Utility of Ultrasound Guidance for Central Venous Access in Children

Chen He, MD,* Rebecca Vieira, MD, RDMS,† and Jennifer R. Marin, MD, MSc‡

BACKGROUND: Placement of a central venous catheter (CVC) in a pediatric patient is an important skill for pediatric emergency medicine physicians but can be challenging and time consuming. Ultrasound (US) guidance has been shown to improve success of central line placement in adult patients.

OBJECTIVES: This article aims to review the literature and evaluate the benefit of US guidance in the placement of CVCs, specifically in pediatric emergency department patients, and to review the procedure.

RESULTS: Four meta-analyses of US-guided CVC placement in adult patients concluded that US guidance reduces placement failure, decreases complications, and decreases the need for multiple attempts. Two studies in the emergency department setting support these conclusions. Pediatric-specific data related to US-guided CVC placement include data suggesting a benefit with US guidance, as well as data indicating no difference in outcome measures when US guidance is used compared with the landmark technique.

CONCLUSIONS: The evidence surrounding US-guided CVC insertion supports its use in adult patients. Pediatric-specific literature is sparse and includes mixed results. As more pediatric emergency physicians adopt the use of point-of-care US, we expect an increase in data supporting its use for CVC placement in pediatric emergency department patients.

KEY WORDS: central venous access, intravenous, ultrasound

1. Summarize the evidence for using ultrasound guidance in the placement of central venous catheters in adult and pediatric patients.
2. Explain the procedure for ultrasound-guided central venous catheter insertion in pediatric patients.

STUDIES IN ADULT PATIENTS

A 1996 meta-analysis reviewed 8 randomized controlled trials evaluating the effect of real-time US guidance for internal jugular and subclavian vein cannulations. The authors concluded that compared with standard techniques the use of US guidance reduced placement failure in both locations (relative risk [RR], 0.32; 95% confidence interval [CI], 0.18–0.55), decreased complications (RR, 0.22; 95% CI, 0.10–0.45), and decreased the need for multiple attempts (RR, 0.60; 95% CI, 0.45–0.79). Hind et al published in 2003 a meta-analysis of 18 randomized clinical trials involving US guidance for central venous access. They concluded that there is evidence to support the use of US guidance to place CVCs in internal jugular veins in adults, with lower failure rates overall (RR, 0.14; 95% CI, 0.06–0.33) and with the first attempt (RR, 0.59; 95% CI, 0.39–0.88).

In 2002, Keenan evaluated 17 randomized controlled trials and 1 quasi-randomized trial comparing the relative effectiveness and morbidity of the 2 insertion techniques. Pooled results showed a significant reduction in failure (risk difference [RD], −0.12; 95% CI, −0.18 to −0.06), number of attempts (risk reduction, 0.81; 95% CI, 0.64–0.97), and arterial puncture rate (RD, −0.07; 95% CI, −0.10 to −0.03). The number of successful venous cannulations on first attempt was higher using US (RD, 0.24; 95% CI, 0.08–0.39), and no difference was found in time to insertion. Subgroup analyses suggested that US improved outcomes most convincingly for cannulations of internal jugular veins and by less experienced clinicians. A 2013 meta-analysis examined 26 studies comparing the 2 techniques. Compared with the landmark
In 2009, Froehlich et al\(^7\) compared 93 CVC placement attempts using the landmark technique to 119 US-guided CVC placement attempts in pediatric intensive care unit patients. This study found that US-guided CVC placement in children was associated with fewer number of attempts to gain placement (1 vs 3, \(P < 0.001\)), fewer attempts at more than 1 anatomical site (5.9\% vs 20.7\%, \(P = 0.001\)), and fewer inadvertent artery punctures (8.5\% vs 19.4\%, \(P = 0.03\)) compared with the landmark technique. Ultrasound guidance did not improve success rates. More recently, Gallagher et al\(^8\) retrospectively compared femoral and internal jugular CVC placement attempts with and without US assistance in a pediatric emergency department. They found that the proportion of successful placement attempts was significantly higher when using US assistance compared with those attempted with the landmark technique, (98\% vs 79\%; odds ratio, 13.1; 95\% CI, 2.9–59.4). Complication rates were similar in both groups.

### US GUIDANCE FOR CENTRAL VENOUS CANNULATION: A REVIEW OF THE PROCEDURE

There are 2 approaches to the insertion of CVCs: the traditional landmark approach and the US-guided approach. The traditional landmark approach, where the provider uses known anatomic landmarks to guide needle insertion, has long been used in emergent situations, when time to insertion is critical. The US-guided approach is recommended as the preferred method for insertion of catheters into the internal jugular vein in adult patients and in children in elective situations.\(^5\) There are several considerations for implementing this technique.

#### Site Selection

In pediatric patients in the emergency department, the femoral vein has traditionally been the preferred site for CVC placement for pediatric resuscitations.\(^9\) The femoral site is easy to access, especially if there are airway or cervical spine stabilization considerations, and is associated with high success rates.\(^1\) By comparison, in a survey of pediatric surgeons,\(^4\) most respondents indicated their preference to place CVCs in the subclavian or internal jugular veins over the femoral vein. Froehlich et al\(^7\) and Vieira et al\(^10\) have shown that the use of the internal jugular site for CVC placement in pediatric patients increased with the use of US guidance.

#### Site Identification: B-Mode or Real-Time Method Versus Continuous Doppler Method

There are 2 main methods to identify the vessels in US-guided central venous cannulation: B-mode/real-time and continuous Doppler. B-mode US converts reflected sound waves into a real-time gray-scale image.\(^2\) Fluid is anechoic, appearing dark on the screen, whereas tissue is more isoechoic and appears gray. The vein can be differentiated from the nearby artery in that the vein is more compressible, nonpulsatile or less pulsatile than the accompanying artery, and distensible in the case of the internal jugular vein by the Valsalva maneuver or the Trendelenburg position. If time allows, both sides of the patient should be interrogated, as 1 side may have more favorable anatomy.\(^2\)

Doppler US transforms the sound waves reflected from a moving object (ie, blood flow) into an amplified audio signal. The venous waveform is distinctly different from arterial pulsations.\(^2\) The continuous Doppler method is rarely used alone but can be helpful in identifying actual blood flow in vessels, confirming vascular structures and differentiating vein and artery. It is most useful in identifying artery versus vein prior to the procedure. The data behind using Doppler for vascular access are
associated with a longer learning curve than B-mode US and a longer overall average time necessary to achieve cannulation.25

Procedure: Static Technique Versus Dynamic Technique

The 2 commonly used methods for US-guided CVC placement are the static technique and the dynamic technique. In the static technique, the vein is identified with US and marked prior to sterile preparation of the site. Ultrasound is not used during needle insertion.26 In the dynamic technique, cannulation of the target vein is performed with direct visualization of the needle entering the vein under US visualization.

Cannulation can be performed using either a transverse (short axis) or longitudinal (long axis) approach, although the transverse approach is used more frequently because of the easier visibility of small vessels and shorter learning curve.27 Although blood present in the syringe with aspiration suggests needle entry into the vessel, CVC placement is confirmed with direct US visualization of the wire or catheter in the vein.

Ultrasound guidance with the dynamic technique can be performed with either the “1-person” or “2-person” method. In the 1-person method, the operator can perform the procedure by himself/herself, controlling the US probe with the nondominant hand and the needle with the dominant hand. The 2-person technique requires an assistant (also with full-barrier sterile precautions) to hold the probe, while the operator controls the needle and performs the procedure.

EDUCATION

Vieira et al22 described the development of an emergency US program in a pediatric emergency department and its association with a significant increase in the use of US for CVC placement. Werner et al28 showed that the use of a simulation-based educational intervention resulted in improved pediatric emergency medicine physician competency in US-guided CVC placement, the effect of which was maintained over time. Other such programs and studies may lead to the proliferation of US guidance as the standard of care in obtaining central vascular access in pediatric patients. Further research may be done in this area, specifically evaluating teaching modalities and quality assurance programs involving pediatric emergency medicine programs.

SUMMARY

The evidence surrounding US-guided CVC insertion supports its use in adult patients. Multiple meta-analyses have shown that compared with the landmark technique the use of US guidance improves overall success, as well as success on the first attempt, and decreases complications. Pediatric-specific literature is sparse, mainly confined to the anesthesia literature, and includes mixed results. It should be noted that much of this early work regarding US-guided CVC placement in children was done in infants requiring internal jugular vein placement during cardiac surgery. Therefore, the results of these studies may not be generalizable to the pediatric ED setting.

Evidence does continue to mount, and as more pediatric emergency physicians adopt use of point-of-care US, it is likely there will be more data evaluating US guidance for CVC placement in pediatric emergency department patients.

REFERENCES


