

Ultrasound guidance for central vascular access in the neonatal and pediatric intensive care unit

Al Sofyani Khoulood,
Guilbert Julia, Boker Abdulaziz¹,
Chevalier Jean Yves,
Renolleau Sylvain

Department of Pediatric and Neonatal Intensive Care Unit, Armand Trousseau Hospital, APHP, UMPC Paris VI, Paris, France, ¹Department of Anesthesia and Critical Care, King Abdul-Aziz University, Jeddah, Saudi Arabia

Address for correspondence:

Prof. Sylvain Renolleau,
Armand Trousseau Hospital,
Paris, France.
E-mail: sylvain.renolleau@trs.aphp.fr

ABSTRACT

Background: Percutaneous central venous cannulation (CVC) in infants and children is a challenging procedure, and it is usually achieved with a blinded, external landmark-guided technique. Recent guidelines from the National Institute for Clinical Excellence (NICE) recommend the use of ultrasound guidance for central venous catheterization in children. The purpose of this study was to evaluate this method in a pediatric and neonatal intensive care unit, assessing the number of attempts, access time (skin to vein), incidence of complication, and the ease of use for central venous access in the neonatal age group. **Methods:** After approval by the local departmental ethical committee, we evaluated an ultrasound-guided method over a period of 6 months in 20 critically ill patients requiring central venous access in a pediatric intensive care unit and a neonatal intensive care unit (median age 9 (0–204) months and weight 9.3 (1.9–60) kg). Cannulation was performed after locating the puncture site with the aid of an ultrasound device (8 MHz transducer, Vividi General Electrics® Burroughs, USA) covered by a sterile sheath. Outcome measures included successful insertion rate, number of attempts, access time, and incidence of complications. **Results:** Cannulation of the central vein was 100% successful in all patients. The right femoral vein was preferred in 60% of the cases. The vein was entered on the first attempt in 75% of all patients, and the median number of attempts was 1. The median access time (skin to vein) for all patients was 64.5 s. No arterial punctures or hematomas occurred using the ultrasound technique. **Conclusions:** In a sample of critically ill patients from a pediatric and neonatal intensive care unit, ultrasound-guided CVC compared with published reports on traditional technique required fewer attempts and less time. It improved the overall success rate, minimized the occurrence of complications during vein cannulation and was easy to apply in neonatal and pediatric patients.

Key words: Neonate catheterization, pediatric, ultrasound-guided cannulation, vascular access

INTRODUCTION

Central venous cannulations (CVCs) have become a mandatory part of clinical management in a variety of clinical circumstances in pediatric groups. It allows resuscitation for intravascular fluid depletion and access for vasoactive medications and antibiotics, and it provides a means for hemodynamic monitoring and pacing.^[1] The internal jugular, subclavian, and femoral veins are

commonly used for central venous access. Femoral vein catheterization is the most common central vein accessed in adult and pediatric emergency departments because it is successful in the vast majority of patients and it is suitable for many indications.^[2,3] The femoral vein is the most common site attempted during pediatric resuscitation, and it is associated with a low complication rate during insertion in hypovolemic or low cardiac output patients compared with the internal jugular and subclavian sites.^[3] However, disadvantages include a higher incidence of thromboembolic and infectious complications.^[4]

Groff and Ahmed^[5] have described 5 major complications associated with subclavian vein (SCV) access in 44 children younger than 2 years of age. Therefore, the internal jugular vein (IJV) provides the best means of achieving intrathoracic venous cannulations in children.^[6] However, this procedure leads to a higher incidence of carotid artery

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(CA) puncture in children younger than 5 years than in older children.^[7]

The ultrasound-guidance technique is becoming the gold standard for IJV catheterization because it can both increase the success rate and decrease the complications related to central venous catheter placement.^[8,9] Since 2002, the National Institute for Clinical Excellence (NICE) has recommended the use of ultrasound guidance as the preferred method for insertion of a central venous catheter into the IJV in children.^[10]

Reports on the use of ultrasound-guided CVCs in children and newborns are limited and insufficient to support the utility of ultrasound for CVCs. The aim of our study was to evaluate this method in a sample of patients from pediatric and neonatal intensive care, assessing the number of attempts, access time (skin to vein), incidence of complications, and the ease of use for central venous access in the neonates.

METHODS

This study was conducted with the approval of the departmental ethical committee, and patients undergoing CVC were studied for a period of 6 months.

Ultrasound-guided CVC was studied in 20 critically ill patients from the neonatal and pediatric intensive care unit (median age 9 [0-204] months and weight 9.3 [1.9-60] kg) who required central venous access for intensive care treatment or long-term intravenous treatment, had difficult peripheral venous access, or were scheduled for major surgery. We divided them into a neonatal group (n=8) and a pediatric group (n=12). The age, weight, sex, and reasons for CVCs of each patient were recorded. The sites of cannulation were the right IJV in 40% of the patients and the femoral vein in 60%.

General anesthesia was preferred in all patients. Peripheral intravascular lines were inserted, and CVC was attempted. All procedures were assigned to and performed by 3 experienced intensive care doctors, and usually, a single operator simultaneously manipulated the transducer while inserting and guiding the needle into the vessel. We used the out of plane technique during our procedure.

Either a 4 or 5 Fr double-lumen central venous catheter (Arrow International®, Reading, PA, USA) was chosen based on the patient's age. The ultrasound technique was performed with the aid of a portable ultrasound device (8 MHz transducer, Vivid i General Electrics®, Horten city, Norway) covered by a sterile sheath and gel.

The patient was placed in the appropriate position for the cannulation. We measured the depth and position of the vein before the sterile procedure was performed [Figure 1]. The vein was required to be compressible by gentle pressure of the probe on the skin, and pulsation of the (carotid or femoral) artery was observed [Figure 2]. Following identification of the ideal puncture site, the area was washed and draped, conductive gel was put inside the sterile sheath, and the probe was inserted. Sterile conductive gel was applied to the skin, and the probe was placed perpendicularly to the vessel. Following identification of the pulsating vessel, the central mark of the probe was placed over the center of the vein. When the needle point was positioned correctly, the needle would dimple the vein and indent the overlying skin. Excessive pressure on the skin compressed the vein but not the artery. After perforation of the wall, the vein regained its circular shape and blood

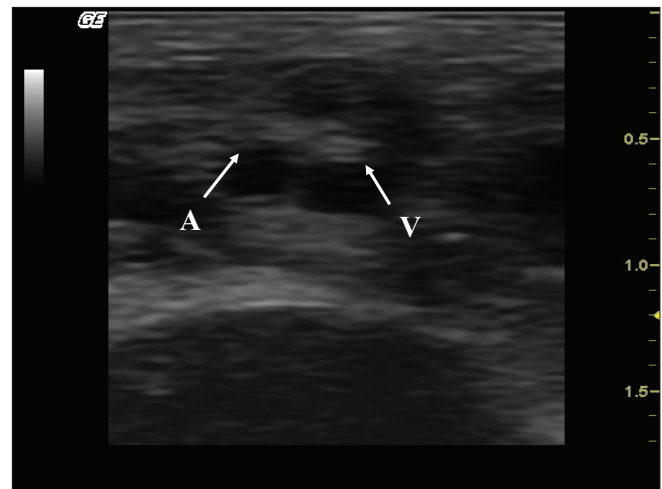


Figure 1: Two-dimensional ultrasound image of right femoral vein (V) and right femoral artery (A) in a 3065 g neonate

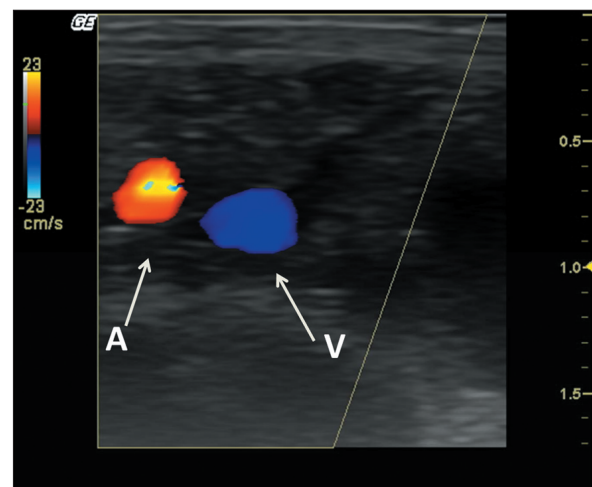


Figure 2: Two-dimensional ultrasound image of right femoral vein (V) and right femoral artery (A) in a 3065 g neonate demonstrated the compressibility of the right femoral vein (V) by gentle pressure of the probe on the skin

could be aspirated into the distal part of the syringe. The probe and syringe were removed, and the guide wire advanced through the needle into the vein. Cannulation was performed using the Seldinger technique, and chest X-rays were used regularly to confirm catheter placement.

The access time, number of attempts, success rate, and incidence of complications during each attempt (CA puncture; venous hematoma; hemodynamic alteration; pneumothorax; and catheter-related complications, such as kinking or threading difficulties) were recorded.

Access time was defined as the time between needle penetration of the skin and the easy aspiration of blood from the vein to the distal part of the syringe. An attempt was defined as the time between needle entry into the skin and its removal.

Statistical analysis

The 2 groups were compared for age and weight using the Mann–Whitney *U* test. The time taken for cannulation and the number of attempts were compared using the Student's *t* test. Statistical significance was defined as $P < 0.05$. The data were expressed as the mean \pm SD and the median (25th–75th percentile) for the number of attempts, the cannulation time, and age and weight.

RESULTS

The patient data are shown in Table 1. During this 6-month period, cannulation was successful in all 20 patients (median age 9 [0–204] months and weight 9.3 [1.9–60] kg). In 15 out of 20 patients, the vein was punctured on the first

Table 1: Patient demographics

	Neonate (≤ 1 month) n= 8	Pediatric (> 1 month) n=12
Mean age (months)	0.32 \pm 0.35	65.5 \pm 70.8
Median	0.18	36
Quartile	0.06–0.7	14.2–90
Average weight (kg)	3.18 \pm 0.80	22.2 \pm 18.4
Median	3.15	17
Quartile	2.4–4	12.3–27.3
Diagnosis		
Meconium aspiration syndrome	4	
Enterocolitis	1	
Congenital diaphragmatic hernia	1	
ARDS		3
ALL		4
Septic shock	2	3
SCA with cries		2

ARDS - Acute respiratory distress syndrome; ALL - Acute lymphocytic leukemia; SCA - Sickle cell anemia. Values are mean \pm SD, Quartile 25th percentile; 75th percentile

attempt and the median number of attempts necessary to perform CVC in all patients was 1 in both the neonatal and pediatric groups.

The median access time, between penetration of the skin with the needle and the easy aspiration of blood from the vein for both groups, was 64.5 s. There was no significant difference in the access time or the number of attempts between the neonatal ($P=0.154$) and pediatric ($P=0.984$) groups.

There was no incidence of arterial puncture or pneumothorax, hemopneumothorax, hematoma, or serious cardiac arrhythmia that needed treatment during catheterization. There was one incident of catheter kinking (not guide wire) in an 8-year-old child with threading problems as a result of inadequate skin dilatation.

DISCUSSION

This study clearly demonstrates the effectiveness of ultrasound-assisted CVC in neonatal and pediatric patients. This method is effective in confirming the best puncture of the identified vein with fewer attempts, and it is less time consuming and without complication. Moreover, this technique is as effective in neonates as it is in older children.

CVC is performed to monitor central venous pressure and infusion of vasoactive drugs in critically ill infants and children. In our institution, femoral vein and IJV are the preferred locations for cannulation, rather than the SCV because of the higher incidence of pneumothorax and subclavian artery puncture (6% and 14%, respectively) associated with the SCV.^[11,12] Anatomic variations have been reported in the relative positions of the IJV and the CA in children^[8] that are similar to those seen in adults.^[13,14]

Troians *et al.*^[13] showed a high incidence (54%) of posteriorly placed CA, which predisposed those patients to CA puncture if the cannulation needle traversed the IJV.

Denys and Uretsky^[14] assessed the position of the IJV in 200 adult patients. In 5.5% of patients studied, the location of the IJV was shown to be outside the path that had been predicted by external anatomic landmarks; in 8.5% of patients, the anatomy was sufficiently aberrant to complicate access using a blind method.

Alderson *et al.*^[8] examined the anatomy of the jugular vein in 50 infants younger than 6 years of age by ultrasonography. They reported an 18% incidence in anomalous venous anatomy. In a pediatric group, the incidence of a posteriorly positioned CA was 10%. The diameter was unusually small (≤ 3 mm for neonates and infants, ≤ 5 mm for older

children) in 4% of normally positioned IJVs and could not be seen at all in 2%. They also reported a decrease in the complication rate from 60% to 20% when an ultrasound technique was used to guide cannulation.

Our results [Table 2] show the ease of identifying and puncturing the vein using the ultrasound-guided technique. All of the previous publications have also shown this technique to be superior to the landmark technique.^[15-17,19,20] In the current study, the overall successful venous puncture rate in neonates and children was 100% using guided ultrasonography.

Verghese *et al.*^[15] studied 95 infants scheduled for IJV cannulation who were undergoing cardiovascular surgery. The infants were randomized into 2 groups: 43 infants in the ultrasound technique group and 52 in the landmark technique group. The 2 groups were similar with respect to age and weight. Cannulation of the IJV was successful in all 43 (100%) infants in the ultrasound group and in 40 out of 52 (77%) infants in the landmark group. Hayashi *et al.*^[16] reported a 97.2% overall success rate in their study of 106 children, 40 of whom were infants. However, in infants younger than 3 months, successful catheterization rate was only 81.3%. Asheim *et al.*^[17] performed cannulation of the central vein guided by an ultrasound technique. They were successful in all 42 infants and children (median age of 16.5 months) and reported no complications using the IJV in 40 patients and the femoral vein in 2.

A number of studies have suggested that an increase in the number of insertion attempts is associated with a higher complication rate. McGee and Gould^[18] reviewed central venous catheter complications and found that the incidence of mechanical complications after 3 or more insertion attempts was 6 times the rate after one attempt. In this study, cannulation was successful on the first attempt in 15 out of 20 (75%) patients and a second attempt was needed in 5 patients without hematoma. We experienced

difficulty observing perforation of the anterior wall of the vein because the vein diameter was small, superficial, and occluded easily by the ultrasound probe. We achieved successful cannulation by avoiding excessive pressure while manipulating the probe, we directed the needle nearly perpendicular to the skin and the venous blood was identified as the needle was drawn back through the vein.

Asheim *et al.*^[17] found that the vein was punctured during the first attempt in 40 out of 42 patients in their study of 42 infants undergoing CVCs guided by ultrasound. Chuan *et al.*^[19] studied 62 infants with body weight less than 12 kg undergoing IJV cannulation for cardiovascular surgery and randomized the patients into the landmark technique group and the ultrasound prelocation technique group. The authors reported that the median numbers of attempts necessary to perform cannulation of the IJV in the ultrasound and landmark groups were 1 and 2, respectively.

Some studies have suggested that ultrasonography guidance for CVC in pediatric age groups led to a faster insertion time. Verghese *et al.*^[15] have shown a significantly lower cannulation time in infants and children using the ultrasound technique (3.3 min) compared with the landmark technique (10 min) ($P < 0.0004$). They found no incidence of CA punctures in infants and children using the ultrasound technique, compared with 25% in the landmark group. In our current study, the median access time (skin to vein) was 1 min for both groups. Complications, including arterial puncture, hematoma, and pneumothorax, did not occur in this series. Catheter kinking (not guide wire) with inability to thread was observed in one 8-year-old patient.

In a meta-analysis of pediatric studies, Hind *et al.*^[21] found a higher success rate using a 2-dimensional (2D) ultrasound guidance technique for right jugular vein cannulation compared with the landmark technique. Ultrasound guidance also reduced complications due to faster access. The explanation for these benefits is that ultrasonography clarifies the relative position of the needle and the vein and its surrounding structures. Catheterization using 2D ultrasound guidance is quicker and safer than the landmark method in both adults and children.

The experience of our group and others (Skippen and Kissoon^[3]) suggests that the pediatrician and neonatologist should be extremely experienced in the use of ultrasonography guidance for CVCs. Expertise will reduce the number of attempts and the time required for cannulation, and it will also to prevent the occurrence of major complications, such as arterial puncture. For that reason, a physician training program on the ultrasound technique for vascular catheter placement should be established in pediatric and neonatal intensive care units.

Table 2: Access time, attempts, success rate, and complications for neonates (n=8) and children (n=12)

	Neonate (≤1 month) n=8	Pediatric (>1 month) n=12	P
Average access time (s)	65.3±7.57	154±240	0.154
Median	64.5	62.5	
Average number of attempts	1.8±1.12	1±0.28	0.984
Median	1.5	1	
Success rate, %	100	100	
Incidence of arterial puncture	0	0	

Values are mean±SD, and median, P values <0.05 were considered significant

CONCLUSION

In a sample of critically ill patients from a pediatric and neonatal intensive care unit, ultrasound-guided CVC compared with published reports on traditional technique required fewer attempts and was less time consuming. It improved the overall success rate and was easy to perform in neonatal and pediatric patients. This technique minimized the occurrence of complications during vein catheterization because it allowed a clear view of the underlying anatomy and its variations, which contribute to the occurrence of complications.

We suggest that this method should be preferred in pediatric and neonatal intensive care units, particularly in complicated hypovolemic patients and in patients with low cardiac output with difficulty feeling an arterial pulse using the traditional technique. Patient safety and better practice depend on the familiarity of the pediatrician and neonatologist with ultrasound-guided CVC in this age group.

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