Decision-Making for Emergent Vascular Access

11

James H. Paxton and Alexandra Lemieux

Introduction

Decision-making on emergent vascular access can be challenging, even for the most experienced provider. As mentioned in previous chapters, many factors must be considered when deciding upon which type of vascular access device (VAD) to use, including patient-specific, provider-specific, environmental, and time-related factors. Despite these challenges, it is still possible for providers to develop *a structured, systematic approach to their own decision-making* regarding establishing vascular access under emergent conditions. This chapter will outline some of the existing evidence on how to select the right VAD for a specific patient, operating under the assumption that providing vascular access in an emergency differs from providing access under other clinical circumstances.

The first and most crucial step in deciding upon the proper VAD for use under emergent circumstances is making an *accurate and rapid assessment of the circumstances* surrounding that decision. The ability to make such assessments constitutes a unique skill set that emergency care providers will develop over time and with proper training. While it is possible to establish guidelines and policies relating to the use of VADs for specific patient populations and circumstances, even the most comprehensive clinical guidelines cannot account for all possible situations. Consequently, decision-making in emergent vascular access is as much an "art" as a "science." Like all artists, providers of emergent vascular access will bring their own unique talents, perspectives, and understanding of the patient's clinical

J. H. Paxton (✉)
Department of Emergency Medicine, Wayne State University School of Medicine, Detroit, MI, USA
e-mail: james.paxton@wayne.edu

A. Lemieux
Wayne State University School of Medicine, Detroit, MI, USA
e-mail: fh1310@wayne.edu

J. H. Paxton (ed.), *Emergent Vascular Access*,
https://doi.org/10.1007/978-3-030-77177-5_11

condition and circumstances to the task. In this chapter, we will provide some of the tools needed to make the "right" decisions for patients, although the final solution will always be dependent on providers' ability to recognize when and how to use those tools.

Have a Game Plan

Providers should *develop a vascular access "game plan*" before starting the first vascular access attempt. This might be a simple mental algorithm that the provider has used on innumerable previous patients, but should include next steps that the provider will take if preceding approaches are unsuccessful, and must be able to be quickly adapted to changing circumstances. Under stressful and time-limited conditions, providers should have at least a rough sketch of this game plan going into the encounter, with the understanding that the plan will be modified as conditions change. This may help to prevent bad decision-making "in the heat of the moment" and should enable providers to gather the anticipated resources prior to needing them.

One example of such a game plan might be: "Try for a visualized/palpable vein large-bore peripheral IV in the upper extremity. If no PIV is established after two attempts and the patient is stable, consider US-PIV. If the patient is unstable, establish a proximal humerus IO or EJ PIV." Establishing such a vascular access plan *a priori* provides a cognitive framework for the provider that will facilitate rapid transition from one failed effort to the next sequential step, without requiring a cognitive pause on the part of the provider. This type of cognitive unloading should help the provider to focus upon the task at hand, rather than subconsciously (or consciously) worrying about what the next step should be. Most providers who are involved in establishing emergent vascular access on a regular basis already have a mental algorithm that they use regularly, even if they don't recognize it. For those who do not yet have one, efforts to develop such a mental algorithm should help to enhance efficiency and increase the likelihood of successful line placement.

Environmental Limitations

Before considering patient- or provider-specific circumstances, it is important for providers to *accurately assess the environment that they are working in*. Importantly, a provider's environment is not only the *physical space* in which the provider is working, although this is an important aspect. Providers must also consider what local tools and resources are available to them to assist in performing their task. Austere environments (e.g., the prehospital environ) are characterized by limited access to technologies and assistance in establishing vascular access. For providers who are accustomed to working in a specific clinical environment, these limitations will be intuitively incorporated into the provider's decision-making. But individuals who are working in a new or unfamiliar environment should assess their environment carefully before establishing a plan for meeting the patient's vascular access

needs. Providers must know what VADs are available to them, including which adjunct and assistive technologies (e.g., ultrasound, vein-finding devices, etc.) may be available when needed. This includes not just knowing what tools are generally available but being aware of any shortages in stocking supplies, where supplies are kept in one's clinical space, and proactively arranging supplies in one's space (within the realm of possibility) to accommodate anticipated needs during the acute care episode. Providers should try to learn from their difficulties with prior attempts and modify future approaches to prevent those difficulties in the future. One should always hope for the best conditions but plan (and prepare) for the worst.

An accurate assessment of one's environment will help to rule in or rule out the ability to use specific types of vascular access devices or useful adjuncts. A few key questions that providers should ask themselves when assessing their environment include:

- *Where am I*? Providers who are treating a patient in a dark hallway or abandoned building should expect more austere conditions than providers working in a well-lit emergency department or inpatient hospital room. Access to adequate lighting, a crash cart, a stash of medical supplies, or other needed resources will always be dictated by the location of the intervention effort.
- *What did I bring with me*? This may be the easiest thing for a seasoned vascular access specialist to assess. Rapid response teams and prehospital providers will know exactly what is in their "pack," although those new to the emergency department or inpatient setting may not know what they have available at their fingertips, especially if they did not bring it themselves. Providers should also consider what specialized knowledge and training they bring to the patient's care. Sometimes the most valuable tool that a provider can offer to the patient is their own skill set.
- *What resources are summonable*? In any environment, it is important for providers to consider what additional resources can be quickly recruited to the vascular access attempt. Providers must know how to find what they need and which devices and adjuncts may be quickly obtained in their care environment.
- *Is assistance available?* Providers who are working alone will have fewer options, especially if the patient is unstable and requires simultaneous completion of other (i.e., non-vascular access) tasks. Optimally, the vascular access specialist should be focused on establishing vascular access, *not* providing chest compressions, transporting the patient, intubating the patient, etc. Providers must know their limits, including when to ask for help.

Clearly, many such questions about the environment are best asked and answered well before the immediate need for emergent vascular access occurs. For those who are new to the world of emergent vascular access, this educational process will be revealing. Providers should not wait until their patient is crashing to ask these questions. For those who have a long track record of providing emergent vascular access, the answers may be familiar but should bear occasional reassessment. After all, circumstances can change.

Patient Assessment

Once the provider has assessed where they are, and what resources they can quickly access, they must focus on the characteristics unique to the patient and their emergent medical condition. More than likely, these patient characteristics will not already be well-known to the provider. Unfortunately, critically ill or unstable patients may not have the time or ability to educate the provider about their medical history or previous vascular access attempts. Family members or others familiar with the patient may not be available, and medical records may be scarce or unavailable. Emergency care providers are accustomed to this dearth of information on their patients, but it may be unsettling to those less familiar with such circumstances. It is imperative that providers approach each encounter requiring emergent vascular access as objectively as possible, understanding that limited information about the patient's medical condition and past medical history are the rule, rather than the exception. Providers must be able to assess the patient rapidly, with limited information and a critical eye toward how they can achieve your primary objective – to establish vascular access quickly and with a minimum of risk to the patient.

Although each patient's needs are different, providers can still employ a systematic method of patient assessment when establishing emergent vascular access. The experienced provider will begin their assessment even before they have examined the patient. The patient's *ability to assist and comply* with vascular access attempts should be evident within seconds of meeting them, including behavior or exam findings that suggest limiting circumstances such as intoxication, agitation, diminished mental capacity, cardiac arrest, and uncontrollable movement. Such global patient factors will dramatically change the provider's approach, and providers should have a "go-to" approach for managing uncooperative patients that will likely differ from the approach taken with a cooperative patient.

If the patient is awake and able to communicate, important information may be obtained very rapidly from the patient within seconds. When feasible, patients should be *asked about their own vascular access preferences* as well as their self-reported contraindications to considering specific insertion sites and/or modalities. Compliance with vascular access attempts among alert patients may be enhanced by consulting the patient on their VAD preferences. The discovery of relevant physical exam findings (e.g., hemodialysis fistulas, venous scarring, small-caliber veins, etc.) may also be accelerated by simply asking the patient about the success or failure of previous vascular access attempts or access sites that they believe to be "off-limits" to providers.

Unfortunately, hemodynamically unstable patients may be uncooperative and/or unreliable historians. Even stable patients have myriad reasons for not complying with vascular access attempts, including the presence of alcohol or other intoxicants, acute psychiatric illness, dementia, or agitation due to pain and anxiety (just to name a few). When assessing an unstable patient, providers should be prepared for the likelihood that the patient will not be able to provide any helpful information during the assessment, and they may even fight one's efforts to establish adequate

vascular access. Any other baseline assumption is counterproductive. Understanding this, *providers should approach the patient encounter expecting to intuit their way through the process, including a strong reliance on physical exam findings and circumstantial evidence*. Input from the patient, though valuable and worth seeking, may not be forthcoming.

Before anchoring upon a specific VAD insertion site or device, the provider should perform a brief but adequate physical examination of the patient. The purpose of this examination is to *identify the presence of physical characteristics that could influence the provider's choice of site and device* in forthcoming vascular access attempts. A systematic approach is of value here. The provider should expose the patient by removing clothing and other obstacles to full evaluation of their upper extremities, chest, and neck. The patient should be examined for surgical scars or evidence of repeated venous access attempts, as well as extremity swelling or soft tissue patterns that could make cannulation unlikely. The presence of an active hemodialysis fistula or graft will alert the provider to this important limitation, as venous access should not be performed on the same extremity, to preserve dialysis access. Although nonfunctional (e.g., clotted and unsalvageable) hemodialysis sites may be considered for venous cannulation under austere circumstances, it is always preferred to avoid cannulating an extremity with altered anatomy, and the contralateral extremity should be considered first. If the salvageability of the hemodialysis site is unknown to the provider (as is often the case), providers should assume that the extremity is off-limits. For cardiac arrest patients, especially when IO access may be required, it is important to examine both the shoulder and knee joints for surgical scars as joint surgery is a relative contraindication to placement of an IO catheter at that location. Providers should look for long-bone fractures or joint dislocations, to avoid placing an IV or IO on the same extremity as an acute orthopedic injury or disruption of the bony cortex. Acute orthopedic injuries may compromise venous/lymphatic drainage from the extremity. Mastectomy scars may suggest that IV or IO placement should be avoided on the ipsilateral upper extremity due to potentially impaired lymphatic drainage following previous lymph node dissection. These and other contraindications to specific insertion sites can help the provider to immediately rule out certain access points, allowing the provider to prioritize available appropriate insertion sites in their placement algorithm.

An "*anatomic inventory*" (Table 11.1) can provide one means of rapidly assessing the emergent patient's physical state as it relates to potential vascular access sites. This type of approach will quickly identify key anatomic considerations that may compromise the patient's ability to receive specific device types or vascular access sites.

The key component of such an anatomic assessment is the provider's ability to rapidly evaluate the patient and identify key physical examination findings suggesting which vascular access sites and devices may be compromised for the patient.

When assessing a patient's vascular access needs, providers should also attempt to predict how the VAD will be used during the patient's subsequent care. In the acute setting, it may be necessary to establish "bridging" access to stabilize the patient's condition while appropriate definitive vascular access is being attempted.

Table 11.1 Anatomic inventory for rapid assessment of vascular access obstacles

Anatomic finding	Key obstacles	Types of VAD compromised
Altered mental status	Inability to follow commands or comply with assessment and VAD insertion effort	PIV, CVC, IO
Unstable vital signs	Venous collapse, reduced pulse perception	PIV, CVC
Cardiac arrest	Venous collapse, impaired circulation, extremity movement, chest compressions	
Neck scarring	Central venous collapse, venous obstruction	CVC
Extremity scarring	Peripheral venous collapse, venous fragility	PIV
Surgical scarring at joints (e.g., shoulder, knee)	Distorted bony landmarks, disrupted drainage from intraosseous space	IO
Traumatic orthopedic deformity	Soft tissue swelling, disrupted bony cortex, distorted anatomy, impaired venous drainage	PIV, IO
AV graft or fistula	Need for dialysis site preservation, distorted anatomy, impaired blood flow	PIV
Rash or cellulitis	Risk of infectious complications	PIV, IO
Extremity edema	Obscured anatomy, impaired venous drainage	PIV, IO
Pre-existing access (e.g., PICC line, PIV line, etc.)	Need to preserve long-term vascular access, questionable functioning of existing device	PIV, IO, CVC
Isolated diminished extremity pulse	Impaired blood flow, increased risk of extremity malperfusion	PIV, IO

Table 11.2 Examples of patient needs to consider with the initial vascular access attempt

Immediate needs (stabilization)	Short-term needs (hospitalization)	Long-term needs (post-hospitalization)
Intubation (RSI)	Continuous infusions	Central vein preservation
Vasopressors	Vasopressors	Minimal risk of CRBSI
Fluids (bolus)	Fluids (maintenance)	Minimal risk of CRT
Antibiotics	Antibiotics (inpatient)	Antibiotics (long-term)
Hyperosmolar agents	"As-needed" medications	
Anticoagulation	Anticoagulation	
ACLS medications/CPR	Parenteral nutrition	
Blood sampling	Blood sampling	
Hemodynamic monitoring	Hemodynamic monitoring	
Intravenous contrast	Intravenous contrast	
Patient preference	Patient comfort	
Interventional procedures	Low risk of line failure	
Low risk of complications	Low risk of complications	

Note: *RSI* rapid sequence induction, *CRBSI* catheter-related bloodstream infection, *CRT* catheter-related thrombosis, *ACLS* advanced cardiac life support, *CPR* cardiopulmonary resuscitation

However, *providers should always seek to establish definitive vascular access that satisfies all the patient's anticipated needs on the first vascular access attempt*. This might prevent additional VAD placement from being necessary and may ultimately improve the quality of care afforded to the patient. Examples of important considerations when assessing a patient's needs for immediate vascular access are provided in Table 11.2. Each of these considerations should be assessed for the patient prior to making first attempts at establishing access.

Presenting Medical Conditions

The patient's presenting condition is an important consideration when assessing vascular access needs. Some patients may not require immediate access, although the underlying assumption in this chapter is that emergent vascular access is required. Other patients (e.g., cardiac arrest) may require immediate intervention that is only possible through a VAD. Many patients will fall somewhere in between these two extremes. The primary distinction here is the *time-sensitive need for an intervention that requires a vascular access device*. This determination should be made by the medical provider who is treating the patient's medical condition, and this person may not always be the same person who is providing vascular access. In such cases, communication between the medical provider and the vascular access provider is paramount to appropriate and successful line placement. As discussed previously in Chap. 10, time constraints are an important contributor to difficult vascular access. Consequently, providers should give themselves as much time as possible to plan and execute VAD placement but must also avoid delays. Thus, the provider must strike a balance between the needs of the patient for immediate therapy and the needs of the provider.

The *presence of specific medical conditions* may also guide the selection of an appropriate VAD. For example, patients presenting with suspected septic shock may reasonably be expected to require large volumes of bolus crystalloid infusion and vasopressors. Although fluids may be delivered by various routes, vasopressor infusion should be delivered by central venous access. In this case, the provider should anticipate that central venous access may be required, although a bridging device (e.g., large-bore peripheral IV) may be established to initiate fluid infusion. This will allow the patient to receive required antibiotics and fluids early, which may improve the patient's intravascular volume and enhance the likelihood of a successful subsequent central line attempt by enlarging the central vein targets. In some cases, "fluid-responsive" patients suspected of septic shock may improve hemodynamically after receiving fluids alone, thereby postponing or eliminating the need for central venous access. An awareness of the patient's suspected medical condition, as well as the appropriate interventions planned to treat this condition, may allow such a staged approach to vascular access. This example highlights the need to predict a patient's future vascular access needs, as well as the importance of modifying or adapting the vascular access plan in response to subsequent events.

The need for *infusion of crystalloid* (e.g., normal saline, lactated Ringer's solution) or colloid (e.g., hetastarch, albumin) solutions is a common indication for vascular access device placement. In the acute setting, providers often think of fluid infusion in terms of "bolus" aliquots of large volumes infused over a short period of time. As discussed in Chap. 2, fluid flow rates are dependent on a variety of factors, including internal catheter diameter, catheter length, fluid viscosity, and infusion pressure gradients. Longer, thinner catheters typically have lower maximal flow rates than shorter, wider catheters. Larger veins typically have lower resistance to flow than smaller veins. Higher viscosity fluids may infuse more slowly than less viscous fluids. Understanding these concepts will inform the provider's choice of

vascular access device and decisions on whether to use devices that enhance the infusion pressure gradient (e.g., pressure bags, infusion pumps). Blood products are more viscous than crystalloid fluids, and fluids containing red blood cells (e.g., whole blood, packed red blood cells) introduce the additional concern of red blood cell (RBC) lysis, which can cause or worsen hyperkalemia and reduce the effectiveness of the RBCs infused. It is important to predict the patient's need for immediate bolus fluid infusion when planning VAD placement. In many cases, multiple VADs may be indicated to accommodate the patient's need for immediate bolus infusion, especially when other medications (e.g., antibiotics, electrolyte replacement) may be competing for infusion space at the same time.

Many sources recommend selection of the proper gauge catheter based upon the patient's presentation and the indications for VAD placement. Commonly recommended indications for different gauges of peripheral IV insertion are illustrated in Fig. 11.1.

The Advanced Trauma Life Support (ATLS) guidelines recommend the immediate establishment of two large-bore (i.e., 18-gauge or larger) peripheral IV lines at the forearm or antecubital fossae for adult major trauma victims [1]. These patients often require large volumes of crystalloid fluid and blood products; both indications suggest the need for large-bore catheters.

The American Heart Association (AHA) Advanced Cardiac Life Support (ACLS) guidelines recommend attempting PIV insertion prior to the use of other vascular access techniques for victims of cardiac arrest, although no specific guidance is offered regarding the gauge or location of PIV insertion [2]. The only caveat to this is that *PIV insertion is recommended to be above the diaphragm for pregnant patients*, although common practice for all cardiac arrest victims is to seek PIV

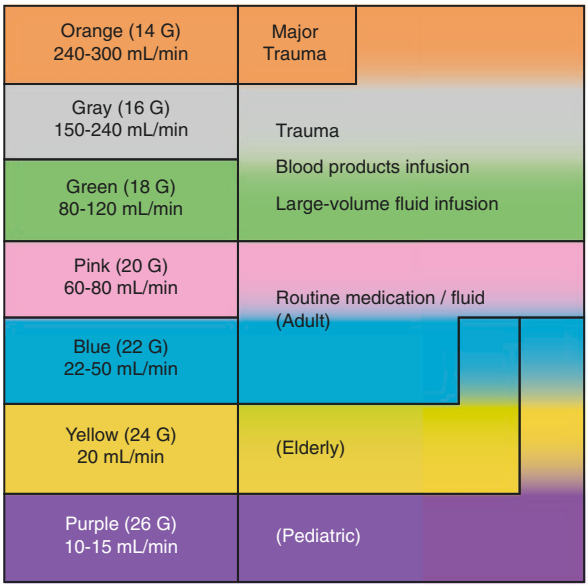

Fig. 11.1 Commonly used peripheral IV line gauges and their indications

placement at the antecubital fossa whenever possible. Intraosseous access should be considered when PIV access is unsuccessful or deemed to be infeasible [2]. However, the ACLS guidelines offer no specific guidance on how many PIV attempts should be made (or the duration of said attempts) prior to the decision to initiate IO access.

Most of the published literature on IO access for cardiac arrest highlights the use of proximal tibial IO placement, although this is a subdiaphragmatic location, and therefore appears to be suboptimal. Humeral or sternal IO catheters may be preferred, as these sites are associated with higher flow rates and are situated closer to the central circulation. Among neonates, umbilical venous cannulation is the preferred vascular access route in the delivery suite, although IO access may be attempted if the umbilical vein access is not available or the patient is being treated outside of the delivery room. Additional information about umbilical vein catheterization is provided in Chap. 8.

Patients with septic shock appear to enjoy improved mortality when receiving a central venous catheter (CVC) on the same day as admission, as compared to those who receive CVC placement later in their hospital course [3]. Of course, a diagnosis of septic shock requires that patients with sepsis fail to respond to an adequate (e.g., 30 mL/kg) resuscitative crystalloid fluid bolus and ultimately require vasopressors [4]. Many hypotensive patients presenting to the acute care provider are not yet differentiated, and some may respond to aggressive fluid resuscitation without the need for vasopressors. Thus, undifferentiated patients with hypotension, including those who are suspected of septic shock, should ideally receive adequate crystalloid fluid resuscitation through large-bore PIV cannulae before a central line is deemed to be required. Methods to assess the patient's intravascular volume status (e.g., collapsibility of the inferior vena cava on bedside ultrasound, response to leg lift, etc.) should be employed to gauge the patient's need for, and subsequent response to, fluid boluses. The management of hypotensive patients suspected of sepsis may therefore benefit from a staged response, including immediate placement of adequate large-bore peripheral vascular access, followed by central venous access as suggested by the patient's subsequent response to bolus fluid administration.

Indications for a central venous catheter are well-defined in the medical literature. In the emergent setting, the indications for CVC placement include inadequate peripheral venous access, need for continuous infusion of vasoactive medications, or need for hemodynamic monitoring. Of course, perceptions of the adequacy of peripheral access and need for hemodynamic monitoring are subject to provider interpretation.

Medication Characteristics

The need for intravenous medication infusion is another common indication for emergent vascular access. Although many medications can be administered safely via peripheral venous access, others may require central venous infusion. The *Infusion Nurses Society Standards of Practice* state that continuous infusions of

medication with irritant or vesicant properties should be achieved with a CVC whenever possible [5]. For time-critical infusions of life-saving therapies, such as vasopressors, the infusion should be initiated with a PIV until a CVC can be safely inserted, preferably within 24–48 hours [5]. Hemodilution, the process by which potentially noxious medications are diluted in the bloodstream during infusion, is limited with infusion through peripheral veins. This can lead to injury to the vein or surrounding tissues when certain substances are infused through a peripheral vein, especially in the event of *infiltration* (i.e., infusate escaping from the vein/cannula into the surrounding tissue).

It is important to note the distinction between *venous irritants* and *vesicants* when assessing a patient's vascular access needs. Venous irritants cause pain or discomfort with infusion, while vesicants are agents capable of causing blistering, tissue sloughing, and soft tissue necrosis in the event of solute infiltration. Venous irritants may cause injury within the vessel lumen, including phlebitis and thrombophlebitis. *Extravasation* is the term generally used when describing infiltration of a vesicant solute, as opposed to less noxious (i.e., non-vesicant) solutes. Damage to the soft tissues due to vesicant extravasation can require aggressive management, including surgical debridement [5]. Common medications that qualify as venous vesicants are provided in Table 11.3.

Drugs that qualify as *venous irritants* can usually be safely administered via PIV with adequate monitoring, although central venous infusion is preferred when these medications are given as continuous infusions. Agents classified as venous irritants that should not generally be administered via PIV include potassium chloride (≥20 mEq/100 mL), sodium chloride (23.4%), acyclovir >7 mg/mL, and long-term epoprostenol infusions. Of course, some venous irritant drugs are commonly given

Table 11.3 Common venous vesicants used in emergency care [5–7]

Drug	Recommended VAD
Adrenergic agents (e.g., dobutamine, dopamine, epinephrine, norepinephrine, vasopressin)	CVC
Aminophylline	CVC, monitor if PIV
Antiemetics (e.g., promethazine)	PIV (if proximal to wrist); may be given IM
Cardiovascular agents (e.g., amiodarone >2 mg/ml, digoxin, tromethamine)	CVC, monitor if PIV
Contrast (radiographic) agents	CVC, high-pressure injector midlines, monitor if PIV
Dantrolene	CVC, use PIV for emergencies
Diazepam	CVC, monitor if PIV
Electrolytes, high osmolarity (e.g., mannitol ≥5%, dextrose ≥10%, calcium chloride 10%, calcium gluconate 10%)	CVC, monitor if PIV
Methylene blue	CVC, monitor if PIV
Parenteral nutrition	CVC if contain >10% dextrose; use peripherally-compatible PN for PIV
Phenytoin	CVC, monitor if PIV

via PIV infusion under specific emergent circumstances such as dextrose (up to 50% solution, for severe hypoglycemia), calcium chloride 10% and amiodarone (in cardiac arrest), mannitol ≥5% (for brain herniation), dantrolene (for malignant hyperthermia), and methylene blue (for methemoglobinemia or shock states) [5–7].

Vasopressors should generally be infused through a CVC, although these medications are occasionally provided through peripheral venous access. In one recent review, 85.3% of local tissue injury events were associated with vasopressor infusion through a PIV distal to the antecubital or popliteal fossae, and 96.8% occurred after 4 hours of infusion [7]. These results suggest that brief (<4 hours) vasopressor infusion may be considered through a proximal PIV (i.e., proximal or at the antecubital fossa) when the risk of delaying vasopressor initiation to obtain a CVC is high. It has been recommended that patients who require extended (duration >4 hr) vasopressor infusion should receive CVC placement to avoid such complications [5].

Providers may wish to administer *multiple medications through the same IV access*, utilizing secondary (piggyback) IV tubing. A typical IV tubing setup is illustrated in Fig. 11.2. The *primary set* is generally used for fluid infusion, although secondary lines of IV tubing can be linked into the primary tubing to facilitate simultaneous infusion of other fluids or medications through the same IV tubing system [8]. The *secondary set* used for piggybacking often features a shorter length of tubing than the primary set, typically without access ports or a backcheck valve. The bag attached to a secondary set is generally hung higher than the bag attached to the primary set, to increase the relative effect of gravity on infusion and overcome any flow obstruction imparted by the connection system. Piggyback bags are often smaller in volume than the primary bag, which can lead to reduced flow from the secondary set if both bags are held at the same height. Higher-volume bags will typically drain faster than lower-volume bags due to the effect of gravity on fluid flow, although different tubes from these infusion sets may have different inherent flow rates [9]. When needed, an extension hook may be used to drop the height of the primary set bag.

Extension adaptors are used to connect two or more tubing lines for piggybacking and other secondary line setup and may be found in a variety of shapes. The most commonly encountered forms are V-set, T-set, and Y-set connectors (Fig. 11.3). The Y-set and T-set connectors feature a "common space" where solutions from the two limbs can mingle before being drawn into the distal IV tubing, although V-sets lack this feature.

Certain medications may be incompatible with one another and should not be infused through the same VAD tubing at the same time. Incompatibilities are characterized by physical and/or chemical reactions that occur between two (or more) drugs when the solutions are combined in the same syringe, tubing, or bottle [10]. Such reactions can lead to reduced efficacy of the drugs, increase drug toxicity, or contribute to other adverse effects [10]. Many different incompatibilities exist, and the likelihood of these events should be assessed using a source such as Trissel's™ IV compatibility database [8]. However, some common examples of incompatible drug combinations are provided in Table 11.4.

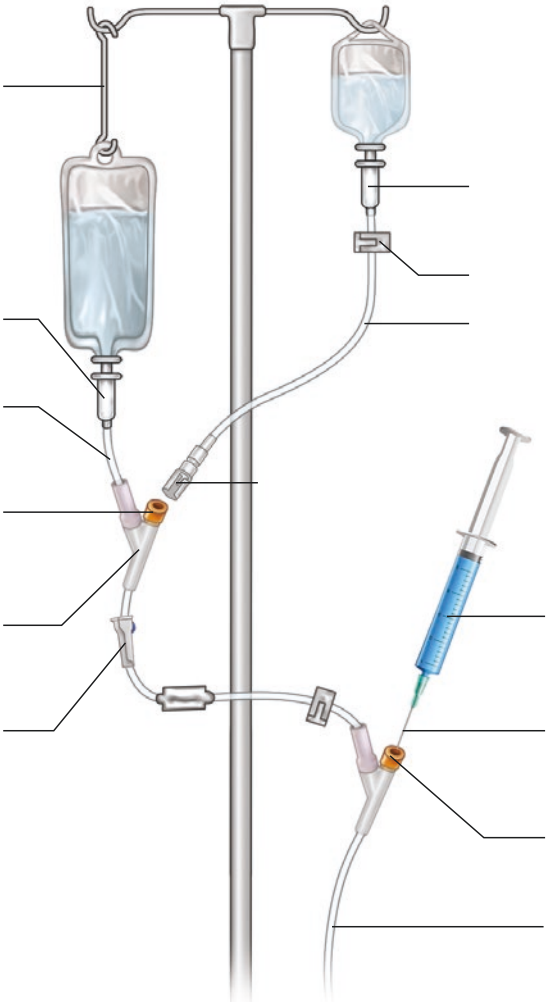

Fig. 11.2 Generic IV tubing setup, including Y-port

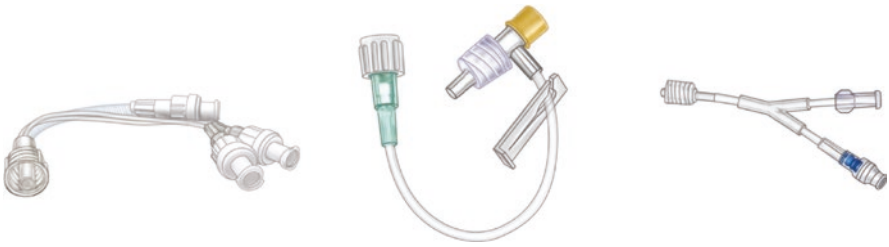

Fig. 11.3 V-set, T-set, and Y-set three-way connectors

Table 11.4 Common drug incompatibilities encountered in the care of critically ill patients [8, 10–11]

Drug + drug combinations	
Midazolam +	Cefepime Omeprazole Phenytoin
Hydrocortisone +	Midazolam Vancomycin Calcium chloride Vitamin B1
Vancomycin +	Cefepime Omeprazole
Phenytoin +	Ranitidine Noradrenaline Fentanyl
Sulfamethoxazole-trimethoprim +	Vancomycin Fentanyl Hydrocortisone Ranitidine
Lactated Ringer's +	Ciprofloxacin Cyclosporine Diazepam Ketamine Lorazepam Nitroglycerin Phenytoin Propofol

Provider-Specific Considerations

Providers should reflect on their own training and limitations prior to selecting a device or technique for use with an initial vascular access attempt. The provider's comfort and familiarity with placement techniques and devices are crucial to placement success. Thus, when establishing critical vascular access for an unstable

patient, providers should generally refrain from selecting a new or unfamiliar technique. We suggest that providers learn new techniques when the "heat is off," so that they can refine their skills when the "heat is on." Provider-specific contributors to difficult vascular access are provided in Chap. 10, including distractibility, fatigue, stress, and lack of adequate experience. These factors will influence the provider's choice of vascular access device, and providers should be self-aware enough to recognize their own limitations and challenges that they bring to the vascular access effort.

Device Limitations

Traditionally, vascular access providers have been instructed to select the smallest-possible gauge required for the patient's care. Small-gauged devices take up less space in the vein, thus allowing increased blood flow around the device and theoretically reducing trauma to the vessel and surrounding tissues. This philosophy makes sense when considering stable patients with predefined indications for vascular access. However, such conservative strategies may be more challenging to employ in the earliest stages of patient resuscitation and stabilization, since the patient's future vascular access needs with subsequent care may not be apparent to the provider at the time of initial assessment. Providers must recognize this ambiguity in the emergent care of unstable patients and attempt to balance the need for selecting a minimally invasive device with the potential for inadequate access to meet the patient's needs.

A step-wise approach to vascular access device placement is therefore often indicated when managing undifferentiated patients with potential (or recognized) clinical instability. The concept of a "bridging device" is important here. In this context, *bridging devices* are vascular access devices that are understood *a priori* by the provider to be temporary vascular access points by which stabilizing interventions can be administered while planning or preparing for definitive vascular access device placement. A *definitive device* represents the ideal vascular access device needed (or anticipated) for optimal management of the patient's condition. If definitive device placement is the goal of the vascular access episode, bridging devices represent a means by which providers can achieve this goal for patients in whom definitive device placement is either impossible or unacceptably delayed. For example, IO or PIV catheter placement may be necessary to initiate bolus crystalloid fluid, blood product, or vasopressor infusion in an unstable (e.g., hypotensive) patient who cannot safely receive immediate and necessary CVC placement. The understood implication in placing a bridging device is that the initiation of intravenous infusion cannot be safely delayed while seeking definitive device placement. Although the circumstances surrounding the use of a bridging device may vary, they are often deployed when the provider has either failed definitive device placement or has determined that the time needed to achieve definitive access introduces greater risk than the decision to rely on suboptimal access to initiate therapy. *The perceived need for a bridging device results from a time-sensitive and subjective assessment by the vascular access provider*. In some cases, devices initially placed

as a bridging device may ultimately serve as definitive access if the bridging device facilitates adequate clinical improvement so that the anticipated definitive access device is no longer required. For example, an undifferentiated hypotensive patient may be suspected of septic shock and receive PIV placement to initiate antibiotics and bolus fluid infusion while plans are made for CVC placement for continuous hemodynamic monitoring and vasopressor infusion. However, subsequent assessments may lead the provider to determine that the patient is merely dehydrated, which could obviate the need for CVC placement. As this example illustrates, decisions regarding specific vascular access needs for undifferentiated patients are dynamic and must be adjusted accordingly when the provider is faced with new clinical information.

Guidelines and Policies

Several published guidelines have been provided by proposed authorities on infusion therapy and acute care. Some of the more prominent guidelines are described below, including relevant guidance relating to emergent vascular access.

Michigan Appropriateness Guide for Intravenous Catheters (MAGIC) [12]

This reference focuses upon providing guidance on appropriate use of peripherally inserted central catheters (PICCs), including indications for insertion and duration of use. However, they have also opined on the use of other devices, especially as it relates to the duration of therapy and type of infusates to be administered. This multispecialty international panel concluded that *PICC lines are inappropriate for peripherally compatible solutions* when the proposed duration is ≤5 days. Patients requiring only peripherally compatible infusates for ≤5 days should ideally receive PIV placement in the dorsum of the hand (avoiding the forearm veins) if they are at risk for the need for dialysis (e.g., stage 3b chronic kidney disease or glomerular filtration rate <45 mL/min). This is intended to preserve veins for anticipated hemodialysis. The forearm insertion sites are preferred in patients with compatible infusions <5 days in non-renal patients, as placement in this area avoids joints and points of flexion.

Table 11.5 provides a summary of the MAGIC recommendations for peripherally compatible infusates, according to the duration of infusion.

For infusion of *non-peripherally compatible infusates*, central venous access is required. The MAGIC panel concluded that non-tunneled CVC is preferred in critically ill patient or if hemodynamic monitoring is needed for 6–14 days. Although PICC lines are considered appropriate for all proposed durations of therapy, tunneled catheters are equally appropriate for infusion durations of ≥15 days. Ports, tunneled catheter, and PICC lines are equally appropriate when the proposed duration of non-peripherally compatible infusion is ≥31 days. Ports should be considered as a first option unless there is a known complication with the device. However,

Table 11.5 MAGIC recommendations for peripherally compatible infusates, according to the duration of infusion [12]

Duration of infusion	Preferred device	Considerations
≤5 days	PIV or US-PIV	
6–14 days (non-critically ill)	US-PIV	US-PIV is preferred to PIV. Midline catheter is preferred to PICC
6–14 days (critically ill)	Non-tunneled CVC	If hemodynamic monitoring is needed for 6–14 days
15–30 days	PICC	PICC preferred to midline catheter, tunneled CVC, or port
≥30 days	Tunneled catheter or port	

the appropriateness of port use for emergent resuscitation is not addressed directly in these guidelines. It should be noted that tunneled catheters and ports are placed in the operating room or interventional radiology suite and are not options for emergent vascular access in the emergency department or other acute care environments. Placement of a PICC line, though recommended for various indications by the MAGIC guidelines, may also be impractical under emergent conditions. At many institutions, the placement of PICC lines is restricted to specific vascular access specialists, who may not be available when access is needed. Thus, guidance from the MAGIC guidelines and other resources should be balanced with the acute needs of the patient for immediate therapy.

Among patients with difficult vascular access (DVA), the MAGIC guidelines suggest that midline catheters and US-PIVs should be preferred to PICCs for duration of use between 6 and 14 days. However, in patients with stage 3b or greater chronic kidney disease (CKD), US-PIV is considered by the MAGIC panel to be inappropriate, due to the need to preserve forearm veins for future dialysis needs. They recommend placement of a small-bore tunneled central catheter instead for this population. External jugular (EJ) peripheral venous cannulation is appropriate for emergent situations when the duration of therapy is expected to be <96 hours. Placement of PIV lines in the lower extremities is considered inappropriate – except in rare emergency situations when other veins are unavailable. For the administration of IV contrast agents, panelists recommended the use of a proximal 16-, 18-, or 20-gauge PIV, rather than a PICC line.

Among critically ill patients, non-tunneled central venous catheters are preferred over PICC lines when the anticipated duration of use is ≤14 days. Among cancer patients who are likely to require irritant or vesicant infusion (e.g., chemotherapy), PICC lines were deemed appropriate, if the duration of therapy is ≤3 months.

Infusion Nurses Society (INS) Infusion Therapy Standards of Practice

This resource [5] offers comprehensive guidance to nurses and others who engage in vascular access placement and management and is updated every 5 years. The 8th edition (published in 2021) features 230 pages of material, including standards and

practice recommendations with associated references. The scope of this resource is quite broad, although certain specific recommendations can be applied to the topic of emergent vascular access:

- *Short peripheral IV catheters*. In general, the INS standards recommend against "blind sticks," favoring vessels that can be directly visualized or palpated. The standards recommend that clinicians be allowed "*no more than two attempts*" to establish a PIV catheter, after which time the placement attempt should be escalated, "to a clinician with a higher skill level and/or consider alternative routes of medication administration." They also recommend that providers use the, "*smallest-gauge PIVC that will accommodate the prescribed therapy* and patient need," including a "20- to 24-gauge PIVC for most infusion therapies." Larger (>20-gauge) catheters are more likely to cause phlebitis but are recommended when rapid transfusion is required. Regarding continuous infusions of medications with irritant or vesicant properties, they suggest that "for time-critical infusions of lifesaving therapies, such as vasopressors, [providers may] *begin the infusion through a PIVC until a CVAD can be safely inserted*. Insert CVAD as soon as possible and within 24 to 48 hours." Avoid the cephalic vein whenever possible, to preserve future dialysis access.
- *Long peripheral IV catheters*. The INS standards recommend that long PIV catheters be used instead of short PIV when "all aspects of a short PIV are met, but the vessel is difficult to palpate or visualize with the naked eye; ultrasound guidance/near infrared technology is recommended. Evaluate depth of vessel when choosing a long PIVC to *ensure two-thirds of catheter lies within vein*."
- *Midline catheters*. These devices are inserted into a peripheral vein of the upper arm (e.g., basilic, cephalic, brachial), with the terminal tip located at the level of the axilla. They differ from a central line in that the catheter *tip terminates in a proximal peripheral vein* rather than in a central vein. In neonates, these devices can be inserted into scalp veins or veins of the lower extremity as well. These should be used for infusates that are *peripherally compatible*. Further research is needed to establish the safety of using midline catheters for intermittent vesicant infusion. Avoid these devices in patients with history of thrombosis, hypercoagulability, decreased venous flow in the extremities, or end-stage renal disease requiring vein preservation. For PICC or midline catheters, ensure a catheter-to-vessel diameter ratio of <45%.
- *Intraosseous (IO) access*. The INS standards recommend that providers "anticipate use of the IO route in the event of adult or pediatric cardiac arrest if IV access is not available or cannot be obtained quickly" and "consider the IO route for emergent and non-emergent use in patients with *limited or no vascular access*; when the patient may be at risk of increased morbidity or mortality if access is not obtained, such as during shock, life-threatening or status epilepticus, extensive burns, major traumatic injuries, transfusion, or severe dehydration, and/or *when care is compromised without rapid vascular access*."
- *Central venous catheters*. The INS standards recommend the use of ultrasound with CVC placement, "to increase success rates and decrease insertion-related

complications." They report that the IJ site is preferred for patients with *pre-existing respiratory compromise*, due to higher risk of pneumothorax with medial subclavian insertion. They further state that "if significant unilateral lung disease is present, ipsilateral insertion is recommended for IJ or SC cannulation to prevent further respiratory compromise with pneumothorax in lungs without injury or disease." Patients who have a *cardiovascular implantable electronic device* (e.g., pacemaker) should have either contralateral CVC placement or ipsilateral PICC line placement if central venous access is required. Patients who are actively anticoagulated should not receive SC line placement. Among patients who have *advanced kidney disease* and may ultimately require hemodialysis, it is recommended to avoid SC CVC or PICC lines due to increased risk of thrombosis and central vein stenosis; these patients should receive IJ, EJ, or femoral CVC placement instead of the SC site. Patients who present with an existing implanted port should have the port utilized as the "preferred IV route, in preference to insertion of an additional VAD."

Vessel Health and Preservation: The Right Approach for Vascular Access

This ebook [13] provides a practical approach to vessel health and preservation (VHP), including strategies for patient-specific vascular access assessment. The authors describe traditional vascular access methods as "reactive, painful, and ineffective, often resulting in the exhaustion of peripheral veins prior to consideration of other access options." The emphasis is on development of vascular access clinical pathways that can help to align VAD selection with the patient's medical condition, diagnosis, treatment plan, and vessel health. The "four quadrants of care" for the VHP model are (1) assessment/selection, (2) insertion, (3) management, and (4) evaluation.

Among the recommendations and observations provided in this resource are the following:

- Patients should be able to trust that "the VAD selected has the lowest risk for insertion location, device size not to exceed 33% of vein diameter, length, and number of lumen, and is the most appropriate to deliver the treatment." This 33% metric is intended to reduce the risk of venous thrombosis.
- Although placement of a PIV in the hand or antecubital fossa "is initially easier in most respects due to identification of veins visually and through palpation," these devices are also "uncomfortable for patients, and often fail in less than 72 hours" [14].
- "Optimal peripheral cannula site selection is one that allows ultrasound-guided needle access in a vein 2–4 mm in diameter or larger and 0.2–1.5 cm in depth" [15]. These measurements should be made in the veins' "native state," without a tourniquet.

Rapid Assessment of the Central Veins (RaCeVA) and Peripheral Veins (RaPeVA)

These resources from the Italian Group for Venous Access Devices (GAVeCeLT) are intended to help providers in evaluating the central (RaCeVA) and peripheral (RaPeVA) veins with ultrasound prior to attempting VAD insertion [16]. A thorough US assessment of the major veins prior to VAD insertion has been shown to reduce complications and improve placement success [17].

The *RaPeVA rapid peripheral vein assessment protocol* includes a systematic ultrasound evaluation of the peripheral veins, in the following sequence:

- Position 1 – *cephalic vein* at lateral cubital crease (antecubital fossa)
- Position 2 – *median cubital/basilic veins* at medial cubital crease
- Position 3 – *basilic vein* at bicipital humeral groove (upper arm)
- Position 4 – *brachial veins* (*venae comitantes*) at upper humerus
- Position 5 – *cephalic vein* at upper arm
- Position 6 – *cephalic vein* to intersection with *axillary vein*
- Position 7 – *subclavian/external jugular/internal jugular veins*

This assessment starts distally (at the antecubital fossa) and works proximally to the central veins. Vessels are evaluated for compressibility (lack of venous thromboses), size, and shape.

The *RaCeVA rapid central vein assessment protocol* includes a systematic ultrasound evaluation of the central veins, in the following sequence:

- Position 1 – *mid-neck* transverse US view of the *IJ vein* and carotid artery
- Position 2 – *low-neck* transverse US view of the *IJ vein* and carotid artery
- Position 3 – *sternal notch* transverse US view of *brachiocephalic vein*
- Position 4 – *supraclavicular* view of *subclavian/external jugular veins*
- Position 5 – *infraclavicular* view of *axillary/cephalic veins* in long axis
- Position 6 – *deltopectoral fossa* view of *axillary/cephalic veins* in long axis
- Position 7 – *second intercostal space* assessment of lung for pneumothorax

The purpose of this assessment is to systematically assess the peripheral and central veins for patency, suitability for cannulation, and presence of nearby anatomic structures (e.g., artery, nerve, lung) that should be considered in the cannulation attempt.

Guidelines for the Prevention of Intravascular Catheter-Related Infections

This reference [18] was published by the US Centers for Disease Control and Prevention (CDC) in 2011, with the targeted goal of reducing intravascular catheter-related infections through communication of best practices on catheter placement

and management [18]. Select recommendations from this resource include the following:

- "Avoid using the femoral vein for central venous access in adult patients. Use a subclavian site, rather than a jugular or femoral site, in adult patients to minimize infection risk for nontunneled CVC placement. Avoid the subclavian site in hemodialysis patients and patients with advanced kidney disease, to avoid subclavian vein stenosis."
- "Use a sutureless securement device to reduce the risk of infection for intravascular catheters."
- "There is no need to replace peripheral catheter more frequently than every 72–96 hours to reduce risk of infection and phlebitis in adults. Replace peripheral catheters in children only when clinically indicated."
- "In adults, use of the radial, brachial, or dorsalis pedis [arterial cannulation] sites is preferred over the femoral or axillary sites of insertion to reduce the risk of infection. In children, the brachial site should not be used."

A Decision-Making Algorithm

Despite the abundance of guidance offered by reputable authorities on the topic, no adequate evidence-derived algorithm has yet been developed informing proper vascular access device selection for adult patients under emergent conditions. The lack of such a resource has traditionally impaired providers in seeking appropriate vascular access in the emergency department or similar pre-hospital or early in-hospital environment. Most existing algorithms relate to the placement of VADs in stable or ambulatory patients and include options such as PICC line placement, which is clearly not an option for critically unstable patients. Although VAD selection should be guided by the patient's specific clinical circumstances, and include consideration of national and international guidelines, algorithmic guidance on VAD selection may have value for specific medical and environmental conditions. Providers should determine whether their institution has an algorithm for VAD selection that encompasses emergent vascular access. If not, providers should consider creating such an algorithm, based upon existing evidence from the medical literature and incorporating their own institutional/professional policies and guidelines. Figure 11.4 shows an example of a VAD placement algorithm that might be considered for adult patients.

Conclusions

Decision-making is an underappreciated aspect of emergent vascular access, which deserves dedicated research and discussion in academic *fora*. Many factors must be considered in making decisions about the need for vascular access in critically ill and unstable patients. Device limitations and indications for use should be

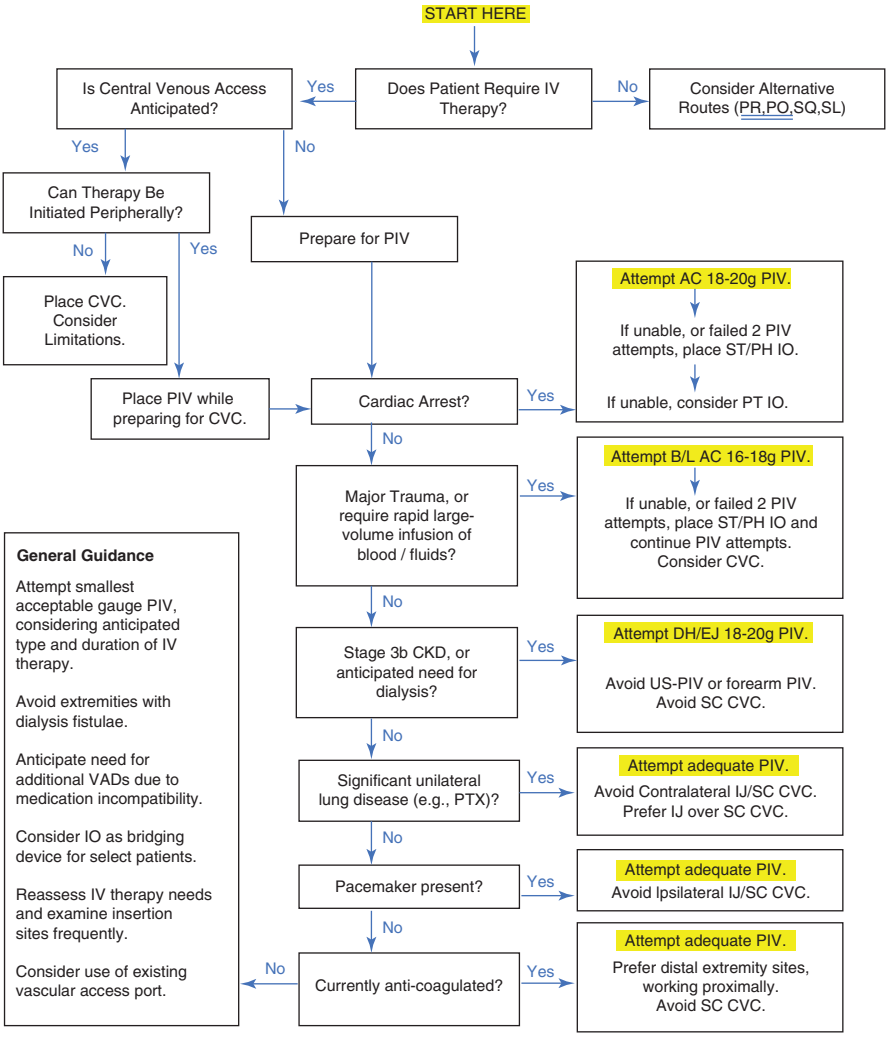

Fig. 11.4 Example of a VAD placement algorithm for adult patients. Notes: AC antecubital, CKD chronic kidney disease, CVC central venous catheter, DH dorsal hand, EJ external jugular, IJ internal jugular, IO intraosseous, PIV peripheral intravenous, PO per oral, PR per rectum, PTX pneumothorax, SC subclavian, SL sublingual, SQ subcutaneous, ST sternal, US-PIV ultrasound-guided peripheral intravenous

considered, as should potential immediate- and long-term complications from their use. Providers are inundated with myriad recommendations on how and why specific devices should be used, but much of this information relates to the management of stable, hospitalized patients and should be measured against the need for reliable and effective immediate vascular access in the setting of a medical emergency. Future research into the best practices for emergent vascular access device placement is needed.

Key Concepts

- Providers should establish a "game plan" for emergent vascular access prior to the acute episode of the access attempt, guided by their understanding of the patient's specific need for vascular access as well as the resources available to them with the attempt. This might include or be derived from an institutional algorithm guiding VAD selection.
- Best practices for emergent vascular access techniques should be determined, in part, by local institutional protocols, with consideration of evidence-based algorithms provided by reputable authorities.
- Decisions on optimal vascular access should be informed by familiarity with the recommendations endorsed by national and international guidelines on appropriate emergent vascular access.
- Current recommendations on the appropriateness of specific VADs for emergent patients should be viewed with an understanding of the applicability of these recommendations to the emergent patient. Recommendations pertaining to stable, hospitalized patients may not be universally applicable to patients requiring emergent vascular access.

References

1. American College of Surgeons. Committee on Trauma. Advanced trauma life support: student course manual. 10th ed. Chicago, IL: American College of Surgeons; 2018. p. 52.
2. Soar J, Maconochie I, Wyckoff MH, et al. 2019 international consensus on cardiopulmonary resuscitation and emergency cardiovascular care science with treatment recommendations: summary from the basic life support; advanced life support; pediatric life support; neonatal life support; education, implementation, and teams; and first aid task forces. Circulation. 2019;140:e826–80. https://doi.org/10.1161/CIR.0000000000000734.
3. Walkey AJ, Wiener RS, Lindenauer PK. Utilization patterns and outcomes associated with central venous catheter in septic shock: a population-based study. Crit Care Med. 2013;41(6):1450–7.
4. Singer M, Deutschman CS, Seymour CW, et al. The third international consensus definitions for sepsis and septic shock (sepsis-3). JAMA. 2016;315(8):801–10.
5. Gorski LA, Hadaway L, Hagle ME, et al. Infusion therapy standards of practice. J Infus Nurs. 2021;44(suppl 1):S1–S224.
6. Le A, Patel S. Extravasation of noncytotoxic drugs: a review of the literature. Ann Pharmacother. 2014;48(7):870–86.
7. Loubani OM, Green RS. A systematic review of extravasation and local tissue injury from administration of vasopressors through peripheral intravenous catheters and central venous catheters. J Crit Care. 2015;653:e9–e17.
8. Gorski LA, Phillips LD. Phillips's manual of I.V. Therapeutics. 7th ed. Philadelphia: FA Davis Company; 2018.
9. Lannoy D, Décaudin B, Dewulf S, et al. Infusion set characteristics such as antireflux valve and dead-space volume affect drug delivery: an experimental study designed to enhance infusion sets. Anesth Analg. 2010;111(6):1427–31.
10. Marsilio NR, da Silva D, Bueno D. Drug incompatibilities in the adult intensive care unit of a university hospital. Rev Bras Ter Intensiva. 2016;28(2):147–53.

11. Vallée M, Barthélémy I, Friciu M, et al. Compatibility of lactated Ringer's injection with 94 selected intravenous drugs during simulated Y-site administration. Hosp Pharm. 2019:1–7. https://doi.org/10.1177/0018578719888913.
12. Chopra V, Flanders SA, Saint S, et al. The Michigan appropriateness guide for intravenous catheters (MAGIC): results from a multispecialty panel using the RAND/UCLA appropriateness method. Ann Intern Med. 2015;163:S1–S39.
13. Moreau NL, editor. Vessel health and preservation: the right approach for vascular access. Cham: Springer; 2019. (eBook) Available at: https://doi.org/10.1007/978-3-030-03149-7. Accessed 15 March 2021
14. O'Grady NP, Alexander M, Burns LA, et al. Guidelines for the prevention of intravascular catheter-related infections. Am J Infect Control. 2011;39(4 Suppl):S1–S34.
15. Alexandrou E, Ray-Barruel G, Carr PJ, et al. Use of short peripheral intravenous catheters: characteristics, management, and outcomes worldwide. J Hosp Med. 2018;13. https://doi.org/10.12788/jhm.3039
16. Witting MD, Schenkel SM, Lawner BJ, Euerle BD. Effects of vein width and depth on ultrasound guided peripheral intravenous success rates. J Emerg Med. 2010;39:70–5.
17. Pittiruti M, Scoppettuolo G. GAVeCeLT manual of PICC and midline—indications, insertion, management. Edra S.P.A; 2017.
18. Pirotte T. Ultrasound-guided vascular access in adults and children: beyond the internal jugular vein puncture. Acta Anaesthesiol Belg. 2008;59:157–66.