Landmark-Based Peripheral Intravenous Catheters

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Introduction

Peripheral intravenous (PIV) catheters are the most common lines placed by providers treating emergent patients. Because of this, the landmark-based PIV line is often considered to be the "gold standard" by which other vascular access attempts are measured. We feel that mastery of the landmark-based PIV insertion is essential for all providers who wish to provide venous access for patients under emergent conditions.

As described in Chap. 2, the venous system is composed of both central and peripheral veins. Peripheral veins emanate from the central veins, much like the branches of a tree. Access to these peripheral veins may be compromised by factors reducing blood flow to the extremities, including the human body's normal response to hypotension. Because peripheral veins have a less pronounced vasomotor response to circulating adrenergic factors, due to their relative lack of smooth muscle as compared to arterial vessels, they are likely to be collapsed in states of low intravascular volume.

Under emergent conditions, when hypovolemia and hypotension are likely present, blood flow to the lower extremities may be inordinately compromised [1]. Although blood flow to the upper extremities may also be somewhat compromised under such conditions, we suggest that the optimal peripheral veins to target in the

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unstable patient are in the upper extremities. Thus, the peripheral veins of greatest interest to the emergent provider will be found in the neck, torso, and upper extremities.

Peripheral Intravenous Catheter Design

Peripheral intravenous catheters have traditionally been composed of polytetrafluoroethylene (PTFE), specifically Teflon® materials, although superior materials have recently been introduced into the market. The polyurethane biomaterial Vialon® appears to possess a substantially higher tensile strength than traditional materials [2], and clinical studies have shown reduced incidence of phlebitis and longer dwell times when compared to Teflon® [3, 4].

The parts of a generic PIV catheter include the *hub*, *cannula*, and *tip*. Infused substances enter the catheter at the hub end, travel through the cannula, and egress from the catheter tip into the vessel lumen (Fig. 3.1).

As described in Chap. 2, the *radius* and *length* of the cannula are the primary determinants of flow through a catheter. In general, wider and shorter catheters provide less resistance to flow and are therefore capable of higher flow rates (typically measured in milliliters/minute). The radius of the catheter is reflected by the *gauge* of the PIV catheter, which is a measure of the internal (i.e., intraluminal) cross-sectional diameter of the cannula. The most common gauges of PIV catheter are listed below in Table 3.1, along with their usual characteristics. Differently gauged PIV catheters typically have differently colored hubs, to aid in easy identification during clinical use. The gauge number is *inversely* related to the diameter of the cannula and usually

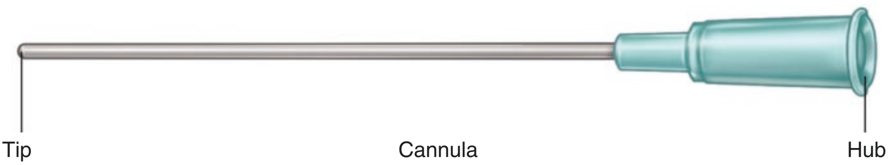


Fig. 3.1 Components of a PIV catheter

Table 3.1 Characteristics of common PIV gauges [5–8]

Gauge	Hub color	Cannula width (mm)	Cannula length (mm)	Gravity flow rate (mL/min)
26	Purple	0.7	19	~10–15
24	Yellow	0.8	19	~20
22	Blue	0.9	25	~22–50
20	Pink	1.1	32	~60–80
18	Green	1.3	32–45	~80–120
16	Gray	1.7	45	~150–240
14	Orange	2.2	45	~240–300

also inversely related to catheter length. In other words, larger gauge catheters have a smaller internal diameter and usually have a shorter cannula length. It should be noted that the approximate flow rates provided in Table 3.1 are for *in vitro* water infusion with gravity and would be expected to be slower for more viscous substances (e.g., blood, albumin) and faster with pressure bag application [5–8].

In the emergent setting, an 18- or 20-gauge PIV catheter is generally preferred, to permit efficient fluid volume infusion. Keep in mind that larger-diameter PIV catheters may inordinately occlude venous flow around the catheter, while smaller-diameter PIV catheters may provide inadequate flow rates.

Another consideration with larger-gauge (e.g., 14-, 16-, and 18-gauge) PIV catheters is the *rigidity* of these cannulae. Since they are thicker and less flexible, these catheters may perform better in areas characterized by thick or severely scarred soft tissues. When targeting an insertion site demonstrating extensive scarring, the provider should weigh this potential advantage against the need to use the smallest-gauge PIV catheter adequate for the patient's needs. When first learning techniques for PIV access, a familiarity with the larger catheter gauges is important. Once placement of the larger devices has been perfected, use of the smaller catheters will come easily. Providers should feel confident in their ability to place a large-gauge PIV in the emergent patient. When limitations due to smaller vessels or suboptimal location are encountered, the smaller-gauge devices can be a fallback for life-saving measures. Whatever the choice, any access is better than no access under emergent conditions.

Although some variation exists in the design and safety features present in modern devices, a generic safety PIV catheter would include certain features: *activation button, safety barrel, flashback chamber, projection finger grip, PIV cannula* (i.e., catheter) *with push-off tab and colored hub*, and the *guidance needle*. The activation button will cause retraction of the guidance needle after penetration of the target vessel has occurred, which leads to retraction of the needle into the *safety chamber*. This chamber shrouds the needle once it has been retracted, to reduce the risk of inadvertent provider injury following cannulation. The *guidance needle* is located at the interior of the catheter and includes a beveled tip which is used to penetrate the target vessel. Once the tip of the needle has entered the vessel, blood will be seen entering the *flashback chamber* (in larger catheters), although larger-gauge (i.e., smaller diameter) catheters may not have a flashback chamber, so blood may instead be seen entering the catheter lumen after successful penetration of the vessel. The *projection grip* is a prominence of the catheter-needle complex which promotes optimal control of the complex during needle insertion, while the *push-off tab* (a part of the catheter itself) gives the provider a point of traction on the catheter for advancing the catheter over the guidance needle during cannulation. Some catheters (especially those used for pediatric patients) may have "wings" emanating from each side of the hub which promote more stable anchoring of the catheter once it has been properly inserted. The cannula usually has a tapered tip, which promotes minimal injury to the target vessel with insertion. Because modern PIV catheters are tapered at the tip, it is not recommended to trim PIV catheters before placement, as this will remove the tapering at the tip and will increase the risk of vascular injury during insertion attempts. Figure 3.2 illustrates these features of modern safety PIV catheters.

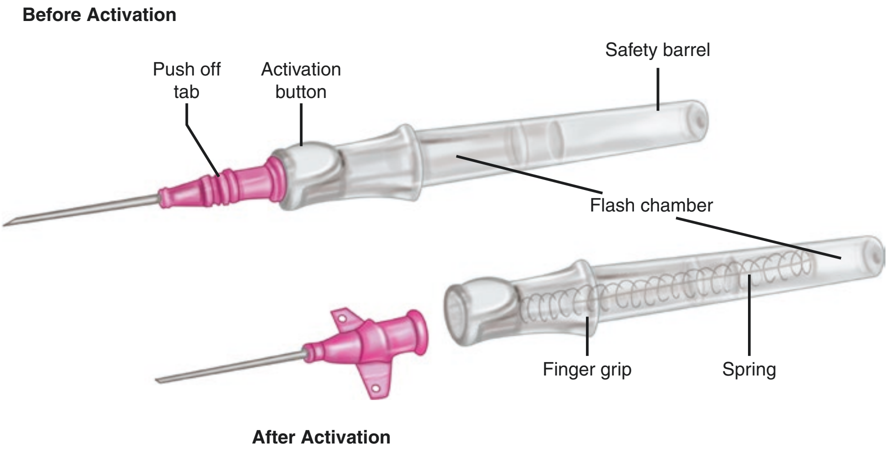


Fig. 3.2 Components of a generic PIV safety catheter

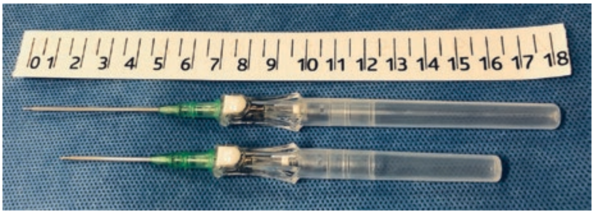


Fig. 3.3 Standard and extended-length short 18-gauge PIV catheters

In addition to standard "short" PIV catheters, extended-length standard PIV catheters are also available. These longer catheters may be utilized for US-guided techniques or for cannulation of deeper veins, such as the *external jugular (EJ) vein*. It should be noted that the cannula length is not equivalent to the entire catheter length, as the cannula length only refers to the length of the portion of the catheter that is deep to the skin surface with placement, and does not include the length of the hub. For example, Fig. 3.3 shows a standard 18-gauge 30-mm (1.16-inch) short PIV safety catheter compared to the extended-length version of the same catheter, which features a 48-mm (1.88-inch) cannula. The only difference between these catheters is the length of the cannula and safety barrel.

Technique for Landmark-Based PIV Placement

In general, the steps required for placement of a peripheral intravenous catheter should be similar regardless of the specific catheter and location selected. These steps include:

1. Provider preparation
2. Insertion site selection

3. Tourniquet application
4. Site targeting and sterilization
5. Puncture of targeted vessel and tourniquet release
6. Confirmation of back flow
7. Needle retraction and vein occlusion
8. Heplock/infusion tubing attachment
9. Catheter flushing
10. Dressing application
11. Catheter stabilization
12. Assessment of catheter infusion

1. *Provider preparation* includes attention to standard antiseptic techniques. Providers must wash hands with warm water and soap prior to PIV insertion and wear appropriately fitted gloves. The provider should also adequately confirm the patient's identity and consider any patient preferences or contraindications for PIV insertion sites. Relative site contraindications for PIV placement are discussed later in this chapter. When possible, the risks and benefits of PIV insertion should be reviewed with the patient, and the patient should be made aware of the need and indication for PIV insertion. Emergency providers should remember that PIV attempts will likely be uncomfortable to the sensate patient. Patients should reasonably expect the provider to establish PIV access quickly, with minimal patient discomfort, and they may also have personal preferences about the location or type of PIV insertion that should be attempted. Of course, it is not always possible to accommodate all patient requests, especially if the patient's preferred access site or device would not be adequate for the type and level of care required. The provider should carefully assess the patient's therapeutic needs with PIV insertion and determine the appropriate gauge of PIV likely to be required for adequate patient care.

Provider comfort and safety are of paramount importance. Providers should assume that all patients have an infectious disease and avoid splash exposure to blood. When preparing to place a PIV, the emergency care provider must guard against needlesticks and awkward angles, by positioning the targeted venous access site at a level of comfort for the provider, so that the provider will not be strained during the cannulation attempt. The provider should sit down, when possible, and remain as close as possible to the patient. Ideally, PIV insertions should be attempted with the target site near the provider's waist level. In the ED or hospital setting, providers should ensure that the bed rail opposite to the access attempt is up before elevating the bed, and providers should never leave a bed raised when stepping away from the patient. Patients can sustain serious injuries with a fall from the bed if left unattended. If patients are uncooperative or disoriented, providers should obtain help from other healthcare providers in restraining the patient to avoid injury to the provider and the patient during the vascular access attempt.

During this phase of preparation, the provider should gather any needed equipment for PIV insertion, including sterile 2×2-inch sterile gauze, a transparent

Fig. 3.4 Supplies required for PIV catheter insertion

semipermeable dressing, IV extension tubing, a prefilled normal saline flush syringe, an elastic tourniquet, a 70% alcohol wipe or chlorhexidine antiseptic swab, and clear 1-inch transpore tape. These supplies should be brought to the patient's bedside and made easily accessible prior to initiation of the PIV insertion attempt. Figure 3.4 shows the supplies needed to perform PIV insertion.

2. *Insertion site selection* should be guided by the patient's medical condition and a thorough examination of the patient. When high-volume infusion is needed, providers should seek to target the largest, most proximal veins available, especially those in the AC fossa or the EJ vein. On the other hand, if a smaller-caliber vein is adequate, it is best to start distally on the extremity, since a blown proximal vein may limit options more distally. If attempts on distal sites fail, the provider can always move more proximally.

Once the target vein has been selected, the vein should be palpated to identify sclerosed or hardened veins (which may be suboptimal), or areas where venous valves are located (which may feel like “bulges” in the vein). The provider must feel that cannulation is likely possible before attempted catheter insertion. This phase of preparation is especially important and should be given adequate time to complete, given the great importance of target vein selection to ultimate cannulation success. Once the desired target vein has been identified, providers should optimize their chance of success by ensuring proper patient positioning and ensuring adequate lighting of the area targeted for insertion. Considerations for proper selection of a target vein will be discussed later in this chapter.

3. *Tourniquet application* is generally applied 10–15 cm proximal to the desired insertion site and is intended to engorge the target vein to facilitate easy cannulation. Once the target vein has been cannulated, the tourniquet should be released immediately. In general, tourniquet placement should be above the elbow. However, in certain patients it may be desirable to place the tourniquet below the level of the elbow, especially if there is a significant amount of adipose tissue on the upper arm. Excessive adipose tissue may prevent the tourniquet from achieving its goal of restricting venous blood flow. The location of tourniquet placement should be informed by the amount of adipose tissue identified at the site at which the tourniquet is applied. For extremely fragile veins, it may be best to avoid the use of a tourniquet at all, to minimize the risk of a “blown” vessel.

Although elastic latex tourniquets are most commonly used for this purpose, an adequately inflated manual blood pressure cuff can provide similar vein engorgement. The use of two elastic tourniquets (spaced at least one inch apart) may offer additional benefit, but conflicting evidence exists. If the single tourniquet is adequately tightened, the one-tourniquet approach should be sufficient. Tourniquets should not be left tightened for more than 60 seconds, to prevent ischemic injury and pain through reduced perfusion of the distal extremity. If necessary, apply the tourniquet to identify the target vein, and then release the tourniquet while preparing for insertion and reapply the tourniquet(s) when ready to cannulate. Dependent positioning of the extremity will also aid in vein engorgement by leveraging the effects of gravity on venous return. Tapping or slapping the PIV site should be avoided, as this can cause trauma to the area, although vigorous rubbing or firm palpation of the target veins can create the same vein engorgement without such deleterious effects. Palpation should be done with the non-dominant hand. If the vein “rolls,” the dominant hand will be occupied by the PIV cannula, so it is most efficient to be able to palpate with the non-dominant hand while redirecting the catheter with the dominant hand.

“Fist-pumping” by the patient may engorge the vein but can also lead to *pseudohyperkalemia* (i.e., falsely elevated potassium level on serum testing), so this practice should be avoided.

4. *Site targeting and sterilization* are the next steps in PIV insertion. Sterilization is performed with a 70% alcohol wipe or chlorhexidine antiseptic swab for at least 30 seconds, to reduce the risk of iatrogenic contamination of the PIV insertion

site by native skin flora. The recommended cleansing technique is in an abrasive "back and forth" and "up and down" motion for 30 seconds along the path of the target vein, not in a circular motion from the inside-out at the target site. It is important to allow the skin at the target site to completely dry after application of a sterilizing agent, and the provider should not touch the targeted insertion site again after the area has been sterilized.

5. *Puncture of the targeted vessel* can be attempted after the insertion site has been identified and adequately sterilized. The PIV catheter should be gripped firmly in the dominant ("active") hand with the middle finger and thumb placed on each side of the catheter hub, as illustrated in Fig. 3.5. The pointing finger of the dominant hand (when using the one-hand technique) should be left available to advance the catheter once the vessel has been cannulated. The provider's non-dominant ("free") hand is used to apply skin traction 4–5 cm distal to the insertion site, thereby stabilizing the vein and insertion site. Care should be taken to avoid contaminating the insertion site during this step. Improper free hand positioning while providing traction can obstruct needle insertion or place the provider at increased risk for needlestick injury. For example, placement of the non-dominant thumb too close to the insertion site may force an inappropriately large angle of insertion during the PIV attempt, as depicted in Fig. 3.6.

The needle should puncture the skin with its bevel facing upward (i.e., pointed toward the ceiling), usually at an angle of 15 to 20 degrees relative to the plane of

Fig. 3.5 Dominant hand position with PIV insertion. (*Image courtesy of Jeffrey Eichenlaub RN*)

Fig. 3.6 Improper non-dominant thumb interference with PIV insertion. (*Image courtesy of Jeffrey Eichenlaub RN*)

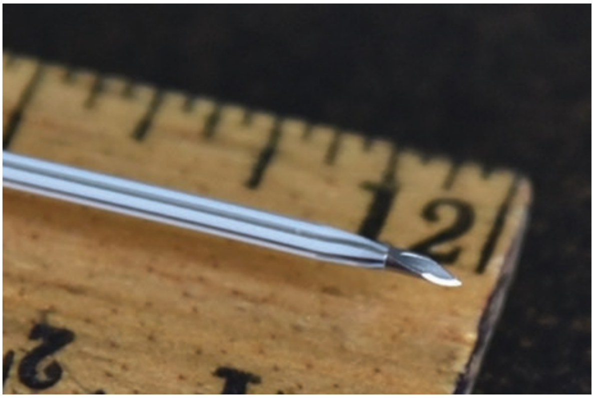


Fig. 3.7 Recommended "bevel-up" needle positioning

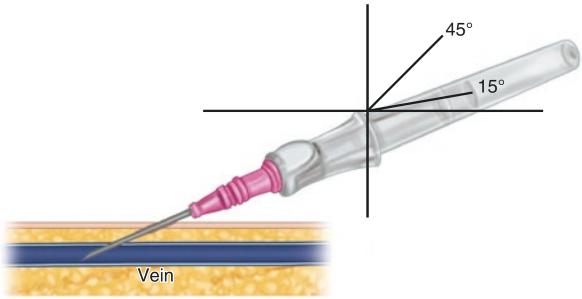


Fig. 3.8 Recommended PIV needle insertion angles during skin puncture

the extremity. Proper bevel placement is depicted in Fig. 3.7. The range of insertion angles typically used is depicted in Fig. 3.8. In general, the angle of insertion should be kept at 15 and 30 degrees relative to the projected plane of the target vessel, as depicted in Fig. 3.8. When deciding upon a skin puncture angle, *the lower the angle, the better*. Excessive angles of insertion (especially those above 45 degrees) risk injury to the vessel wall (Fig. 3.9). As illustrated in Fig. 3.9, excessive angles of insertion for the PIV catheter are more likely to lead to unintentional penetration of the deep wall of the vein, leading to inability to cannulate the vessel and increased likelihood of extravasation and line failure. Of course, the precise angle of skin puncture used (normally ranging from near-zero to 35 degrees) will depend upon limb positioning and the presence of nearby anatomical structures, as well as the predicted fragility and depth of the target vessel. Deeper veins (e.g., AC fossa, or when utilizing ultrasound for guidance) will require a greater angle of insertion, while tortuous, fragile, or superficial (e.g., hand or forearm) veins often require a shallower angle of insertion (Fig. 3.10).

Emergency care providers should ensure that the direction of insertion for the PIV catheter points proximally toward the heart. If a PIV catheter is placed "backward" (i.e., directed away from the heart), the placement will be associated with increased risk of infiltration and/or extravasation.

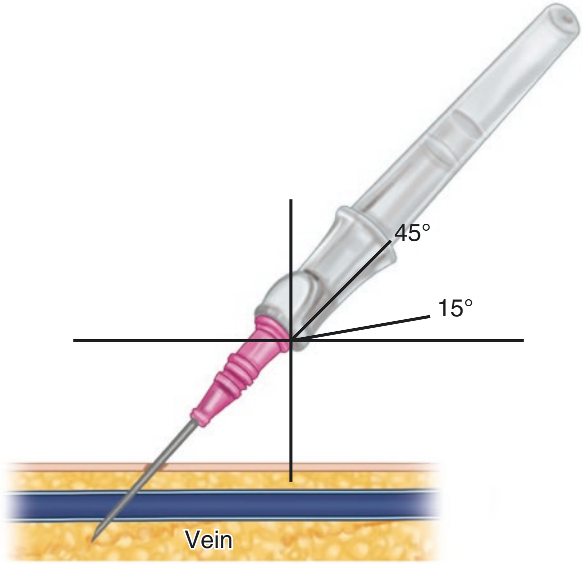


Fig. 3.9 Improper (excessive) insertion angle for skin puncture

Fig. 3.10 Angle of insertion utilized with PIV insertion at the level of the forearm. (*Image courtesy of Jeffrey Eichenlaub RN*)

Both one-handed and two-handed PIV insertion techniques can be utilized, primarily distinguished by which hand is used to advance the PIV catheter after cannulation. Hand positioning with these techniques is illustrated in Figs. 3.11 and 3.12.

The one-handed method is usually preferred, as it frees the non-dominant hand to provide continued traction and stabilization of the targeted insertion site during the access attempt. The non-dominant hand is then available for immediate occlusion of the vein just proximal to the insertion site, while the needle is retracted and heplock is picked up and connected to the hub. The two-handed technique will be suboptimal when patient movement or other environmental factors make stabilization of the insertion site difficult. The experienced emergency care provider should be comfortable with utilizing either the one-handed or two-handed approach, as conditions warrant.

Fig. 3.11 One-handed PIV insertion technique. (*Image courtesy of Jeffrey Eichenlaub RN*)

Fig. 3.12 Two-handed PIV insertion technique. (*Image courtesy of Jeffrey Eichenlaub RN*)

When opening the catheter, it is best to break the seal between the catheter and needle hub so that the index finger of the dominant hand can freely move the tip. While inserting the needle tip, the provider must hold the PIV catheter securely and be guarded against any movement or disruption by the patient. The speed of insertion will depend upon the depth of the targeted vessel, as patient movement can substantially disrupt the access attempt. In general, deeper vessels should be cannulated as fluidly and swiftly as possible, while more superficial or delicate veins may benefit from a slower, more deliberate insertion.

While the PIV catheter is still loaded on one guidance needle, a small (1–2 mm) distance exists between the beveled tip of the needle and the distal tip of the PIV catheter. This relationship is illustrated in Fig. 3.7. When cannulating the vein, the provider must advance the needle-catheter complex just far enough so that the catheter tip is in the lumen, but not so far that the bevel is poked through the opposite side of the vessel. This provides only a small margin of error for the provider when targeting small-caliber veins.

Nursing textbooks and guidelines describe the “direct” and “indirect” methods for PIV insertion [9]. The distinction between these two methods is the number of steps required and the aspect of the vein that is punctured. With the *direct method*, the provider punctures the skin and the superficial aspect of the vein at the same time. Thus, the cannula exits the superficial aspect of the vein, adjacent to the skin surface. With the *indirect method*, the provider first punctures the skin adjacent to the vein and then redirects and punctures the side of the vein. Thus, the cannula exits the side of the vein. The angle of skin puncture (relative to the plane of the vein) should be approximately 30 to 40 degrees using either method [9].

6. *Confirmation of back flow* will be obtained immediately after cannulation and release of the tourniquet, as blood should flow out from the properly placed PIV catheter and directly into the flash chamber. The provider may also feel a "popping" sensation, associated with a sudden change in resistance, once the needle tip has penetrated the vessel. This loss of resistance suggests that the tip of the needle has left the soft tissues and entered into the vessel lumen, as blood is less dense than the surrounding tissues and offers less resistance. Once this "flash" of blood has been observed, the angle of insertion should be dropped immediately by a few degrees. Failure to drop the angle of further insertion after this initial flash will increase the risk of penetrating the opposite vessel wall, leading to extravasation and line failure, or may spear the catheter on the beveled tip of the needle leading to catheter damage. After dropping the angle of insertion, the needle-catheter complex is advanced another 1–2 millimeters, just enough to ensure that the tip of the PIV catheter remains within the lumen of the target vein. If this forward movement is met with resistance, the catheter tip is likely not in the lumen of the target vessel. If this resistance is encountered, the provider should not attempt to advance the needle tip further into the vessel. The provider should either retract the needle tip 1–2 millimeters (if the tip is believed to be too deep) or advance it 1–2 mm further (if considered too shallow) and then re-attempt cannulation. Once the provider believes that the tip of the needle is within the vessel lumen, the index finger of the dominant hand (if using the one-handed technique) is then used to carefully advance the PIV catheter into the lumen of the vessel. When cannulation is successful, venous blood should be noted to flow freely from the catheter.
7. *Needle retraction and vein occlusion* should be performed once the provider has confirmed adequate intraluminal catheter placement through observed continued blood flow through the catheter following insertion. In this step, the provider retracts (i.e., decannulates) the needle from within the catheter and applies firm pressure to the skin just proximal to the insertion site with the index finger of the non-dominant hand to occlude the venous lumen and reduce further blood flow from the catheter. This will facilitate connection of the IV extension apparatus to the hub of the PIV catheter.
8. *Heplock/infusion tubing attachment* is performed after the catheter has been placed and is believed to be in good position without suspicion for misplacement. Continued blood flow from the catheter hub may be an indicator of good positioning within the vessel lumen. Care should be taken to avoid touching the hub or connector portion of the infusion tubing with the gloved hand, as this

may contaminate the catheter with skin flora. It is also important to stabilize the catheter during attachment of the infusion tubing, to avoid inadvertent dislodgement of the catheter during this step.

9. *Catheter flushing* is performed once the catheter has been adequately positioned and the needle has been retracted. The provider should flush the catheter with a prefilled 3-mL or 10-mL normal saline flush to confirm that immediate extravasation of the infused saline into the tissues surrounding the target vein does not occur. If the vein has been properly cannulated, catheter flushing should be painless, without swelling or extravasation of the adjacent soft tissues. However, the vein just proximal to the insertion site will normally blanch and cool slightly due to infusion of the saline solution. If swelling of the soft tissues in this area is observed, the vein is likely ruptured and the placement attempt failed. Further infusion will likely yield extravasation of the infused materials and should be discontinued. Once extravasation has been observed, future attempts at more distal sites on the same extremity should be avoided. However, if the catheter appears to be in good position within the vein, without evidence of extravasation, the catheter should be deemed well-seated and useable for subsequent infusion.
10. *Dressing placement* should be performed immediately after appropriate cannulation of the target vein has been confirmed. Dressing application is usually achieved by placing a transparent sterile semipermeable dressing (e.g., Tegaderm™) over the insertion site, with the center of the dressing located over the insertion site. This dressing shields the insertion site from subsequent bacterial infection, maintaining a waterproof barrier that will also allow oxygen to penetrate for appropriate skin health and wound healing. When the patient is diaphoretic, a sterile absorptive gauze dressing should be applied to the site until the diaphoresis is resolved. If the dressing becomes moist, loose, or soiled, it should be replaced immediately. Certain liquid adhesives (e.g., Mastisol® or tincture of benzoin) can help maintain dressing integrity while providing an additional adhesive property. When using liquid adhesives, the provider should ensure that the liquid adhesive has completely dried after application before applying the overlying dressings. It is worth noting that these liquid adhesives may be more commonly utilized in the ICU setting or with PICC and midline catheters but can be utilized with PIV catheters.
11. *Catheter stabilization* is a critical final step in the placement of PIV catheters. The intention of PIV catheter stabilization is to reduce movement at the insertion site, to prevent inadvertent dislodgement of the catheter. An engineered stabilization device (ESD), placed subcutaneously or topically after PIV placement, is recommended to reduce these risks [9]. Cyanoacrylate tissue adhesives (e.g., Dermabond® or Histoacryl® or ESDs (e.g., "wings") incorporated into the catheter hub are the standard recommended measures for catheter stabilization.
12. *Assessment of catheter infusion* should be performed immediately after insertion of the catheter and intermittently following catheter insertion. *Drip rates* can be used to estimate fluid flow rates. Drip chambers come in two types:

Table 3.2 Drip volumes according to drip set utilized [10]

Drip set	Drip volume (mL/gtt)
Macro (10 gtt/mL)	0.10
Macro (12 gtt/mL)	0.0833
Macro (15 gtt/mL)	0.0666
Macro (20 gtt/mL)	0.05
Micro (60 gtt/mL)	0.0166

macro drip sets (ranging from 10 to 20 drips (gtt)/mL) or micro drip sets (60 drips (gtt) / mL). By counting the number of drips in the chamber over one minute, one may estimate the corresponding infusion flow rate according to the following formula:

$$\text{Flow Rate}\left(\text{mL}/\min\right) = \text{Drip Rate}\left(gtt/\min\right) \times \text{Drip Volume}\left(\text{mL}/gtt\right)$$

In this formula, the Drip Volume has a constant value, which is determined by the type of drip set utilized. The corresponding Drip Volume (mL / gtt) values needed for this calculation are found in Table 3.2.

Providers should periodically observe the drip rate in the IV tubing chamber to determine whether the infusion rate is appropriate. If the provider observes that the drip rate is lower than expected, the catheter and infusion tubing should be inspected to determine whether the IV line is clamped and/or kinked. Catheters located at joint creases (e.g., the AC fossa) may be at higher risk of catheter kinkage with occlusion due to joint flexion, and providers should advise the patient to extend the joint if drip rates are observed to be lower than expected values.

Common Peripheral Vein Targets

We recommend that emergency care providers seek “any port in a storm” when attempting to establish vascular access in the “crashing” patient. Even the most tenuous and hard-fought PIV may have value to critically ill patient under the right clinical conditions. However, there are certain “ports” that are more likely to be available to the emergency care provider than others. The wise clinician will know where to look for these “go-to” access points and should assess the usual and optimal sites first, before deciding to pursue a suboptimal site. Deeper and more proximal veins are usually of larger caliber, providing a larger target for cannulation as well as improved rate of flow, when compared to smaller and more superficial veins. However, deeper veins may also be difficult to visualize and may increase the risk of complications including line placement failure. Thus, an optimal target for landmark-based venous cannulation would be an adequately sized vein that is also identifiable from the skin’s surface. Optimal insertion sites should also offer few impediments to access, provide adequate blood return, be able to withstand high infusion pressures, and be associated with minimal risk of complications from line placement and infusion.

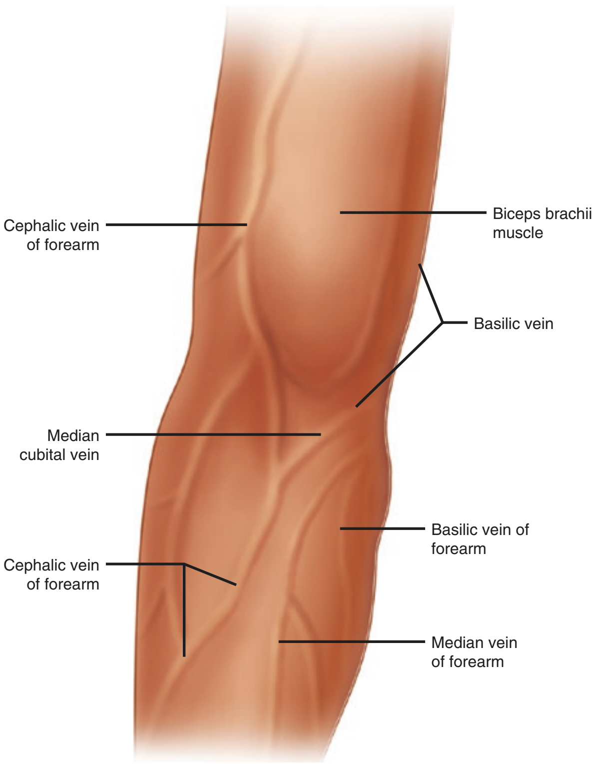
It is critically important when selecting a peripheral target vein to consider (1) whether the selected site is likely to last the full course of the patient's expected therapy and (2) whether the selected site likely exposes the patient to an excessive risk of complications.

The Antecubital (AC) Fossa

The most common sites for PIV access in the emergent setting are located within the antecubital (AC) fossa, which is positioned anterior to the elbow joint. Optimal target veins in this area, also known as the cubital fossa, include the *median cubital*, *basilic*, and *accessory cephalic veins*. These veins are illustrated in Fig. 3.13.

The *median cubital vein* is the largest and most accessible vein for cannulation within the antecubital fossa. As a result, it is often the "go-to" site for PIV insertion at the AC fossa. The *basilic vein* is the next largest but is usually the "last resort" due to concerns about injuring the underlying *brachial artery* and *median nerve*. The *accessory cephalic vein* is smaller, more challenging to secure, but remains an often-accessed vein.

Fig. 3.13 Veins of the antecubital fossa



Although the AC fossa is a commonly utilized site for emergent PIV insertion, there are several disadvantages to the use of veins in this region. Proximity of the brachial artery and median nerve (just deep to the basilic vein) complicates cannulation with the risk of injury to these structures. In addition, flexion at the elbow may cause kinking of the PIV catheter, which will ultimately inhibit forward flow through the catheter. Patients with a PIV inserted at the AC fossa should be instructed to keep their elbow extended as much as possible during venous infusions, which may be both uncomfortable to the patient and difficult to maintain during prolonged infusions. Once inserted, the PIV catheter can compress the median nerve, causing pain that worsens with elbow flexion.

The Upper Arm

If a PIV insertion site cannot be identified at the AC fossa, landmark-based cannulation of an upper arm vein may still be possible. Proximal to the elbow, the provider may be able to visualize and palpate the *basilic vein* or an accessory vein in the upper arm. These veins are large and have the same desirability for cannulation as the AC region. Unlike more distal peripheral targets, upper arm veins are usually straight, out of the way, and not very positional with patient movement. However, access to these veins can present a challenge to novice providers due to the angle for insertion required and increased mobility of the veins. The *brachial vein* may present itself in select patients, but this vein is not always visible on surface landmarking. If the brachial vein is not readily visible, blind placement should not be attempted, due to the poor reliability of this technique and high risk of iatrogenic injury to the underlying nerves and arteries.

The Forearm

Distal to the AC fossa, the most commonly accessed veins are the *basilic*, *cephalic*, and *median veins*, all of which should be accessible on the ventral side of the forearm. The basilic and median veins are located on the medial aspect of the forearm, while the cephalic vein is generally located more laterally. Understanding that proximal veins are likely larger in diameter and therefore preferable for cannulation, providers should seek to cannulate the most proximal vein that presents itself to the provider. The search for a suitable vein should start proximally (i.e., in the upper arm or near to the AC fossa) with attention turned distally once more proximal veins have been deemed inaccessible. The commonly accessed veins of the forearm are illustrated in Fig. 3.14.

The *basilic vein* is located on the medial aspect of the forearm. This vein is often easily visualized and palpated but can be difficult to access. When it travels over a bony prominence, it will be mobile and require firm securement to access. When it travels over the length of the arm, it is more flexible and may require unique positioning to access. One approach to accessing the basilic vein is depicted in Fig. 3.15.

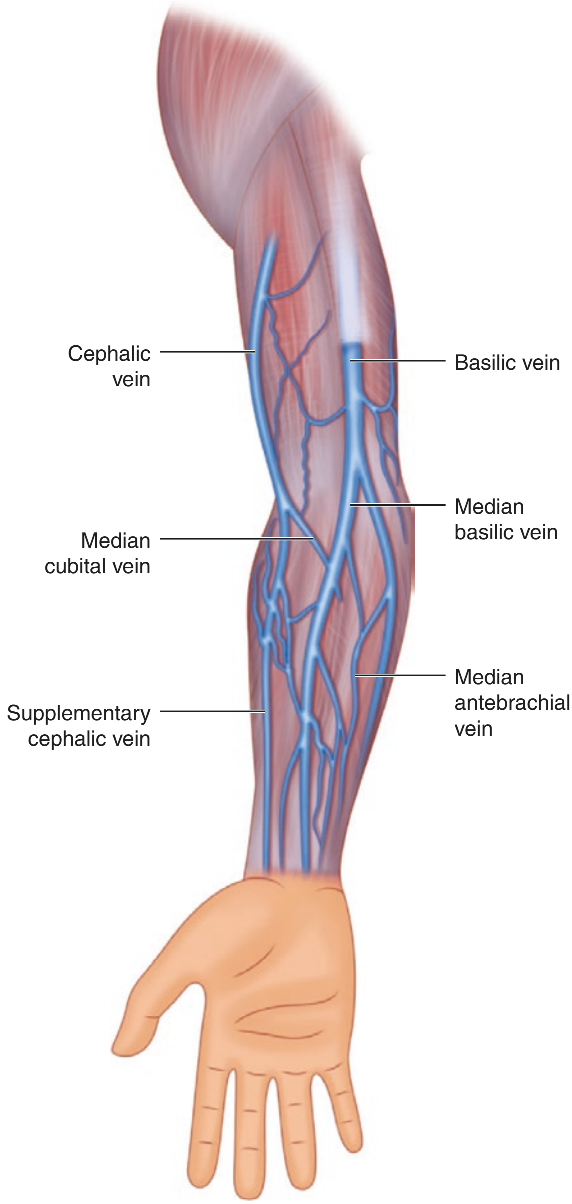


Fig. 3.14 Peripheral veins of the forearm

Note that the patient's elbow is flexed and the provider is situated on the medial and inferior aspect of the forearm.

The *supplementary cephalic vein* is an often-accessed forearm vein that is large, straight, and situated at an optimal anatomic insertion site. This is the "go-to" vein in most trauma resuscitations, as a large (e.g., 14- or 16-gauge) PIV catheter can

Fig. 3.15 Approach to accessing the basilic vein. (*Image courtesy of Jeffrey Eichenlaub RN*)

Fig. 3.16 View of the cephalic vein. (*Image courtesy of Jeffrey Eichenlaub RN*)

often be accommodated, providing high infusion rates. The most common site selected for insertion is just proximal to the wrist joint, on the lateral aspect of the dorsal forearm. This vein must be accessed at a lower angle relative to the plane of the arm when compared to more proximal veins and requires stable securement. An example of the cephalic vein is provided in Fig. 3.16.

The Hand and Wrist

If forearm and AC fossa veins are not available, the next areas to consider are the hand and wrist. The hand is generally not an optimal area for emergent PIV placement, as these veins are usually more tortuous, have smaller diameter, and have

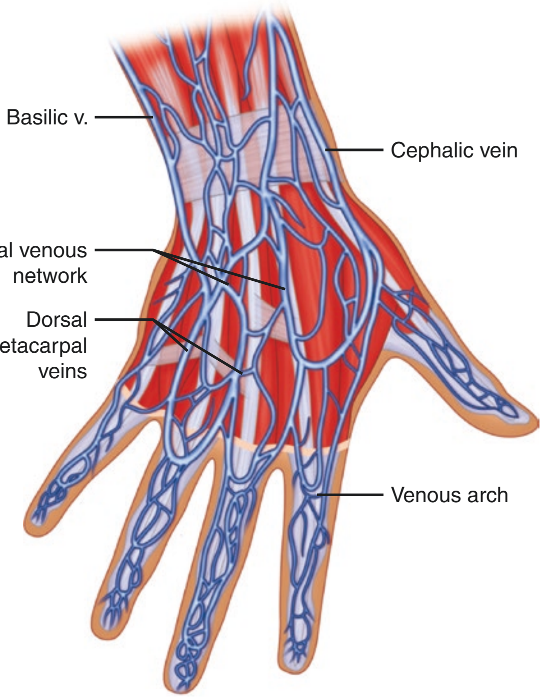


Fig. 3.17 Peripheral venous network of the hand

more valves than the proximal veins of the upper extremity. These smaller veins can be problematic when medications must be infused quickly or may be caustic to the soft tissues. Valves in these small veins may obstruct forward advancement of the catheter. Placing a PIV in the hand also prevents blood draws from being performed proximal to the site when IV fluids are being infused, due to dilution of the venous blood sample with infusates. Furthermore, intravenous contrast injection and other testing may not be able to be delivered through PIVs distal to the wrist due to concern with extravasation of caustic infusates. An illustration of the venous network of the hand is provided in Fig. 3.17.

The most commonly accessed hand veins are the *cephalic, dorsal metacarpal*, and *palmar metacarpal veins*. The dorsal digital veins arise from the adjacent sides of the fingers to form three *dorsal metacarpal veins*, terminating in a dorsal venous network opposite the middle of the metacarpus. These veins are a popular site for peripheral venous cannulation because they tend to be prominent veins which are easily accessible and do not lie over a point of flexion, so cannulation is usually not too uncomfortable for the patient. Veins in the fingers can be used, but require a smaller-gauge PIV catheter, and are usually accessed as a last resort. Veins of the anterior wrist can also be accessed, with the same limitations as digital veins.

The use of veins located on the ventral (palmar) aspect of the wrist, as well as the cephalic vein at the level of the wrist, is not generally recommended due to increased risk of nerve and/or vascular injury [9].

The External Jugular Vein

When veins of the upper extremities are inaccessible, the external jugular (EJ) vein should be considered for cannulation. The EJ vein usually extends between the angle of the mandible and the midpoint of the clavicle, as depicted in Fig. 3.18. The EJ vein is separated from the carotid artery and other vital structures by the sternocleidomastoid muscle (SCM), but iatrogenic injury to the vital structures of the neck (e.g., trachea, lungs, and arteries) is still possible with improper technique. We recommend that the EJ vein be accessed at the most proximal site available, to avoid iatrogenic injury to the lung or other structures. Venous valves are usually located more distally (at the entrance to the subclavian vein and approximately 4 cm superior to the clavicle) and should be avoided.

When attempting EJ vein cannulation, the patient should be placed in Trendelenburg position (i.e., head down) to engorge the vein, with the neck turned to the opposite side, as depicted in Fig. 3.19. The vessel will be noted to collapse in volume-depleted patients with inspiration but can be engorged with direct pressure to the vein just above the clavicle. Stabilization of the vein can be maintained with direct pressure from the thumb of the non-dominant hand during the cannulation attempt. The vein is usually best accessed at an angle of 10 to 25 degrees, although the angle will be dropped once "flashback" of blood has been noted. Cannulation of the EJ vein is relatively contraindicated when the patient cannot tolerate lying flat, has a ventriculoperitoneal (VP) shunt on the targeted side, or is suspected to have cervical spine trauma.

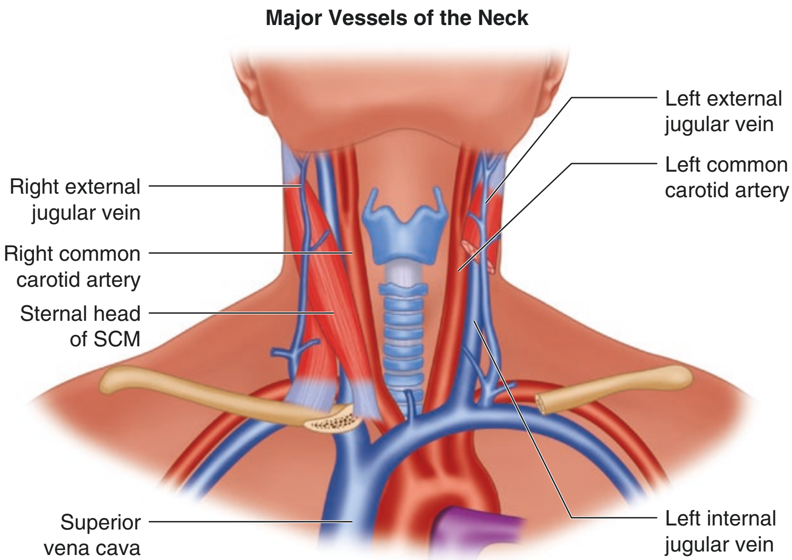


Fig. 3.18 The external jugular (EJ) vein and other great vessels of the neck

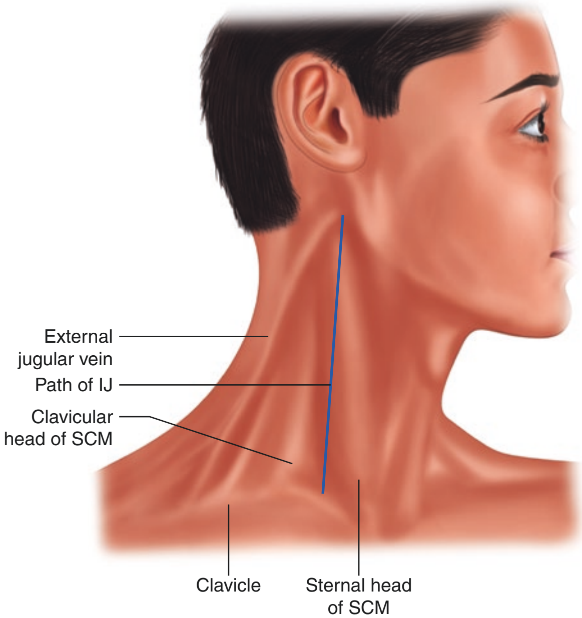


Fig. 3.19 External landmarking for the external jugular (EJ) vein

The Lower Extremity

Veins in the upper torso and legs are usually superficial or tortuous and represent a suboptimal site for PIV insertion. These veins are accessed without a tourniquet, with the catheter inserted at a shallow angle with a smaller-gauge catheter. In general, lower extremity peripheral veins should not be accessed in adults, due to increased risk of complications, but may be appropriate for pediatric patients [9]. The veins of the feet should only be accessed in those patients who do not have known risk factors for complications with vascular access, such as diabetes mellitus, poor wound healing, or known peripheral vascular disease [9]. At most institutions, a physician's order is required to place a pedal PIV, due to the increased risks associated with their use. The most frequently accessed veins of the feet are the *lateral marginal*, *medial marginal*, and *saphenous veins*, which are presented in Fig. 3.20. Due to increased risk of swelling, it is often recommended to elevate the foot for several hours after a failed PIV attempt.

Providers should avoid securing catheters over bony prominences. When selecting a target vein for cannulation, providers should not limit themselves to the most commonly accessed sites if these insertion sites are not available. Rather, the emergency care provider should seek to select the best possible PIV insertion site that may be accessed with the largest possible gauge PIV catheter.

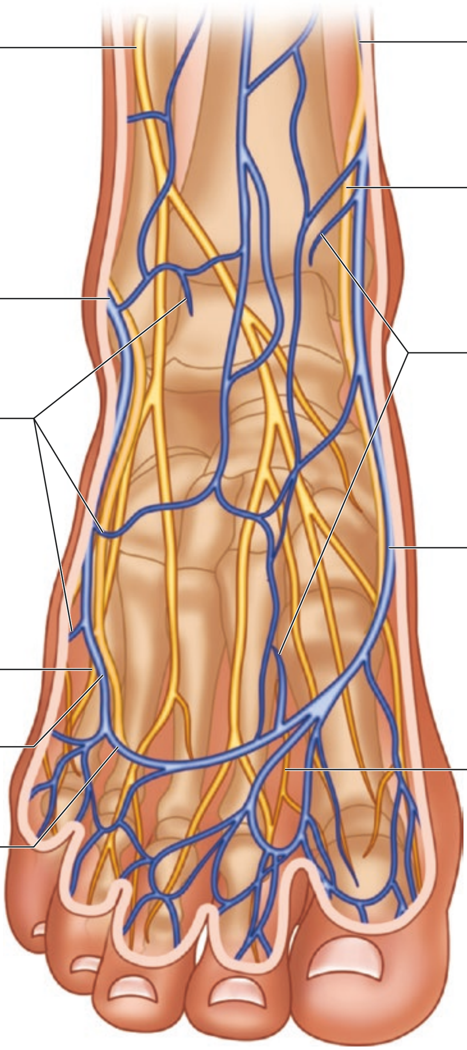


Fig. 3.20 Peripheral veins of the foot

Special Considerations for PIV Insertion

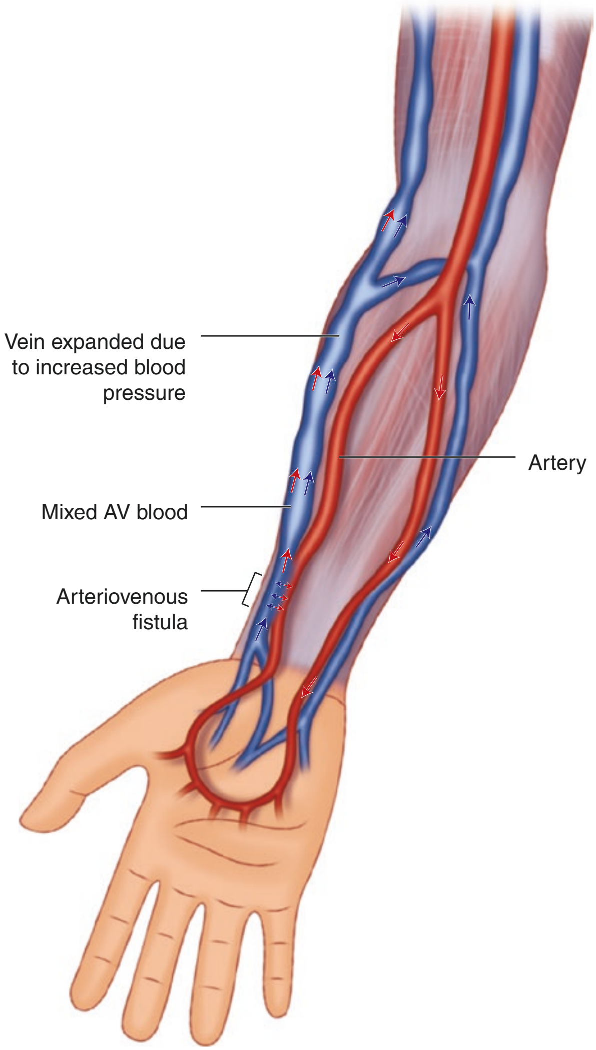
Breast Cancer

Patients with a history of breast cancer should be assessed for a history of mastectomy. If the patient's mastectomy included axillary lymph node removal, the American Cancer Society recommends that the arm on the affected side should not be used for peripheral venous access, due to the likelihood of impaired venous/lymphatic drainage from the extremity [11]. If the patient has had bilateral mastectomies, the arm with the least number of lymph nodes removed or an alternative site should be considered.

Hemodialysis

Patients with end-stage renal disease requiring hemodialysis may have an arteriovenous fistula (AVF) or arteriovenous graft (AVG) [12]. While an AVF anastomoses a native artery and vein, AVGs connect the artery and vein with a synthetic tube or harvested vein. Some patients may have failed AVFs or AVGs at multiple extremities, depending upon the duration of their dependence upon hemodialysis. In the emergent setting, defunct or abandoned AVF/AVG sites should not prevent providers from utilizing the involved extremity, although providers should avoid the AVF or AVG itself, as abandoned AVFs are likely thrombosed and unable to accommodate infusion. However, any extremity containing an AVF/AVG being actively used for dialysis purposes should be avoided. If these active dialysis sites are cannulated, vascular trauma or other complications from the PIV cannulation could cause irreversible damage to the site that may make further dialysis at the site impossible (Fig. 3.21).

Fig. 3.21 Arteriovenous (AV) fistula



To prevent inadvertent compromise of future dialysis therapy, emergent providers should closely examine the patient for evidence of an AVF or AVG prior to establishing PIV access. The most common site of AVF creation is at the level of the wrist, utilizing the radial artery and cephalic vein [11]. When patients have an inadequate cephalic vein, or have failed distal AVF formation, they may have a more proximal AVF created in the upper extremity, either at the level of the proximal forearm (using the brachial artery and cephalic vein) or the upper arm (brachial artery and basilic vein). In general, more proximal AVFs have a higher rate of complications, so the vascular surgeon will usually attempt a more distal site before resorting to more proximal AVF creation [11].

A viable, functional AVF should have a palpable "thrill" (vibration) and audible "bruit" (rumbling or swooshing sound perceived via stethoscope) at the AVF site. The provider should also observe a bulging of the vessel at the AVF site, which is usually quite visible superficially. However, arteriovenous fistulae can take weeks or months to "mature" to a useable state, so the absence of a bruit or thrill (especially in the presence of a dialysis catheter) does not necessarily suggest that the AVF has been abandoned. The AVF may simply be immature. In general, it is best to avoid cannulating a peripheral vein on an extremity that has evidence of an AVF or AVG. Although most AVFs/AVGs will be in the upper extremities, providers should examine the lower extremities as well, as patients with long-standing dialysis requirements may also have lower extremity AVFs. Consequently, the skilled emergency provider will examine the target extremity fully before attempting vascular access in a patient with end-stage renal disease.

Contractures

Patients with contractures can be a challenge for the emergency provider. Attempting to straighten an extremity that is contracted can damage the underlying structures. The best target veins in "contracted" patients are usually located on the posterior aspect of the forearm, the dorsal aspect of the hand, or the external jugular vein. When placing a PIV in a contracted patient, the provider should seek assistance holding position to avoid unsuccessful IV attempts.

Deep Vein Thrombosis

If a patient presents with unilateral upper extremity edema, consider the possibility for a deep vein thrombosis (DVT). It is not appropriate to place an IV in an extremity that could or does have a blood clot. The risk for dislodgement of the DVT or obstruction of flow could be harmful to the patient. These extremities should be used only as a last resort.

Traumatic Injury

Patients presenting with traumatic injuries require special considerations for peripheral IV placement. If the patient has a unilateral upper extremity injury, place the peripheral IV in the contralateral upper extremity. If the patient has bilateral upper extremity injuries, consider PIV placement in the external jugular (preferred) or a lower extremity.

Scar Tissue

Old scar tissue can create difficulties with PIV insertion. Scar tissue is difficult to penetrate and typically requires a larger-gauge catheter (with a thicker cannula) to bypass. The presence of scar tissue should also alert the provider to the likelihood of underlying chronic vascular injury. Scar tissue is also more sensitive to pain than unscarred skin. Certain vessels may develop sclerotic regions related to a history of previous therapeutic cannulations or certain lifestyle choices (e.g., intravenous drug injection). Scarred veins may be readily palpable to the provider but may not be easily accessed. The provider should ensure when palpating the vein that there is a "spongy" texture and not a "tendon-like" feel before selecting the target vein. In general, it is best to avoid PIV insertion in areas of visible scarring. If venous scar tissue is detected in the target area of interest for the line attempt, the provider should start distal to the scarred region rather than proximally. Scarring of the vein may cause a partial obstruction to blood flow, which could (slightly) engorge the more distal contributing veins and collapse more proximal portions of the venous system. The same principle applies to hematomas, which should be avoided and may reduce venous flow at the site of the hematoma and more proximally.

Soft Tissue Edema

Although it is generally preferred to avoid PIV insertion in an area already edematous, this may be necessary in some patients who have widespread peripheral tissue edema. Peripheral veins in these patients are often deeper than expected, requiring a somewhat steeper angle of skin puncture to reach the target. Additionally, edema fluid in the soft tissues is likely to enter into the needle as it is advanced, which increases the importance of "wasting" the initial aliquot of blood drawn through the catheter, when blood sampling is required. The use of a tourniquet and gauze to absorb the fluid may be necessary, and the provider may also be able to manually "push" the edematous tissue away from the targeted skin puncture site. However, care should be taken to avoid excessive force on the underlying vein, as this may compress the target vein (reducing the size of the target), damage the vein, or cause hemolysis of the drawn blood.

Phlebotomy and Order of Blood Draw

In general, the process by which *phlebotomy* (drawing blood) is performed mirrors that of PIV insertion. Whether the goal is simply to obtain venous blood specimens, or to establish peripheral venous access, the provider will utilize a similar technique to cannulate the patient's vein.

Venipuncture for the sole purpose of phlebotomy often involves either a straight needle (typically 21- or 23-gauge) (Fig. 3.22) or a so-called butterfly needle (typically 21-, 23-, or 25-gauge) (Fig. 3.23) to access the target vein. These needles are not intended to be left in place after the phlebotomy has been performed and are not used for venous infusion. Butterfly needles are typically composed of a narrow (21-, 23-, or 25-gauge) needle with "wings," attached to a short length of tubing which

Fig. 3.22 21-gauge straight needle with Vacutainer® tube. (*Image courtesy of Becton, Dickinson and Company Inc. © 2020 Becton, Dickinson and Company Inc. All rights reserved*)

Fig. 3.23 23-gauge butterfly needle with Vacutainer® Safety-Lok® blood collection set. (*Image courtesy of Becton, Dickinson and Company Inc. © 2020 Becton, Dickinson and Company Inc. All rights reserved*)

terminates in a Luer connector. This connector can be attached to a Vacutainer® tube (Becton, Dickinson & Company) or syringe for vacuum-assisted blood extraction.

However, many patients who require emergent vascular access also require blood tests for their care. Thus, it is very common for providers to draw blood directly

Fig. 3.24 Vacutainer® system multiple sample device with Luer adapter. (*Image courtesy of Becton, Dickinson and Company Inc. © 2020 Becton, Dickinson and Company Inc. All rights reserved*)

from the PIV (or CVC) catheter immediately after the line has been placed, but before the infusion tubing is attached. This may be accomplished with use of a Vacutainer® tube (Becton, Dickinson & Company) system or by direct connection of a syringe to the catheter (Fig. 3.24).

Hemolysis is a common problem with phlebotomy. When it occurs, multiple false laboratory derangements will be resulted, including pseudohyperkalemia. Unfortunately, hemolysis is estimated to occur in up to 8% of all blood draws performed in the emergency department [13]. Hemolysis occurs when red blood cells (RBCs) are fragmented, which may be attributed to a variety of factors. The use of needles that are too large compared to the diameter of the target vein can cause hemolysis, as will excessive vacuum suction force. For this reason, providers should use small (e.g., 5- or 10-mL syringes) to draw blood from PIV starts and should draw the blood as slowly as possible. Larger-capacity (e.g., 20-mL) syringes will generate much larger vacuum force than smaller syringes. The need to reduce vacuum force is especially important with small-diameter PIV catheters, as the blood flows more turbulently and is exposed to greater mechanical friction. The use of smaller volume (e.g., 5-mL) Vacutainer® tubes may also reduce this risk [14, 15]. Fist-pumping, placement of the tourniquet too close to the puncture site, and failure to immediately invert the collection tube after drawing also increase the risk of specimen hemolysis.

Blood sample clotting is another common problem, especially with coagulation studies. Blood begins clotting the moment it first enters the needle, and prolonged blood draws can risk clotting of the blood before the specimen ever enters the collection tube. Drawn blood should be immediately injected into the collection tube, and the provider should immediately and adequately invert the collection tube. Samples should be sent to the laboratory as soon as possible after collection.

The *order of blood* draw must also be respected, whether the blood is obtained through a venous catheter or simple venipuncture. The correct order of draw is depicted in Table 3.3. Additives specific to each tube will differentiate their properties for laboratory processing. If one additive contaminates another one during the blood draw, the test may be rendered ineffective, and blood samples may need to be redrawn. For example, blue (sodium citrate) tubes are used for PT and PTT – it would not be ideal for this tube/test to be contaminated with either a clotting agent or a heparinizing agent.

Table 3.3 Vacutainer® tubes with corresponding labs, in correct order of draw

Order of Draw	Color Tube / Top	Additives	Common Tests*	Number of Inversions
1	 **Blood culture**	N/A	Blood cultures	Invert gently to mix
2	 **Light Blue**	Sodium citrate anticoagulant	D-dimer Factor assays Fibrinogen INR / PT/ PTT Lupus anticoagulant Special coagulation studies	3-4
3	 **Red** **Gold** **"Tiger top"**(red and black speckled)  	Clot activator (silicone-coated) Clot activator and gel for serum separation	Alcohol level Amylase / lipase Anticonvulsant levels Vitamin B12 / Folate Biochemistry profiles Cancer markers Cardiac markers Digoxin Hormone studies HCG (i.e., pregnancy test) Hepatic / Hepatitis panel Human Immunodeficiency Virus (HIV) Homocysteine (on ice) Insulin Iron studies Lidocaine level Lipid panel Lithium level Rheumatoid factor Salicylate level Thyroid studies Therapeutic drug levels Vitamin D	5
4	 **Light Green**	Lithium heparin, with gel separator for plasma separation	Ammonia (on ice) Biochemistry profiles (STAT) Blood alcohol level Hepatic panel Ionized calcium Lipid Panels Renal function tests Rheumatoid factor Therapeutic drug levels (except Vancomycin) Toxicology tests Troponin	8-10
5	 **Dark Green**	Lithium heparin, without separator (***not used often in acute settings***)	Similar to Light Green Lactic Acid (NOT on ice)	8-10

Table 3.3 (continued)

6		**Lavender / Purple**	Spray-coated K_2EDTA anticoagulant	Adrenocorticotropic hormone (ACTH) Brain Natriuretic Peptide (BNP) Complete Blood Count (CBC) w/differential CD3 / CD4 counts Cyclosporine Erythrocyte Sedimentation Rate (ESR) Factor V Leiden Hemoglobin & Hematocrit HgbA1C Parathyroid Hormone (PTH) RBC folate Reticulocyte count Thalassemia screening Vancomycin	8-10
7		**Pink**	K_2EDTA anticoagulant	Antibody screens Crossmatch Rhogam workup Type & Rh Type & Screen	8-10
8		**Gray**	Sodium fluorideand Potassium oxalate	Glucose Lactic acid (on ice)	8-10
9		**Royal / Navy Blue**	K_2EDTAanticoagulant	Aluminum Arsenic Cadmium Chromium Lead Manganese Mercury	8-10

[a]Note: list is not exhaustive and may vary between laboratories

Conclusions

Landmark-based peripheral IV catheter placement remains the “gold standard” for vascular access and should generally be the first type of vascular access attempted for most patients, including those presenting under emergent conditions. Insertion site selection should be informed by a general understanding of the usual human anatomy but also by the patient’s specific clinical condition and therapeutic needs. Providers must balance the patient’s anticipated therapeutic needs with the availability of peripheral veins for cannulation. A thorough examination is essential to proper site selection, including identification of certain risk factors for difficult or complicated vascular access. When accessing the peripheral veins for simple phlebotomy or for PIV placement, consider the patient’s anticipated needs for care, including which medications or fluids may be needed to stabilize the patient.

Key Concepts

- Peripheral intravenous access is best obtained by "feel," not by sight. The provider can usually judge the location and depth of the vein by rebound following gentle direct pressure.
- The provider should use their heart, not just their head, when placing a peripheral IV catheter. They should have an appropriate level of confidence in their abilities, and not "overthink" the process.
- Providers should always place the tourniquet tightly. Even if it seems tight enough, it probably is not.
- Under emergent conditions, always use the largest gauge catheter that can be placed safely without additional risk of complications to the patient. Critically-ill patients often require large-bore vascular access, and it may be difficult to predict what medications and/or fluids may be needed for an undifferentiated and unstable patient.
- Catheters should be inserted from the proper angle, starting superficially. Providers can always "go deeper" if they did not hit the vessel the first time. It is much harder to salvage a vessel after injuring it by going too deep.
- Providers must take care to never obstruct their access to the insertion point with their own thumb or other objects. This will force the insertion angle to be too steep, and put the provider at increased risk of accidental needlestick injury.
- Providers should not reuse a needle once it has punctured the skin. Peripheral intravenous devices are "one poke only" devices and lose their sharpness after the initial puncture.
- When a patient is overly mobile, scared, or combative, providers should always bring a "buddy" to help secure and stabilize the insertion site. Holding the patient's hand, or gently restraining the patient's extremity, may reduce the risk of placement complications for both patient and provider.
- Providers should always exercise caution to avoid accidental blood exposure or self-injury.
- Prior to selecting the appropriate catheter insertion site, providers should fully examine the patient to identify dialysis fistulas/grafts, scar tissue, traumatic injuries, distortion of anatomic landmarks, and other anatomic features that may ultimately prove to be obstacles to placement success.

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