 to 1.29 per patient), whereas the plastic cannula group had a notable drop (1.25 to 0.69 per patient $P = 0.004$). Infiltrations during HD were higher in the metallic needle than those in the plastic cannula (71% vs 31%, $P = 0.03$). The unit cost of the plastic cannula was 3 times higher than that of metal

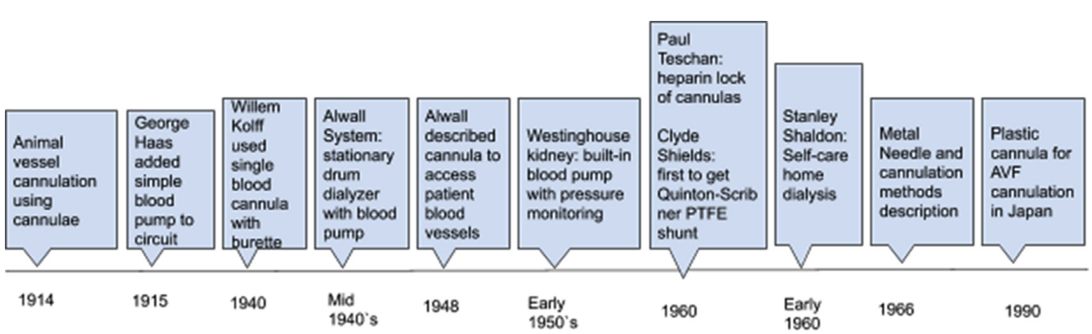

Figure 1. Significant historical developments in dialysis and cannulation of dialysis access.

needles (CAD 3 vs CAD 1). Still, a significant cost saving was noted with a plastic cannula group when the cost of the procedures needed to address the complications was included (CAD$3787 vs CAD$6622 total estimated cost/patient-month, respectively). The cost of the plastic cannula and the limitation of the inner diameter on achieved BFR are significant hurdles toward widespread acceptability. Plastic cannulas are currently not marketed in the United States but have found patronage in Europe, Asia, and Australia.

The National Kidney Foundation Kidney Disease Outcomes Quality Initiative (NKF KDOQI) work group on VA did not include the utilization of plastic cannulas in the clinical practice guideline statements for 2019 update.[26] "The safety, efficacy, and patient satisfaction with using plastic cannulae" is listed as one of the 8 topics of needed research. The research topics recommended include a topic on "randomized control trials to assess standard needles vs plastic cannulas in preserving arteriovenous access patency and reducing complications." Plastic cannulas, while being excellent alternatives to metal needles with their favorable fluid dynamic characteristics, and comprehensive cost benefit profile, still involve paradigm shift in dialysis staff workflow and necessitate an advanced skill set, including the use of ultrasound, making them less practical in the current scenario. Without the recommended research, it is difficult to support wide spread utilization of the plastic cannulas based on available literature.

NEEDLE DIRECTION

Venous needle direction is the direction of blood flow back to the heart. In typical AV fistula configurations, the venous cannulation zone is the vessel section closest to the chest/heart. The typical arterial cannulation zones are in the vessel section closer to the hand (Figs 2 and 3).

Recirculation of blood is induced when the access flow nears or falls lower than the set blood pump speed. Theoretically, an opposing needle direction should reduce the incidence of recirculation. A prospective pilot study found no difference in recirculation rate and HD adequacy between needles in the same direction compared with the opposing direction.[27] The separation between needles is likely more important than the course itself. The study by Basile and colleagues[28] using the transonic ultrasound dilution recirculation method reported zero recirculation when a minimum of 2 inches separates the needles. The cannulation policies of the 2006 NKF KDOQI Vascular Access Guidelines also recommend at least 2 inches needle separation to reduce the risk of recirculation.

Currently, there is lack of evidence to support an optimal needle direction configuration for the arterial needle. The needle cannulation should be individualized to maximize the cannulation zone usage, while simplifying the cannulation procedure, especially for a patient doing self-cannulation.[29]

SELF-CANNULATION

In the early 1960s, Dr. Stanley Shaldon from Royal Free Hospital in London and his team trained a patient to self-cannulate the Quinton-Scribner shunt in his leg, which allowed the use of both arms during his dialysis.[4] In the United States, the Medicare and Medicaid Program Conditions for Coverage for End-Stage Renal Disease Facilities detail the patient's right to be involved with self-cannulation to the degree

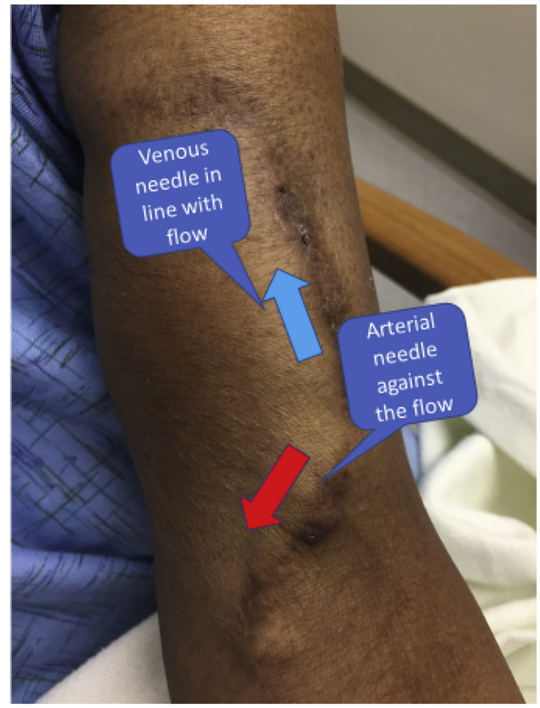

Figure 2. Arterial needle retrograde and venous needle antegrade.

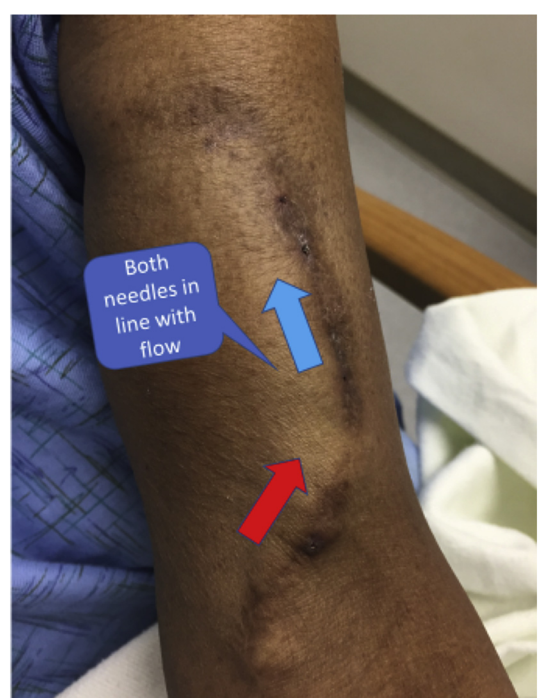

Figure 3. Antegrade cannulation of both needles.

the patient wishes and must be adequately trained to accommodate their self-cannulation procedure.[30] Location of the VA plays an essential role in self cannulation and self-dialysis. Nondominant arm VA is suitable for the use of the dominant hand for cannulation, whereas dominant arm access is not a limitation for self-cannulation. Self-dialysis requires that the VA location not impede the hand or elbow movement of the VA limb to allow safe movement of the arm to respond to the HD machine alarms or any required action. A self-cannulating patient masters the technique for only one VA, while dialysis staff cares for multiple patient's accesses. Self-cannulation protects a patient's VA from complications of miscannulation owing to the use of various cannulators. The patient has a unique perspective of feeling cannulation real time and can react to needle movement by rapidly altering the pressure or needle advancement to avert miscannulation or infiltration. Self-cannulation also empowers them in identifying access dysfunction and the use of optimal RL techniques. The KDOQI highlights the significance of self-cannulation in their recommendation for future research in answering if self-cannulation can lead to better access outcomes.

Self-cannulation training varies with dialysis facilities. The BH technique is most commonly used in self-cannulation. Healthcare professionals could create the BH site in coordination with a patient preference on the angle of the needle track. The creation of the BH needle track formation is ideally done by the self-cannulator to ensure the needle track is compatible with their viewpoint and needle positioning for cannulation. Self-cannulators must do the cannulation one-handed while crossing their body to reach the fistula. Needle direction is a novel challenge faced by self-cannulators as only one hand is used for both needles. The antegrade course is the most convenient for self-cannulators and closely mimics dialysis staff cannulations.

Self-cannulators require education on infection control measures, including proper handwashing, access site washing, and aseptic techniques. The scab removal process is a critical procedure step in BH cannulation. The old scab needs to be removed without causing trauma or bleeding of the BH track using the sterile scab-removal device provided in the needle kit. Skin prep needs to be repeated after scab removal and before needle insertion to reduce infection risk. Hand hygiene should frequently occur to prevent cross-contamination of any bacteria or organisms between BH sites. Topical numbing agents should be eradicated before cannulation. Needle taping for the self-cannulator may also need to be adjusted to allow the application and removal of the tape to occur with 1 hand. The needle direction impacts the needle removal process. Most self-cannulation patients use their hand on the access arm to hold the end of the needle and pull to help remove the needle post HD with the free hand, then applying a small gauze pad with pressure to obtain hemostasis. Self-cannulators using the RL technique perform similar steps minus the need to remove scabs before insertion. The utilization of self-cannulation in endoAVF can reduce the need for multiple cannulators to master the cannulation technique.

CANNULATION ERRORS

Cannulation errors can lead to complications, such as hematoma, infection, and aneurysm formation, with a secondary impact on morbidity, hospitalization, access revision, and loss of access.[17] Cannulation, with its associated pain, negatively impacts the quality of life. Miscannulation of new AVF is very high, with nearly 51% of fistula having a miscannulation within the first 3 dialysis sessions.[31] By 6 months, less than 10% of new AVF would have uncomplicated cannulations with 2 needles for every HD session. New AVF is at very high risk of infiltration (HR 2.98), which leads to more diagnostic tests, expensive interventions, and prolonged catheter use. AVGs have fewer cannulation errors than AVF. A cannulable segment >10 cm in an AVF reduces the risk of cannulation errors. Every measure that can decrease and limit miscannulation should be considered.

MEASURES TO AID IN CANNULATION

The current cannulation techniques depend on tactile sensation. Skin markings, including temporary tattoos or photographic images, are frequently used to assist cannulations.[32] Surface markings lack real-time information, size, depth, and wall characteristics and are not well-studied. Cannulation maps help conceptually in the surface marking of dialysis access. A cannulation map includes details of vessel locations and identifies the potential arterial and venous cannulation segments, vessel diameter, and depth of the vessels at various sites. It helps to determine the optimal needle site, needle length and needle gauge advancement.

Skilled cannulators and cost are major limiting factors in the widespread adoption of ultrasound-guided cannulation. Dialysis technicians and nurses receive on-the-job training, with frequent personnel turnover and burnout. Any delay in the delivery of dialysis leads to ripple effects that affect workflow, patient care, and staffing needs. Traditional ultrasound machines have a large footprint and are clumsy to use for routine access cannulation. They also require a certain level of staff competency, and meeting infection control regulatory requirements can be a challenge. Competency development for dialysis staff will involve educational sessions on ultrasound use, practical sessions using phantom models, and essential hand-eye coordination, along with nearly 500 guided cannulations before use in the clinical setting.[33] This protracted learning curve is a deterrent for a pragmatic adoption of ultrasound for dialysis access cannulation. A coronal mode handheld ultrasound device-assisted cannulation had shown comparable effectiveness to the conventional cannulation technique with a relatively short training period.[34] Other portable points of care ultrasound devices like Butterfly are expected to aid in increasing real-time ultrasound-guided cannulation. Point-of-care ultrasonography provides a comprehensive visual format and greatly enhances cannulation outcome and experience. A pilot study to assess the feasibility of a randomized controlled trial is currently underway in Australia aimed at evaluating whether a point-of-care ultrasound cannulation results in more successful and accurate AVF needle placement than the standard practice of blind cannulation.[35]

Venous Window Needle Guide, a titanium device implanted over a fistula to aid in the cannulation of deep fistula, has shown promise. Another notable device includes BioHole, a polycarbonate peg. It is promising in creating BH tracks but has been unable to gain traction in light of the ever-increasing evidence of infectious complications of the BH method.[36]

CRITICAL CHALLENGES OF DIALYSIS ACCESS CANNULATION

Research into the various aspects of cannulation before the 2006 version of the NKF KDOQI Vascular Access Guidelines was limited. Recommendations for future research highlighted the need for further studies in the areas of cannulation training, the use of expert cannulators, and self-cannulation to improve access outcomes. More than a decade later, few studies have investigated HD cannulation techniques and practices. The current cannulation related research focuses on the infection complications, especially of the BH cannulation technique. In addition, research in needle technologies such as the plastic cannula and the use of point-of-care ultrasound guidance for cannulation is gaining traction. Cannulation-related research is frequently conducted in countries other than the United States. Automated data analysis is hampered because of poor designs of electronic medical records for capturing dialysis data points. Key details such as the needle site locations, needle direction or bevel orientation, needle angle of entry, patient pain level, needle repositioning, and multiple needle attempts are not routinely documented with each cannulation. The use of specific cannulation technique such as RL, area puncture, or BH may not be recorded for each patient at each dialysis session. Minor cannulation technique variances by cannulators are subjective and nonreproducible and cannot be captured on electronic medical records. An impetus is sorely needed to support and fund dialysis nursing-led research in the area of access cannulation.

CHALLENGES OF ENDOVASCULAR ARTERIOVENOUS FISTULA CANNULATION

Endovascular creation of AVF using catheter-guided technology heralds a paradigm shift in AVF creation. The early results from mostly industry-sponsored research studies look encouraging. EndoAVF results in improved primary patency, higher functional cannulation successes, and lower associated first-year costs compared with surgically created AVFs.[37,38] Additional advantages include standardization of anastomotic angles, minimal invasiveness, and avoidance of general anesthesia.

EndoAVF cannulation presents a new set of challenges. A lack of surgical scars limits landmarks and locations, and vessel development may be difficult to discern. The Fistula First Workgroup standardized the look, listen (bruit), and feel (thrill) assessment of an AVF/AVG into a simple "1 minute check" assessment tool. A dialysis technician can perform the check and escalate any abnormal findings to the nurse and nephrologist. Low access blood flow rates or the presence of multiple draining veins limits the reliability of "one-minute checks." Point-of-care ultrasound guidance was used for cannulation of endoAVF in clinical trials, and the plastic cannula was used instead of metal needles. Arm positioning to allow for cannulation and patient comfort during HD and self-cannulation by the patient are additional novel challenges with endoAVF. These differences and their impact on access care and cannulation are summarized in Table 2.

CONCEPT OF A CANNULATION STATION

The idea is to have new or challenging cannulations performed by a dedicated and highly trained cannulation specialist to minimize missed cannulations, cannulation injuries such as infiltrations, and hematoma formations that can lead to access complications or failure. This model has been successful in hospital-based dialysis settings with a large nurse-to-patient ratio.[39] The station can be staffed with a dedicated nurse skilled in ultrasound-guided cannulation. The patient has a VA assessment followed by an evaluation with ultrasound imaging. The expert can create a cannulation map for other staff to use once the access is deemed ready for general cannulation. The mapping can be used with RL cannulation to identify the potential cannulation zones for proper site rotation. The map can also be used to create a BH. After the ultrasound-guided cannulation, needles are secured, a saline flush is used to check proper placement, and a saline lock is instilled to prevent clotting within the needle. The cannulation is documented in the patient's record. The patient is then moved to the dialysis machine location for the other staff to initiate the dialysis treatment. The station is disinfected for turnover to the next patient. A significant workflow advantage of this model is that the expert cannulator has all the necessary tools, including ultrasound, and is not in a time rush to cannulate the patient and initiate the treatment. The patient can be attended to in a relaxed, focused manner while not slowing down the general workflow of the entire dialysis staff.

This same concept can be adopted to dialysis facilities without ultrasound guidance. The expert cannulator can utilize a phlebotomy-style chair in a limited space area away from the general dialysis stations. The expert cannulator uses the same procedure steps as the extensive station. Cannulation maps are part of the patient's medical record, and they can be referenced as needed. The cannulation station is disinfected between each patient. The expert cannulator role varies by country as in the United States, and the most experienced cannulators are typically patient care technician.

DEEP FISTULA

A large number of people in the United States suffer from obesity. Obtaining functional VA is a challenge in patients with obesity, primarily because of vein depth. The problem of functional and reliable cannulation in the face of obesity and deep AVF outflow veins has been addressed by (1) tunneled vein transposition as a primary or staged procedure, (2) outflow vein elevation with superficialization of the AVF outflow tract, (3) excision of subcutaneous tissue overlying the AVF outflow vein, or (4) lipectomy by surgical excision or suction.

Table 2. Differences that Impact Care and Cannulation

Surgical AVF in the Arm	EndoAVF in the Arm	Impact on Care and Cannulation
Surgical scars as landmarks for the anastomosis site	No surgical scars to help identify the location	Healthcare professionals may be unaware of the EndoAVF in the limb and could use the vessels for blood draws or IV sites. Delay in use by the dialysis team and prolonged catheter use or inadvertent referral for access placement
Types: Radiocephalic AVF (Brescia-Cimino) Transposed Basilic Vein AVF Radial artery to forearm cephalic vein (snuff-box AVF) Proximal forearm AVF with an end to side anastomosis between a perforating branch of the cephalic or median antecubital vein and the proximal radial artery (Gracz fistula)	Vessels used by the device Ellipsys device: Proximal radial artery and the deep communicating vein in the proximal forearm (similar to the Gracz AVF or proximal forearm AVF) WavelinQ device: Ulnar Artery to ulnar vein	EndoAVF may develop a vessel that crosses the antecubital fossa Ellipsys: Median cephalic vein and cannulation zone may cross the antecubital fossa WavelinQ: Split flow into basilic and cephalic vein
Physical examination: One-Minute Check	The thrill and bruit may be diminished slightly from a typical AVF Augmentation and arm elevation not proven owing to lower average blood flow rate and multiple outflow veins.	Dialysis staff need retraining for monitoring Note: Blood flow may be a split flow and hence softer bruit and thrill.
Lower arm access flow: 300 mL/min to 800 mL/min Upper arm access flow: 300 mL/min to 3000 mL/min	EndoAVF reported ranges are 400 mL/min to 800 mL/min	Dialysis staff needs reeducation on access flow differences based on vessels used for creation. Need newer access to surveillance methodologies and workflow adaptations. Note: Access flow measurements with clearance or ultrasound dilution methods require the arterial and venous needles to be in the same vessel. Needle placement into split vessels will impact the measurement accuracy.
Intense flashback of blood with cannulation	May see a muted flashback related to lower access flow	Dialysis staff needs reeducation on the differences between the qualities of blood flashback.
Cannulation typically with the arm extended. Once the needles are secured, any movement at the elbow will most likely not cause a needle infiltration. Upper arm cannulation is generally done above the elbow so the same applies as the lower arm.	Arm positioning may require the elbow to be fully extended for cannulation. If the needle entry site or tip of the needle crosses any section of the antecubital fossa, the angle may need to remain extended or movement limited during the hemodialysis session.	Dialysis staff needs retraining on arm positioning. If the elbow must remain fully extended or movement restricted, care must be taken as not to restrain the patient's arm
Self-cannulation of the AVF is offered to all patients as part of their involvement in their care CMS CoC Vtag 456	Self-cannulation of the EndoAVF should be provided to the patient same as a surgical AVF	Self-cannulation of the EndovAVF may also reduce the risk of cannulation related issues.

Abbreviation: AVF, arteriovenous fistula; EndoAVF, endovascular arteriovenous fistula; IV, intravenous.

Tordoir and colleagues[40] reviewed studies for different superficialization methods. The fistula elevation procedure is a simple superficialization procedure during which the fistula is surgically exposed, mobilized, and elevated into a more superficial position to facilitate AVF cannulation. The fistula elevation procedure procedure can be performed in a one- or two-staged operation (the second operation between 4 and 9 weeks after fistula creation to allow for vein maturation). A longitudinal incision is made some distance away from the fistula vein. The fistula is mobilized along the length of the incision. It is essential to be aware that a skin incision directly over the vein can result in excessive scar tissue, which hampers access for future cannulations. The clinical success rate of vein elevation or transposition ranged from 85% to 91% in this study. The primary and secondary patencies at 1 year were 60% and 71%, respectively. Lipectomy is a minimally invasive procedure carried out through small incision(s). Primary and secondary lipectomy procedures have few complications and have acceptable technical and clinical success rates.[41,42]

CONCLUSIONS

HD access cannulation is a combination of art and science. The RL cannulation technique is preferred, whereas BH cannulation is suitable for limited cannulation segment accesses. Access outcome studies evaluating the impact of needle size and cannulation techniques are critically needed. Point-of-care ultrasound-guided cannulation will likely change the paradigm of dialysis access care. Novel cannulation delivery by using cannulation stations, cannulation aids, and robust data collection are sorely needed.

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