CLINICAL UPDATE

NEEDLES AND CANNULAS FOR ARTERIOVENOUS FISTULA ACCESS:

MORE OPTIONS PROMOTE BETTER OUTCOMES

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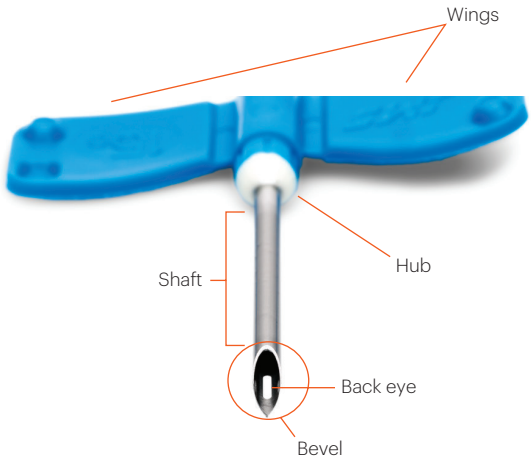
INTRODUCTION

When feasible, the arteriovenous fistula (AVF) is recommended as the first choice for hemodialysis vascular access.[1,2] Unfortunately, cannulation is one of the primary causes of AVF complications and failure.[2,3] Needle punctures into the vessel wall cause endothelial injury, which triggers leukocyte adhesion, migration of smooth muscle cells from the media to the intima, and proliferation. This cascade promotes neointimal hyperplasia, a thickening of the vessel wall that can then lead to venous stenosis, the most frequent cause of hemodialysis access failure.[3-7] Infiltration, aneurysms, hematoma, and ultimately AVF loss, are all attributable to needle-induced vessel injury.[3,4,8] Infiltration alone is a significant complication, with one study reporting an annual major infiltration rate of 5.2%, and concluding that one infiltration leads to three extra months of catheter dependency.[9]

In order to reduce AVF needle injuries, proper cannulation technique must be paired with the right needles to meet individual patient needs. Therefore, using needles that help mitigate vessel injury is critical. In addition, one cannot discount the importance of controlling pain and preserving the physical integrity of the access limb.[10,11] The mere thought of very large needles piercing through their skin and vessels creates tremendous anxiety for most patients, and the trauma of pain and disfigurement from cannulation is a significant barrier to regular attendance at dialysis sessions and to embracing self-cannulation.[12,13] This bulletin describes dialysis needle options, and key features that may be considered when choosing the right needle for the right patient, thereby enhancing patient-centered care and possibly better outcomes in AVF survival.

Figure 1: Basic structure and features of a traditional hemodialysis needle



FIRST CONSIDERATIONS IN NEEDLE SELECTION

Needle type

Most often in the United States, the first type of needle employed for initial cannulations will be a sharp metal needle, whether to begin rope ladder/rotating site technique, or same-site cannulation in order to establish tunnel tracks for the buttonhole technique. Alternatively, plastic cannulas, or pegs, have been left in the vessel for a period of time to develop the buttonhole tunnel track.[14-16]

Metal needles are made of stainless steel, and are either sharp or blunt. Sharp needles, used for the rope ladder technique, have a sharp cutting edge, whereas blunt needles, designed for the buttonhole technique, are rounded on top and do not have a sharp edge. Figure 2 shows the difference between the ends of a sharp and a blunt needle. Metal needles have a silicone coating for smooth insertion and low flow resistance.[17] In certain buttonhole patients, blunt needles may bounce off the vessel (the "trampoline" effect) during entrance into the track, and therefore sharp needles are recommended.[18,19] Some needles have an intermediary sharpness between that of traditional sharp and blunt needle tips. The buttonhole technique is only used with extensive specialized staff training for AVFs and never in arteriovenous grafts (AVGs).

Figure 2: Sharp versus blunt needles

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In some countries, angiocatheters are recommended for the first few cannulations in a new fistula. Although they are normally used for IV catheterization, angiocatheters may be used for cannulating fragile AVFs that have tortuous segments or irregular depths from the skin surface. Because of the flexible and dull plastic tubing, there is less danger of infiltration from arm movement during dialysis. Some programs use angiocatheters for all treatments, but high costs make this approach impossible for many centers; therefore, metal needles are used most often.[17] Angiocatheters have also been used to create buttonhole tracts by leaving the plastic catheter indwelling for extended periods, but there have been reports of this leading to infection, needle dislodgement, and catheter breakage with subsequent migration into a vessel.[20-22] The use of angiocatheters for hemodialysis in the United States is not an evidence-based standard practice, and it is unknown if such catheters can withstand required blood flow rates.

The other needle option is known as a "fistula cannula," "fistula catheter," or "plastic" needle that is designed specifically for hemodialysis cannulation. The basic design is a sharp metal needle housed within a flexible plastic sheath. The metal needle is used to access an AVF and to also guide the insertion of the plastic sheath into the vessel. After the sheath is deployed into the vessel, the metal needle is removed, and only the flexible blunt sheath is left within the vessel.[17,23] Fistula cannula needles are not currently available in the United States. Figure 3 is an example of a fistula cannula needle.

Figure 3: Fistula cannula needle (also referred to as a fistula catheter needle or a plastic needle)

a) Only the tip of the metal needle is exposed for insetion when the plastic cannula has not yet been deployed.

b) After insertion of the plastic cannula into the vessel, the metal needle is retracted into the automatic safety device; only the plastic cannula remains in the vessel. The photo shows the metal needle partially retracted.

Studies have been conducted to investigate whether use of a plastic needle can allow earlier access of the fistula. In one retrospective study, 20 patients with AVFs were cannulated with fluoroplastic dialysis catheters within 30 days after access creation and were compared with 19 historical controls. Hematomas occurred in 5 study patients (25%) and in 6 controls (31.6%), p = 0.648, with a total of 12 hematomas in 6 patients during 250 dialysis sessions, and 1 hematoma occurring in each of 5 patients during 299 hemodialysis sessions, p = 0.035. The estimated primary functional fistula survival at 3, 6, and 12 months was 95, 90, and 74% for the study group, and 79, 67, and 60% for the control group (p = 0.106), respectively. The investigators concluded that plastic needles facilitated safe cannulation during AVF maturation because it was an easy method for decreasing the risk of infiltration. They further concluded that expert cannulation under optimal conditions (eg, the same nephrologist who creates the AVF also uses and monitors it) with plastic needles may possibly decrease or even obviate the need for a hemodialysis catheter.[23]

Studies between 1977 and 2002 revealed a high non-maturation rate after creation of primary AVFs, with an average early failure rate of 25% (range of 2-53%).[4] In 2008, Dember et al found that only 40% of newly created AVFs were suitable for dialysis at 4-5 months after surgery.[24] It has been proposed that this high rate of fistula failure could be due to the large number of comorbidities found in an aging hemodialysis population with fragile vessels.[25] Aside from failure to mature as a cause of early AVF failure, infiltration during cannulation is a frequent problem in the US.[9] Lee et al described possible causes for this: significantly high turnover in dialysis nurses; cannulation by patient care technicians; staffing ratios of RNs to dialysis patients being much lower in the US as compared with Europe; and, dialysis being performed exclusively with metal needles.[9,26] In Japan, Canada, and some European countries, fistula catheters are also available, and these may lessen the risk for infiltration when new fistulas are cannulated.[9] The new DOPPS 5 data (2012-2014) indicate that times to start AVF cannulation continue to be longer for US hemodialysis centers than those in all other DOPPS countries. Earlier DOPPS I data (1996-2001) from Rayner et al showed that the US had the longest times to first AVF cannulation (median of 98 days, compared with 25-96 days in Japan and European countries).[27,28]

Early AVF failure leads to dependence on hemodialysis catheters and increases the risk for infection and other complications; therefore, a needle option that can potentially reduce these risks is highly desirable.[10,29,30] However, more studies are needed to determine if and how catheter-encased needles can improve early AVF survival rates, as well as AVF patency and survival over the long term.[23]

Regardless of cannulation technique, hematomas resulting from needle infiltration are associated with increased risk of thrombosis and decreased AVF patency.[9,31] Although MacRae et al hypothesized that the significant reduction in hematoma rate with buttonhole cannulation could lead to improved AVF survival, long-term results from their randomized buttonhole trial revealed no survival benefit, along with an increased risk for infection.[31] Randomized trials comparing the buttonhole technique with plastic needle cannulation are needed to determine if plastic needles could reduce hematomas to the same degree as the buttonhole technique, but with less risk for infection and better AVF survival.

Plastic fistula cannulas/catheters may allow patients greater mobility with a decreased risk for infiltration due to the blunt and flexible lumen that lies within the vessel. This is especially important for agitated patients, and older and frail patients who cannot tolerate immobilization during dialysis, as well as for nocturnal hemodialysis and other modalities that require more frequent weekly cannulations.[23] The flexible catheter may also make it safer to access the cubital fossa and tortuous vessels, thus increasing the number of potential sites for cannulation.[17]

Needle gauge

Small gauge needles (17G) are recommended for at least the first few cannulations of a new fistula. Thereafter, the gauge can be increased incrementally as the fistula matures, and if prior cannulations have gone smoothly.[1,32] Smaller gauge needles have a greater resistance to flow, thus requiring a slower blood flow rate of 200-250 ml/min.[7,16,33] Table 1 lists maximum blood flow rates according to gauge. Gauge is defined as the needle shaft's outer diameter, while the inner diameter also depends on the thickness of the needle wall.[34,35] Standard gauge sizes range from 14G to 18G (outer diameter 2.1 and 1.2 mm, respectively).[36] If the wall of a metal needle is thinner, then the inner diameter of lumen will be larger in relation to the outer diameter. The larger the inner diameter, then the higher the blood flow rate that can be achieved under the appropriate pressure conditions. There is some concern, however, that a higher blood flow can negatively affect AVF survival. Therefore, the influence of needle size on AVF patency continues to be debated.[37]

Choice of gauge may be based on AVF vintage and expansion, patient tendency for bleeding, and patient preference.[34] Except for the initial cannulation, most guidelines do not recommend a specific gauge, but rather that the needle gauge match the blood flow rate.[38] Pre-pump arterial pressure monitoring provides necessary information for correct gauge selection; if the arterial pressure falls lower than -200 to -250 mmHg, then the needle gauge may be changed to accommodate better flow. Changes in gauge require a physician's order because of the impact on blood flow rate and the hemodialysis prescription.[39] Be aware of package labeling regarding gauges, as they vary among manufacturers. For some, the size listed for catheter-encased needles corresponds to the central metal needle: a 16G catheter houses a 16G metal needle (outer diameter); after the metal needle is removed, the lumen for blood flow is approximately one gauge larger than listed on the package.[34] For other cannulas, the gauge listed matches the inner diameter of the plastic cannula.

Table 1. Matching gauge and blood flow rate

Blood flow rate (BFR)	Recommended needle gauge
<300 ml/min	17 gauge
300–350 ml/min	16 gauge
>350–450 ml/min	15 gauge
>450 ml/min	14 gauge

Note: It is important to match needle gauge to blood flow rate. These are minimum recommended gauges for the stated BFR settings. Larger needles, when feasible, will reduce pre-pump arterial pressure and increase delivered blood flow.

Reprinted with permission from: The End-Stage Renal Disease National Coordinating Center (ESRD NCC) Fistula First Catheter Last (FFCL) Workgroup Coalition. Fistula First Initiative: cannulation of new fistula policy and procedure. Available at: http://fistulafirst.org/2014. Accessed December 2, 2015.

Needle length

Different needle lengths are available: ¾" and ⅜" can be used in fistulas that are <0.4 cm below the skin surface; 1" for fistulas 0.4-1 cm from the skin surface; and 1¼" for fistulas ≥1 cm from the skin surface.[17,39] To prevent needle penetration into the back wall of the vessel, the shortest needle length should be used. But in order to reach deep AVFs, such as those found in the upper arm of an obese patient, a 1¼" needle may be needed.[39] Standard metal AVF needles are 1" long, but shorter ⅜" AVF needles may be better for advancing completely into a shallow new fistula.[40] Plastic cannula needles are available in lengths up to 38 mm, which is close to 1½". Appropriate needle length of all needle types can be determined by the dialysis nursing staff.

Back eye

The arterial needle should always have a back eye to maximize flow from the access. Optimal flow prevents suction of the needle to the inner vessel wall and reduces the need for rotating the needle, which adds trauma to the AVF.[1,16] And if the bevel of the needle does adhere to the vessel wall, blood flow through the bevel is not compromised. The back eye should be smooth and flat so that its rim does not cut into the vessel during needle insertion or withdrawal.[17] The plastic lumens of catheter-encased needles also have side holes to improve flow and to prevent vessel wall occlusion.

Other features to consider

Needles are available with different features that may add to patient comfort and safety, as well as clinician safety and ease of use.

- Biocompatibility should be considered if patients exhibit any allergic response to materials from the metal or tubing, and for the same reason, one might consider the sterilization method.
- Rotating hub needles to allow rotation of the bevel without moving the needle wings[41]
- Wings for a secure grip and flexibility in achieving different angles for entry into the vessel and for securing the needle; rotatable wings may offer more flexibility in positioning the needle without stretching the vessel
- Mechanisms to prevent blood back-flow
- Mechanisms to check for blood flashback
- Clamping tube
- Single-needle tubing configurations for single-needle dialysis
- Needle retraction mechanism for overall functionality and ease of use to prevent needle sticks

NEEDLE OPTIONS FOR SELF-CANNULATION AND NOCTURNAL HOME HEMODIALYSIS

Self-cannulation

In general, the rope ladder technique is used with an AVF that has acceptable length and depth. This technique may also be preferred for patients who have low vision or a tremor. The buttonhole technique can be considered in patients who have an AVF with inadequate length, tortuous anatomy, or aneurysmal segments. Patients with a needle phobia may also benefit from the buttonhole technique, but due to its increased risk for infection, this technique is not recommended for patients with a history of AVF infections, mechanical heart valves, or other prostheses.[20]

In countries where fistula cannula needles are available, patients can self-cannulate either with plastic cannulas or with standard sharp needles when using the rope ladder technique, or, with blunt needles when using the buttonhole technique.[20] In the US, the current choices are sharp or blunt metal needles only.[41]

Nocturnal home dialysis

Where available, flexible plastic cannula needles are used for comfort and to prevent needle infiltration during nocturnal home dialysis. This type of needle should be considered for use in:

- Patients allergic to metals
- Restless patients at risk for needle infiltration
- Nocturnal home dialysis patients using the rope ladder technique[20]

A blunt metal needle can also be used with the buttonhole technique to prevent needle infiltration during treatment. Sharp metal needles for nocturnal dialysis are not preferred due to the potential for needle infiltration during treatment. If sharp metal needles are used however, it is critical that they be well secured.[20]

SUMMARY

Just as cannulation technique needs to be individualized, so too should needle selection consider individual patient risk factors, needs, and preferences. Through the interdisciplinary care approach and guidance from a vascular access nurse, many quandaries related to cannulation, including appropriate needle choice, can be solved. Cannulation technique is a primary driver of needle choice, but there are many other variables as discussed. Consider the number of cannulations needed for more frequent dialysis modalities, as well as the patient's potential for frequent and erratic movement, their pain threshold and body image, and whether or not they self-cannulate. Considering these factors will help clinicians in delivering individualized patient-centered care.

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