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# Ultrasound for central venous, arterial and peripheral venous cannulation in the pediatric population

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Key points

1. Although ultrasound techniques can facilitate vascular access, in the emergency situation when access to the circulation is required within seconds, the intraosseous route is recommended and can be used to provide life-saving medications.
2. Although it is generally proposed that the internal jugular vein runs just lateral to the carotid artery, ultrasonographic analysis has demonstrated anatomical variations in up to 10% of the population.
3. In specific clinical scenarios (hypotension, hypoperfusion, systemic anticoagulation), the use of ultrasound for arterial cannula placement may facilitate the procedure and decrease the incidence of adverse effects by allowing visualization of the artery and needle entry.
4. In our clinical practice, by using ultrasound-guidance, we have found a significant decrease in preparation time for major surgical procedures in patients with a history of difficult venous access as well as the ability to place a peripheral cannula when multiple attempts at cannulation have failed.

## Abstract

Adequate vascular access remains a key component of perioperative care. Various factors including obesity, prolonged hospitalizations, and associated co-morbid conditions can magnify problems with vascular access. Although used initially to facilitate central venous access, ultrasound is being used more commonly to facilitate arterial and even peripheral venous access. This practice has been facilitated by improvements in both the quality of the image and the portability of the equipment thereby allowing its easy movement throughout the operating room and beyond. The following article reviews the applications of ultrasound for routine and difficult central venous, arterial, and peripheral vascular cannulation in the pediatric population.

**Keywords:** ultrasound, vascular access, central venous access, arterial cannulation.

## Introduction

Following airway management, vascular access represents the second most critical technical component of perioperative care. Depending on the magnitude of the surgery and the patient's co-morbid conditions, perioperative care may require central venous, arterial or peripheral venous cannulation. In the majority of patients, such access is generally not problematic, being accomplished in either the awake or anesthetized state with limited risk of morbidity. However, various factors including obesity, prolonged hospitalizations, prematuring, and associated co-morbid conditions can magnify problems with vascular access.

In the emergency situation when access to the circulation is required within seconds, the intraosseous route is recommended and can be used for the administration of life-saving medications.[1-3] As such, the routine availability of such equipment is recommended in all anesthetizing locations. In non-emergent situations, ultrasound imaging can be used to facilitate vascular access in patients of all ages. Although used initially to facilitate central venous access, ultrasound is being used more commonly to facilitate arterial and even peripheral venous access. This practice has been facilitated by improvements in both the quality of the image and the portability of the equipment thereby allowing its easy movement throughout the operating room and beyond.

## Central venous access

Although not practiced uniformly, the use of ultrasound for central venous access has rapidly gained acceptance and is now considered by many to represent the standard of care when placing a central venous catheter. The use of ultrasound-guidance may be particularly beneficial in smaller pediatric patients including neonates and infants because of the smaller caliber of the vessels and perhaps a greater likelihood of non-optimal anatomy (carotid artery and internal jugular vein overlapping). The problems posed by these anatomical variations are highlighted by the fact that the greatest risk factor for a complication during placement of a central venous catheter in a child is the number of needle punctures and attempts.[4-6] Prior to the advent of ultrasound in the operating room, the site for placement of a central venous catheter was identified using surface landmarks or the pulsation of the carotid artery.[7,8] However, such techniques fail to provide information regarding variations in the anatomical position of the great vessels in the neck. The potential for such variations is exemplified by an investigation of two-dimensional ultrasound of the internal jugular, subclavian, and femoral vein of 142 infants and children.[9] The authors noted a 7.7% variation for the IJV with the most common being a lateral (n=9) or anterior (n=9) position of the internal jugular vein in relationship to the carotid artery. Similar variation was noted for the femoral vein. The most common anatomic variation was that the femoral ran anteromedially to the femoral artery. Anatomic variation was also noted for the subclavian vein with the most common variant being a vein which ran medially to the subclavian artery. The authors concluded that the relevant percentages of anatomic variations obtained for all these areas support at least a systematic ultrasound screening before attempting to obtain central venous access.

When using ultrasound, two techniques are generally described. Static ultrasonography uses the device to identify anatomic abnormalities and in many cases to optimize head positioning and mark the superficial skin for the appropriate insertion site. Optimization of head position is particularly relevant in the pediatric population as the flexibility of the neck may lead to excessive rotation of the head to the left or right resulting in overlapping of the two vessels (carotid artery and internal jugular vein) or compression of the vein. Dynamic scanning uses ultrasound during central venous cannula placement in real time. The latter technique obviously has a small learning curve as the typical technique may change as one hand is required to hold the ultrasound device while the other is placed on the syringe and needle. The superiority of the static technique and its efficacy compared to the use of surface landmarks is clearly demonstrated by two studies.[10,11] In the first of these two studies, 40 infants less than 2 years of age were randomly assigned to internal jugular vein localization using static ultrasound prior to cannulation or the use of landmarks.[10] The use of ultrasound resulted in a higher success rate (100% versus 80%), shorter procedure time (average of 23 versus 56.4 seconds), and fewer attempts (mean of 1.35 versus 2 attempts). In the second study, randomization to the same two techniques was used.[11] The authors also noted a greater success rate (100% versus 80%), decreased incidence of carotid puncture (3.1% versus 26.7%), and a decreased number of attempts (mean of 1.57 vs. 2.55).[11]

Others have investigated the use of a dynamic ultrasound technique.[12,13] Verghese et al studied 95 infants requiring central venous access for cardiac surgery.[12] Again, with the use of ultrasound, the investigators noted fewer attempts (median of 1 versus 2), shorter time to central venous catheter placement (median of 3.3 versus 10 minutes), fewer carotid punctures (0% versus 25%), and a greater success rate (100% versus 77%). In a follow-up study by the same investigators, 45 infants were randomized to one of three techniques that included use of the landmark technique, external dynamic ultrasound, or an internal ultrasound device.[13] The latter used a continuous-wave Doppler that was built into the introducer needle which produced an audible signal to help differentiate between the internal jugular vein and the carotid artery.[13] The time for cannulation was shorter with external (dynamic) ultrasonography compared with internal ultrasonography, but not different from the landmark technique. The median number of cannulation attempts was lower in the external ultrasound group compared with the other two techniques. Although there are fewer studies, ultrasound has also demonstrated its superiority for femoral and subclavian vein cannulation.[14-17]

The use of ultrasound to facilitate central venous access was first reported in 1986. The literature clearly demonstrates that ultrasound-guided vascular access is being widely adopted as a technique that prevents insertion-related complications (inadvertent carotid puncture), decreases the number of punctures required, decreases procedure time, and increases success rate. Guidelines from the National Institute for Clinical Excellence (NICE) which were finalized in September 2002 recommended the use of ultrasound guidance for central venous catheterization in children.[18] This document recommends the use of real-time ultrasound as the for the elective placement of central venous catheters (internal jugular vein approach) in adults and children. The rebuttal to such a document is that some clinicians have expressed concern that if ultrasound is noted used, complications of central venous cannulation will be difficult to defend in court.[19] These same investigators have also published data suggesting that in experienced hands that ultrasonography is not necessary.[19] In a prospective trial of 142 infants and children, randomized to either ultrasound-guided or traditional landmark-guided central venous catheterization, the authors failed to show an advantage to ultrasound use. In fact, they reported that the success rate was significantly greater in the landmark group compared with the ultrasound group (89.3% vs 78%, $p<0.002$) and that arterial puncture rates were significantly lower in the landmark group (6.2% vs 11.9%, $p<0.03$). Furthermore, they noted no significant difference between the two groups regarding procedure time. They concluded that their results are different from the published results on which the NICE guidelines were based, there are limited data in the pediatric population, and there is currently insufficient evidence to support the use of ultrasound guidance for central venous catheterization in children.

Despite such controversy, it is apparent that ultrasound adds limited risk and that for the majority of patients, it may offer significant advantage. In fact, it is now being considered the standard of care in many countries. Given these findings, the authors believe that ultrasound should be used routinely for obtaining central venous access in pediatric patients. The technique allows visualization of the anatomical relationship of the vessels, identification of the needle entry into the internal jugular vein, and when placed in the longitudinal view, can also be used to identify the wire within the vessel prior to cannula placement (figures 1 and 2). Despite its efficacy and the need to consider its use in most scenarios, it seems prudent to continue to teach landmark techniqques as well as appropriate ultrasound techniques for central venous access.

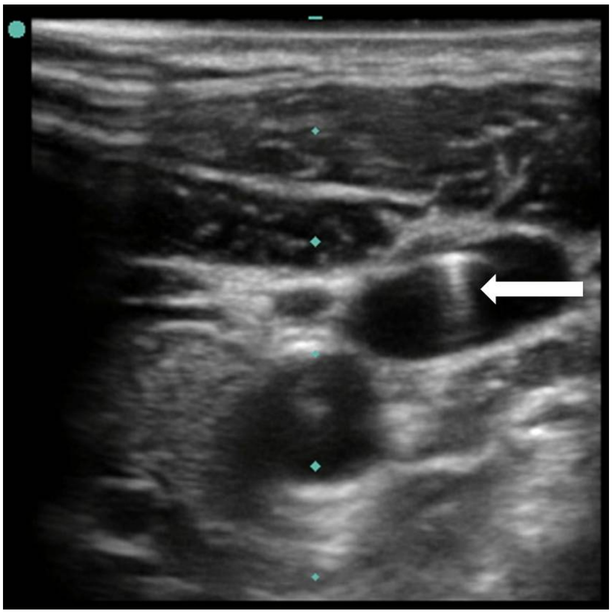

Fig. 1. Ultrasound of the neck showing the relationship of the carotid artery (medial) and internal jugular vein (lateral). Needle entry into the vessel can be noted by the hyperechoic structure (arrow) within the internal jugular vein.

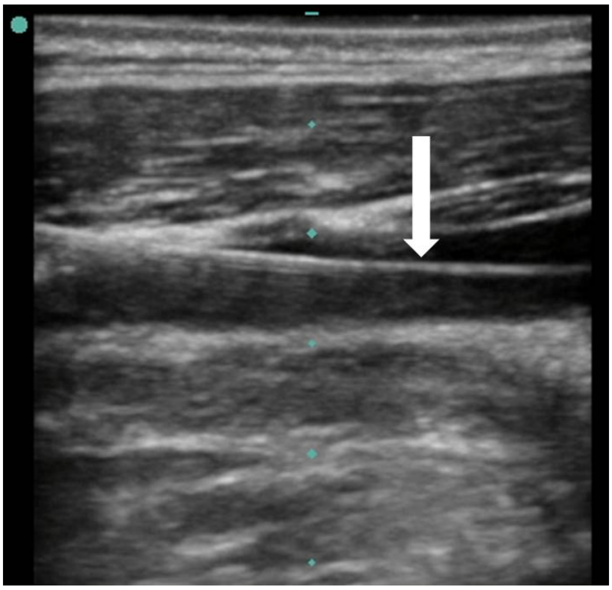

Fig. 2 Longitudinal ultrasound of the internal jugular vein demonstrating the guide wire (arrow) within the lumen of the vessel.

### Arterial cannula placement

In most cases, arterial cannula placement is performed by palpation of the artery and insertion of a cannula blindly. The technique of insertion varies among providers and may include direct placement of a standard intravenous cannula, the Seldinger technique with a separate needle, wire and catheter or use of a commercially available device with a needle, cannula and wire in a single product (Arrow arterial catheterization kit, Teleflex Corporation). In specific clinical scenarios (hypotension, hypoperfusion, systemic anticoagulation), the use of ultrasound may facilitate the procedure and decrease the incidence of adverse effects by allowing visualization of the artery and needle entry. As with central venous access, the first reports regarding the use of ultrasound to facilitate arterial cannulation were from the adult literature. In a prospective trial, 69 adult patients requiring radial artery cannulation, patients were randomized to the classic palpation technique (blind stick) or ultrasound guidance.[20] With ultrasound guidance, there was a higher success rate of cannulation (62% versus 34%) and fewer attempts (average of 1.6 versus 3.1). The potential utility of ultrasound for radial artery cannulation has also been demonstrated in the emergency department setting.[21] With the use of ultrasound, the authors noted fewer attempts (average of 1.2 versus 2.2) and decreased time to successful cannulation (average of 107 versus 314 seconds).

Similar efficacy has also been demonstrated in the pediatric population with decreased time to successful cannulation, fewer attempts, and increased success rate in various studies.[22,23] In the first of these studies, Schwemmer et al. prospectively randomized 30 children requiring radial artery cannulation to ultrasound guidance or the traditional palpation method.[22] With the use of ultrasound guidance, there was an increased success rate (100% versus 80%) and fewer attempts required (average of 1.3 versus 2.3). Although another group of investigators found no difference in success rate, time to cannulation or total number of attempts in a prospective trial of 152 children in the operating, the study has been questioned because of the lack of experience with ultrasound of the study participants.[24] None of participants had performed more than 10 ultrasound-guided radial artery cannulations.

Given that the adverse effect profile with radial artery cannulation is generally less worrisome than central venous cannulation, the author would be hard pressed to state that the use of ultrasound represents that standard of care. However, given the size of the arteries in younger infants and neonates, it seems that if one has gained facility with ultrasound that it can be a useful aid for arterial cannulation.[25,26] The use of ultrasound is especially suggested in patient with bleeding dyscrasias or receiving therapeutic anticoagulation as the risks of cannulation may be magnified should inadvertent arterial damage occur. We have also found it particularly useful for patients with diminished peripheral pulses, in patients with contractures (cerebral palsy) which precludes placement in the distal radial site necessitating use of the radial artery more distally along the forearm, and during femoral artery cannulation. During cannulation, an out-of-plane technique can be used so that the needle and cannula can be seen entering the artery (figure 3). Following this, the transducer can be turned in-plane and the catheter can be observed as it is threaded off the needle into the vessel (figure 4).

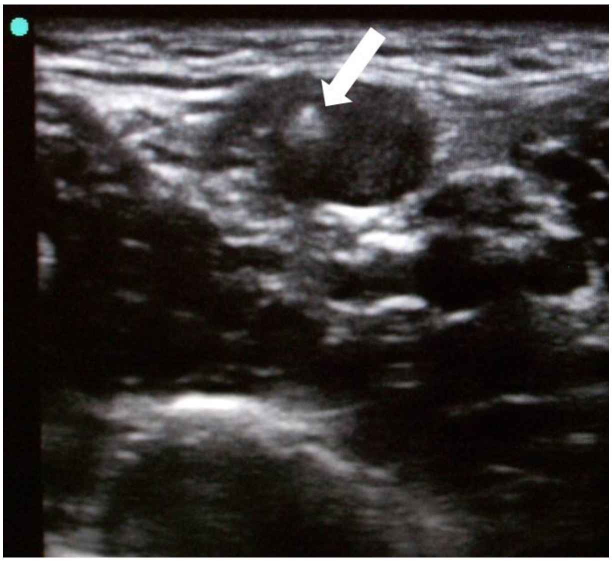

Fig. 3. Sonographic image of an out-of-plane technique with visualization of the needle and cannula (arrow) entering the artery.

Although a standard intravenous cannula can generally be used for routine placement, we have found that use of a Seldinger technique whereby the artery is puncture with a needle followed by guide wire placement is generally easier and may increase the percentage of successful cannulations. For such purposes, we use either a 3 French cannula with a 22 gauge needle and a 0.018" wire or a 2.5 French cannula with a 23 gauge needle and a 0.015" wire.

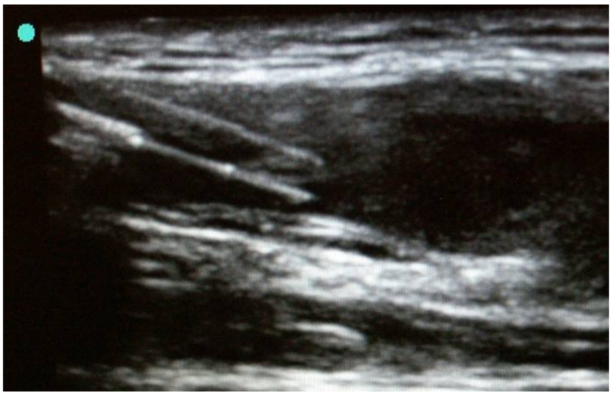

Fig. 4. Sonographic image with the transducer turned for an in-plane technique. The catheter can be observed as it is threaded off the needle into the vessel.

## Peripheral venous cannulation

The timely establishment of peripheral intravenous access in the pediatric patient of any age may at times be challenging. Aside from its routine use in the operating room, the establishment of intravenous access is mandatory for resuscitation in clinical scenarios. Various options have been suggested as an alternative when routine peripheral venous access fails including the intra-arterial, intramuscular (IM), and intraosseous routes.[1-3,27,28] The intra-arterial route is acceptable for a limited number of medications while the IM route results in delays in uptake and onset as well as being feasible for a limited number of medications.[27,28] In the emergency setting when the rapid administration of life-saving medications is necessary, the IO route should be used and equipment for the establishment of IO access should be in every anesthetizing location.[2] However, in less urgent situations, other options may be considered.

Aside from delaying the onset of the operative procedure and its impact on the economics of the operating room, prolonged times from the inhalational induction of anesthesia to the establishment of vascular access may predispose the patient to gastric air insufflation, vomiting with aspiration, atelectasis, hypoxemia, hypercapnia, hypothermia, and hemodynamic instability. While some have suggested the routine use of IO access for elective surgical procedures[3], we have found great utility with the use of ultrasound in securing peripheral intravenous access in difficult clinical scenarios. The use of ultrasound has clinically resulted in a decrease in preparation time, the ability to place large bore venous cannulae for the rapid administration of blood and blood products, and a decrease in the need for central venous access.

The role of ultrasound for difficult venous cannulation has been demonstrated in both the adult and pediatric patient.[29-33] Bair et al noted that the use of ultrasound by Pediatric Emergency Department faculty allowed more accurate visualization of the vein, but no difference in success rate was noted.[31] In a prospective, randomized study in patients less than 10 years of age with a history of difficult venous access or two unsuccessful attempts at peripheral cannula placement, the use of ultrasound increased the success rate (80% versus 64%), decreased the number of attempts (median of one versus three), and decreased procedure time (average of 6.3 versus 14.4 minutes).[31]

The study of Bair et al most closely parallels our current use of ultrasound for peripheral venous cannulation as we turn to the technique when superficial identification of appropriate veins is not possible. When using ultrasound for peripheral venous cannulation, some basic knowledge of the venous drainage system is useful to facilitate placement of the ultrasound probe and identification of appropriate veins. We prefer to use the saphenous above the medical malleolus or higher up the lower aspect of the leg or the saphenous as it crosses the medical condyle of the femur into the middle aspect of the thigh. Alternatively, the deep veins of the forearm or upper arm can also be used (figure 5). In general, except for brief procedures, the antecubital area should be avoided as flexion during positioning may occlude these cannulae and make infusion impractical. For cannulation of the vein, various techniques can be used. Standard intravenous cannulae can be used and advanced into the vein. This can start with a transverse view of the lumen (out-of-plane view) of the vein to identify the vein (figure 6). Assurance that the hypoechoic structure is a vein can be provided by its easy compressibility with minimal pressure from the ultrasound probe (figure 7). The ultrasound probe is then turned to a longitudinal vein (in-plane) to observe the cannula as it is advanced off the needle into the vein. When available, we have found that that non-safety needles may be easier to use. When accessing the deeper veins that are identified by ultrasound, standard gauges (22, 20 and 18) that are longer than those used for standard peripheral access may be helpful (figure 8). Alternatively, a Seldinger technique can be used with a micropuncture kit which has a 21 or 22 gauge needle and a 0.018" wire which has a dilator and sheath. This allows placement of a 4 or 5 French sheath over a 0.018" with puncture of a vessel using the 21 or 22 gauge needle (figure 9).

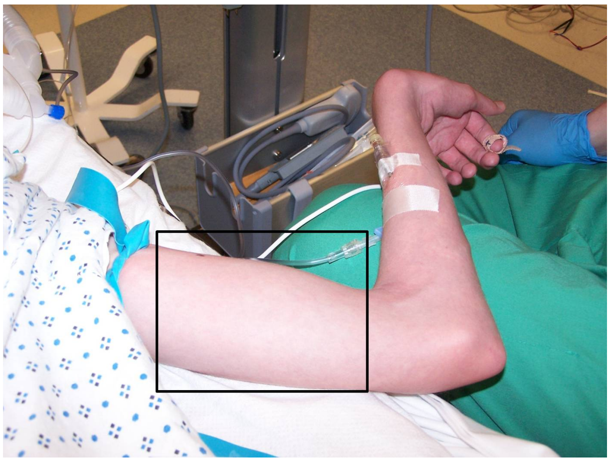

Fig. 5. Upper extremity with tourniquet applied for ultrasound-guided peripheral vascular access. The region enclosed in the black box is the suggested starting point for ultrasound scanning to identify deep venous structures.

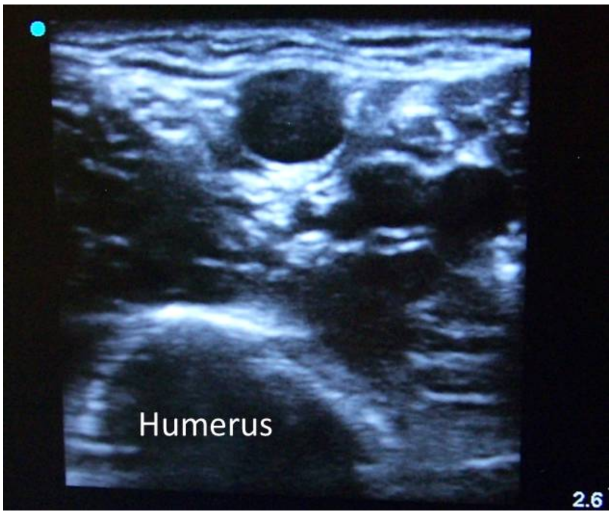


Fig. 6. Sonographic image of a distal blood vessel in the forearm. The deep hypoechoic structure is the humerus.

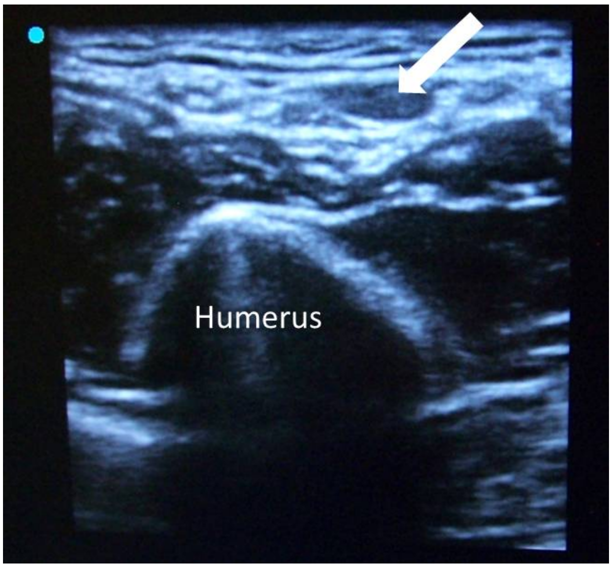


Fig. 7. Sonographic image demonstrating confirmation that the structure is a vein as it is easily compressible (arrow) with minimal pressure from the ultrasound probe.

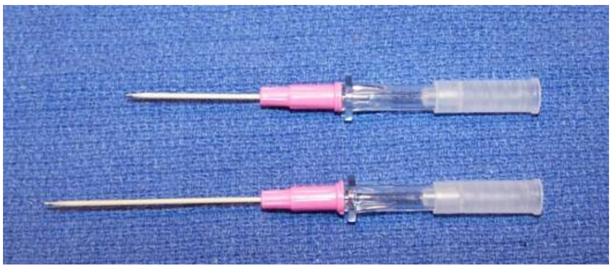

Fig. 8. Non-safety 20 gauge intravenous cannulae for ultrasound-guided peripheral venous access. These catheters are frequently available in various lengths to facilitate cannulation of deeper venous structures.

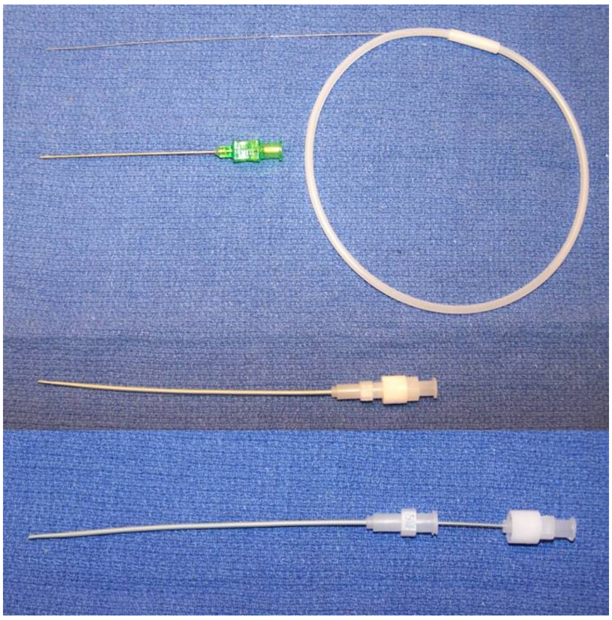

Fig. 9. Commercially available micropuncture kit (Cook Medical, Bloomington, Indiana, USA) for cannulation of deep venous structures using a Seldinger technique. The kit contains a 21 gauge needle, an 0.018" wire as well as a dilator and sheath. This allows placement of a 5 French cannula over a 0.018" with puncture of a vessel using the 21 gauge needle.

## Summary

Since its initial description, there has been growing use of ultrasound-guided techniques for vascular access in clinical practice. These techniques started for central venous access and have expanded to include arterial and peripheral venous cannulation. Regardless of the procedure, it would make sense that a technique which allows visualization of the structures to be cannulated would offer significant advantages over a blind technique. As with any technology, the use of ultrasound requires practice. This includes knowledge of the machine and its working parameters as well as experience to identify the appropriate deep vascular structures. Practice will also increase the hand-eye coordination that is necessary to hold the probe in one hand and cannulate the vessel with the other. The need to hold the ultrasound probe with one hand results in only one hand being free to control the needle and syringe. Without this practice, the time of set-up and use may nullify any time saved during the procedure. We have also found that success can be further increased by a two person procedure. One person holds the ultrasound sound probe and observes for a flash in the syringe or needle while the second person directs the needed. Although initially used for placement of central venous cannula, it appears that the technology is useful for peripheral arterial and venous cannulation. In our clinical practice, we have found a significant decrease in preparation time for major surgical procedures in patients with a history of difficult venous access as well as the ability to place a peripheral cannula when multiple attempts at peripheral cannulation have failed. In some cases, the option of cancelling the case was being considered. The chances of success will also be increased by having the right machine and the correct equipment (needles, wires, dilators, and cannulae) for vascular access. Regardless of the utility of the technique, all anesthesia providers should be facile with placement of an IO needle as it remains the access option of choice during an emergency situation when peripheral venous access is not available.

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