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Review

Optimizing vascular-access device decision-making in the era of midline catheters

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Abstract

This narrative review addresses vascular access device choice from peripheral intravenous catheters through central venous catheters, including the evolving use of midline catheters. The review incorporates best practices, published algorithms, and complications extending beyond CLABSI and phlebitis to assist clinicians in navigating complex vascular access decisions.

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The most common invasive procedures among hospitalized patients are performed to obtain vascular access.[1] Most hospitalized patients have at least a peripheral venous catheter.[2] Millions of intravascular catheters are placed every year; they incorporate an ever-increasing variety of vascular technologies combined with multiple published recommendations and guidelines.[2–5] Common vascular access devices (VADs) include peripheral intravenous catheters (PIVs), midline catheters, peripherally inserted central venous catheters (PICCs), centrally inserted central venous catheters (CICCs), tunneled central venous catheters, and ports.[3,4,6] PICCs, CICCs, tunneled catheters, and ports comprise the VAD category of central venous catheters (CVCs).

For healthcare providers, the variety of intravascular catheters can be confusing, which can create unintentional difficulty in choosing the correct VAD for the patient.[5] This level of variety also results in an increased need for vascular access skills, resulting in the development of vascular access as a multidisciplinary medical specialty.[2] Ultimately, the goal is to provide the right vascular access option for the patient's clinical needs in a way that maximizes the potential benefit while minimizing the inherent risks of vascular access.[4,5]

Why is optimization of VAD choice critical?

With the varying options of VADs and anatomical locations available, providers must consider the clinical indications for intravascular access as part of the decision-making process: certain medications, hemodynamic measurements, or monitoring; anticipated duration of use; individual patient characteristics and comorbidities; and potential target vessels.[1,6,7] CVC indications and medications for infusion should adhere to guidelines and institutional policies.[8] Medications that can be given via a PIV can be given through a midline catheter, including antimicrobials, to avoid PICC placement for courses of therapy that do not exceed 4 weeks. (Duration of therapy is discussed below.) Figures 1 and 2 provide institutional examples of indications for CVC placement and appropriate medications for infusion requirements.

When feasible, current guidelines recommend that catheters in adults be placed in the upper extremity or upper torso to decrease risk of infection.[3] Consideration of each patient's unique clinical scenario, anatomy, and the viability of vascular targets are of paramount importance in choosing the optimal location for any catheter because insertion risks vary for each situation. Examples of possible complications include an increased risk of pneumothorax with placement of a subclavian or an internal jugular CVC compared to a femoral vein insertion site. Conversely, an increased risk of infection accompanies catheters inserted in the femoral vein compared to the upper body.[1,3] Patients with difficult venous access may be candidates for early placement of a non-PIV catheter, such as a midline catheter.[7,9] More detail on potential complications is provided in the following section.

Today, these risk–benefit considerations must extend to the choice among a PIV, a midline catheter, a PICC, a tunneled catheter, or a port.[4,6] All VADs carry potential risks of infection, thrombosis, thrombophlebitis, and vascular injury, among others.[6,9] The duration of anticipated need for access, patient characteristics, and the inherent risks of each catheter type should be considered.

Duration of vascular access can be classified into short term, medium term, and long term, with some potential overlap.[1,4] Generally speaking, short-term catheters include PIVs and nontunneled CICCs, medium-term catheters include midline catheters and PICCs, and long-term catheters may include PICCs, tunneled catheters, and ports.[1] Short-term devices are those needed for <6–10 days; thus, a midline catheter or PICC should be utilized instead of a PIV for patients with an expected duration of intravenous access requirement extending beyond 6 days.[1,3,5,7,9,10] Additionally, PICC placement for phlebotomy access or intravenous administration of <6 days is considered inappropriate according to the Michigan Appropriateness Guide for Intravenous Catheters (MAGIC).[4]

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Indications for CVAD Placement

Inadequate Peripheral Access
- 3 failed peripheral attempts by 2 persons (total) ***—2 experienced persons, not learners — by experienced operators — PICC/SWOOP/Lead***
- Agreement by 2 persons of inadequate peripheral veins

Treatments
- Plasmapharsesis
- Apheresis
- Emergent hemodialysis access
- Continuous renal replacement therapy
- IL2
- Therapeutic hypothermia
- Therapeutic active warming for which CL access is required

Emergent Intervention
- Transvenous cardiac pacing
- ***Shock***
- ***Rapid Massive Transfusion***

Hemodynamic Monitoring
- CVP monitoring
- Pulmonary artery catheter
- Introducer for one of the above

Medications
- Anticipated length of IV antibiotic or other medication therapy ≥6 days
- Antineoplastic medications
- Complex IV therapies including need for multiple IV meds/fluids
- See Table 1 for medications that are commonly administered via a central line
- ***Required for surgery by nature of surgery — i.e., excessive blood loss***

Fig. 1. Nebraska Medicine Indications for Central Venous Catheter Placement (submitted as figure).

Please consult the medication order administration instructions for information regarding which medications should be infused via a central line only.

In general, the following medications are infused via a central venous catheter.*
(Most other medications (NOT on the table below) can be infused via a midline or a peripheral line.)

Amiodarone Concentrations >2mg/mL	**Calcium chloride (central line or deep vein preferred)**
Dextrose >20% (in emergent situations peripheral administration may occur in concentrations up to 50%)	**Epoprostenol**
Hypertonic saline (*recommended* for 3% and <u>required</u> for 7.5% and 23.4%)	**Potassium concentrations >0.1 mEq/mL**
most TPNs (some with lower concentrations can be given peripherally)	**Vasopressors (central line preferred):** Dopamine, epinephrine, norepinephrine, phenylephrine, vasopressin
Vesicant infusions > 60 minutes Dactinomycin, daunorubicin, doxorubicin, epirubicin, idarubicin, mechlorethamine, mitomycin C, trabectedin, verteporfin, vinblastine, vincristine, vindesine, vinorelbine	

***This list is not all inclusive and may change. Consult the MAR, Lexicomp, and/or a pharmacist if there are questions.**

*MAR: medication administration record

Fig. 2. Nebraska Medicine Infusate Indications for Central Venous Catheters (submitted as figure).

Midline catheters have become an increasingly viable option for administration of intravenous medications (including antimicrobials) to outpatients, with a maximum duration of midline indwell time of ~4 weeks (based on individual manufacturer recommendations), although some guidelines suggest limiting use after 14 days.[4,9,10] For central venous access requiring >6–10 days, PICC lines are often considered first as a medium-term option if the intended duration is weeks to months.[1,4,10] Tunneled lines and ports are considered long term, with durations of months to years, and ports are considered less intrusive on a patient's lifestyle than tunneled lines.[1,4]

With any venous access device, the catheter diameter and number of catheter lumens necessary for medical care must be considered. Both diameter and lumens must be minimized to decrease the risk of complications, including infection and thrombosis.[1,3,4]

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What are the complications of device choice?

Venous access is a cornerstone of medical therapy, and similar to other therapy, it can have unintended consequences and complications. Each type of device for venous access has different risks and benefits. Complications include bloodstream infections, thrombosis, thrombophlebitis, venous stenosis, as well as various types of mechanical injury.

Related literature has shown that CVCs have a rate of all complications of ~1%–32%, with lower rates reported among experienced inserters and with image guidance.[1,6,9–11] Mechanical complications are more frequent when a subclavian approach is used for a CICC than when femoral or internal jugular venous catheters are used, and the subclavian CICC approach is particularly associated with the risk of pneuomothorax.[1] If it is necessary to perform multiple percutaneous punctures, the rates of mechanical complications increase significantly.[12,13] When placing a CVC, it is also important to consider the depth to which the guidewire is being placed; longer catheter and guidewire insertions have resulted in cardiac arrhythmias or direct cardiac trauma.[1] All CVCs carry additional potential risks of arterial or venous injury and air embolism, thus demanding expertise and best-practice adherence during insertion, maintenance and removal.[1] PICC lines however, given the peripheral venous puncture, carry a lower risk of mechanical complication during insertion compared to CICCs.[5] Inherently, midline catheters and PIVs do not enter the torso, central veins, or the heart; thus, these devices avoid many of these risks.

Another mechanical complication critical to consider in VADs is the potential development of venous stenosis. A study assessing stenosis due to placement of both PICCs and CICCs found the incidence of stenosis to be about 7% of all insertions.[14] Central venous stenosis has been observed as early as 4 days following insertion, although the duration of catheterization increases the likelihood of the stenosis as well.[14] This complication limits future potential arterio-venous fistulae creation among patients with acute or chronic kidney disease who may require future dialysis.[1,5] Notably, although midline catheters can potentially result in vascular damage, they do not result in central venous stenosis; therefore, they may not result in full loss of potential for future arterio-venous fistulae.[4]

The most common complication seen with PIVs is thrombophlebitis. Several studies have indicated that the process of thrombophlebitis could be mechanical, infectious, or possibly chemical from the infusate through the PIV.[15,16] The rates of thrombophlebitis from PIV also vary, with estimations ranging from 2% for catheterizations up to 80%.[5,16] Some of this variance may be due to the broad array of anatomic sites use for peripheral venous access, including hands, antecubital fossae, limbs, feet, and other locations.[17] PIVs cause thrombophlebitis at a higher rate than that of CVCs.[18] One study found the rate to be ~10 times higher than the rate in CICCs (78 vs 7.5 per 10,000 indwelling days).[18] Rates of phlebitis among midline catheters are similar, and possibly higher, than those of PIVs.[3,7,9,10,19,20]

Two specific concerns frequently raised regarding the utilization of midline catheters are (1) whether there is an increased risk of complications compared to other vascular catheters and (2) whether vancomycin specifically can be given through a midline. Midlines are noted to have decreased rates of phlebitis and bloodstream infection compared to PIVs and PICCs/CICCS, respectively.[3,10] However, among complications considered minor or mechanical (eg, pain, leaking, edema and nonpatency, among others) midlines had a higher rate of complications (2.6%–11.5%) than that of PICCs (1.5%) and CVCs (0.3%), but the overall event rate remains low.[7,19–21]

Historically, certain antibiotics have been considered as indications for CVC placement due to pH or vesicant properties. Vancomycin infusions with a pH < 5 have frequently been called into question, including a 2011 Infusion Nursing Standards of Practice stating that infusions with a pH < 5 or >9, should be given via a CVC.[5,10,22] However, more studies are confirming that infusion of vancomycin via midline catheters is safe for most patients, and in some instances, may even be protective against phlebitis.[10,19,23] A prospective, nonrandomized study of 153 surgical patients receiving vancomycin versus other antibiotics via peripheral intravenous catheters revealed no statistically significant difference in phlebitis.[24] Caparas et al[10] demonstrated in a single-center, prospective, randomized controlled trial that short-term vancomycin (<6 days) infusions were not associated with a statistically significant increase in complications, including phlebitis and thrombosis, among novel midlines compared to PICCs. In a follow-up of these results, the institution removed pH as an absolute indication for central venous access and subsequently published an observational study demonstrating no thrombosis or phlebitis among 24 patients receiving vancomycin infusions via a midline catheter for >6 days (range, 6–23).[23] A 5-year retrospective study of vancomycin through a midline also demonstrated no (DVTs), rare phlebitis (0.6%), and no extravasation injuries among 1,086 patients who received vancomycin infusions via midline catheters.[25]

Additional benefits include findings that infusion of vancomycin via midlines has been associated with decreased overall cost compared to PICCs.[9,10] In a 2015 article in the *Journal of Infusion Nursing*, Gorski et al[26] performed a literature review regarding the pH criteria for CVC placement and concluded that "pH alone is not an evidence-based indication for central line placement."

In 2016, the updated *Infusion Therapy Standards of Practice*, removed pH < 5 as a criterion for requirement of central venous access.[27] In 2017, the Infusion Nurses Society (INS) published the results of a taskforce addressing vesicant medications; the following antimicrobials were removed from the INS vesicant list: amphotericin B, ampicillin, cloxacillin, doxycycline, gentamicin, metronidazole, oxacillin and penicillin.[28] Retained on the vesicant list as having intermediate risk are acyclovir, nafcillin, and vancomycin. However, the guidelines also note that each facility should develop a consensus on what is considered a vesicant based on organizational formularies and recognizes that a VAD choice should "generally not be based on a single factor, such as the medication or solution category of vesicant or irritant."[28]

Catheter-related infections are a significant burden on the healthcare system in patient morbidity, increased length of stay, and increased financial burden.[3,29,30] Incidence does appear to be decreasing, although >80,000 catheter-related line infections still occur each year in US ICUs, and as many as 250,000 such infections occur annually among hospitalized patients.[3,5] The incidence rate of catheter-related infection varies due to several different factors, including possible nonmodifiable patient characteristics, such as patients who are immunocompromised and/or have skin or mucosal membrane integrity breakdown due to medical conditions, trauma, and burns. Infusions with lipid formulations may also increase the potential risk of infection. The rate of infection changes based on location of insertion and duration of catheterization indwell time.[1,3,5] One 2010 study showed the overall incidence density rate of catheter-related bloodstream

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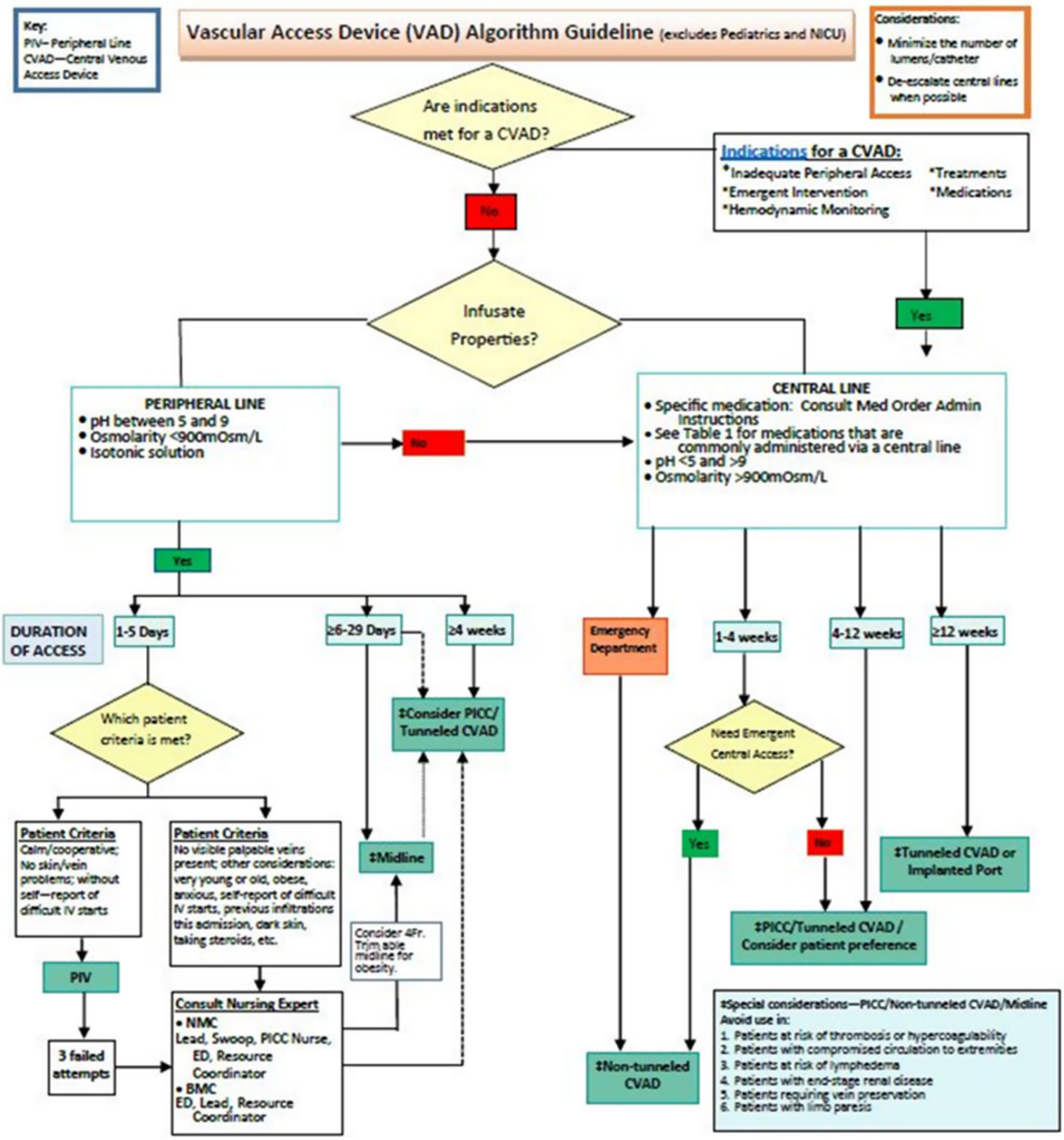

Fig. 3. Nebraska Medicine vascular access algorithm.

infections to be 1.3 per 1,000 catheter days.[30,31] The rate of CICCs has been shown to differ over time, with older studies demonstrating differences in catheter-related bloodstream infections based on anatomical site of insertion (comparing internal jugular, subclavian, and femoral veins); however, more recent data suggest no difference.[5,8,32,33] Avoiding the femoral vein as a method to prevent infection, particularly among the obese, is still recommended.[5,8] The effect of the type of CVC on catheter-related infections has been mixed, and multiple studies have shown that PICCs have similar rates of catheter-related infection as CICCs, particularly in hospitalized patients. Thus, PICC placement should not be used as a primary methodology to decrease CLABSI rates.[5,8,10,34,35] Catheter colonization is a risk for bloodstream infection that is time dependent; the longer the catheter remains in place, the higher the risk of colonization.[36] Catheterization time is thus critical because catheter hub colonization is associated with bacteremia.[37] Due to colonization risks, disinfection of catheter hubs is also recommended before accessing any catheter.[3,8]

Previous studies have indicated that the rate of infection with PIVs was 0.1%.[29] Current literature examining PIVs continue to show rates of 0.1%–0.2%.[15] Midline catheters have a slightly higher incidence of bloodstream infection of ~0.2%–2.5%, although several recent evaluations of midline catheters have found varying results, including lower and similar rates of midline-related

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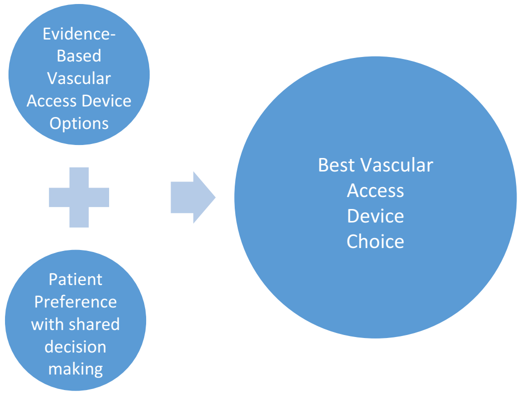

Fig. 4. Diagram of shared decision making.

bloodstream infections as PIVs.[5,9,10,19–21] Compared to PICCs and CICCs, however, midline catheter programs have resulted in decreased overall CLABSI rates.[5,7,21]

All catheters carry a potential risk of thrombosis, although the risk appears to vary by both catheter, anatomic location, and patient characteristics. Up to one-third of patients with CICCs may develop thrombosis, with potential increased risk with femoral and subclavian placements, although this is not consistent in all studies.[1,33] PICCs, compared to CICCs are associated with increased thrombosis in some studies, potentially at least in part due to the longer possible duration of use.[1] A meta-analysis by Chopra et al[38] placed the overall risk of PICC-related DVTs of 2.7%, which was significantly greater than for CICC.[38] This risk increased in critically ill patients and those with malignancies. Although the risk of catheter-related DVT increased with PICCs, the same study did not find and increased risk of pulmonary emboli with PICCs.[38] Some studies have indicated a correlation between diameter size of catheters and risk of thrombosis, but this has not been clearly defined by all studies.[14,39] Compared to PICCs, midline catheters have been reported to have lower overall rates of associated thrombosis in some, but not all, studies.[9,21]

Patient dissatisfaction should also be considered a potential complication in today's healthcare arena. Decreasing the number of needle sticks noted with catheters is a potential area for improved satisfaction.[9] A decreased rate of attempted PIV cannulations with implementation of a midline catheter program has been reported.[7,9] Patient satisfaction was directly affected by complications from central venous ports, and not the cosmetic appearance of the port.[40] Patients who receive PICC lines are more satisfied with a PICC if it is placed above the elbow than at the elbow.[41]

How, in the face of the complexity of vascular access options and potential complications, can frontline clinicians make the best possible decisions for their patients?

Several opportunities exist for improved decision making; they include, but are not limited to, implementation and utilization of a multidisciplinary vascular access team, continued education and training regarding device choice and use, guidance through algorithms and policies, intelligent decision-support tools and ongoing quality improvement processes.

Vascular access as a specialty continues to evolve, with its own consensus statement on scope of practice from the national society (the Association for Vascular Access) speaking to the complexity of the practice from the time of device choice through removal of the catheter.[2] Vascular access teams exist at many institutions to assist with decision making, to maximize efficiency, and to perform maintenance on many different catheter types and insertion sites. However, such teams are frequently only focused on the placement and maintenance of PIVs, midlines, and PICCs.[4,5,7,8]

For organizations without a vascular access team, ongoing education regarding VADs and their inherent risks and benefits combined with procedural training on insertion, maintenance, and removal seems intuitive, yet with the changing landscape of device options, education remains of paramount importance.[3,6,8] Further opportunities include standardization of care through implementation of algorithms to provide guidance on VAD choice based on institutional guidelines and best practices (Figure 3).[5,8] Implementation of a robust midline program has been associated with both decreased complications, specifically CLABSI, combined with decreased overall cost.[7] Finally, with the evolution of the electronic medical record and innovative technology in the healthcare sector, implementation of intelligent, integrated decision support for vascular-access decision making may be an appealing future option to help guide clinicians at the time they are placing an order.

In medicine, the dogmas of 'do no harm' and 'the patient comes first' echo throughout the halls of many of our institutions. Given that these principles remain of paramount importance when considering the best vascular access choice, discussion of options, benefits and risks, with the patient, when feasible, should always be undertaken.[4] Formally, this process is that of shared decision making and when combined with evidence-based medicine, provides the optimal opportunity for the best possible outcomes (Figure 4).[42] Intuitively, we consider shared decision making to be aligned with the informed consent process, but they are not the same. Informed consent is obtained prior to placement of CVCs, but not routinely obtained for PIVs. Midline placement may or may not require consent, potentially varying between institutions. Not all guidelines or recommendations discuss patient preference in vascular access decision making, but overall satisfaction of patients may increase when they are involved in the discussion and adherence to maintenance recommendations may increase as well.[4,7,42]

Finally, all vascular access programs should have ongoing quality assessment and improvement projects with target rates for complications to provide a benchmark for ongoing performance improvement.[1,3,6,8] This may include ongoing educational updates, simulated training, competency assessment, and audits to assess compliance.

Choice isn't everything: Best practices are needed for line insertion, maintenance, and removal

Optimal management of an intravascular device requires a multidisciplinary effort from the time the decision is made to place a device until after it is removed.[3,8] Best practices for catheter insertion, securement, and maintenance of the catheter, dressing, and catheter connectors is crucial to preventing complications.[3,4,8] Breaks in aseptic insertion technique raise particular concern for increased risk of infection; therefore, catheter change should be considered once the patient is stabilized. Appropriate maintenance of dressings to prevent infectious and mechanical complications is necessary, yet deficiencies and variation in both securement and dressing of all catheter types (PIVs to CVCs) may occur in ≥30% of hospitalized patients.[17,43] Education, situational awareness, and skills competency for catheter maintenance among

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healthcare workers may improve the quality of care and thus prevent complications. Discontinuation of unnecessary intravascular catheters is the final critical point in providing the best possible vascular access care for patients.[1,4,8] Midline catheters have been used as a way to "de-escalate" from a CVC in some populations.[10] Because midline catheters do not "count" as a CVC and infections associated with midlines are not reportable, we must resist the temptation to use midlines inappropriately or exchange one set of reportable complications for another set of unreportable complications. Prompt catheter removal may be complicated by lack of physician and team recognition that a CVC remains in place.[4] Therefore, catheter surveillance systems and clinician reminders should be in place to better ensure appropriate CVC use and removal.

Vascular access, with its dizzying array of potential device choices compounded with varying risks for complications, requires a systematic approach to optimize device choice for each patient based on clinical indications, anticipated duration of therapy, risks and benefits of each catheter and anatomic option, and finally, patient preference. Institutional development of algorithms or decision-support tools is recommended in conjunction with ongoing education, vascular access expertise, and continual process improvement. Improved vascular access decision making is a critical need, especially with evolving midline utilization, to decrease risks, complications, and costs while improving care and patient satisfaction.

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