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Centrally inserted central catheters in preterm neonates with weight below 1500 g by ultrasound-guided access to the brachio-cephalic vein

Giovanni Barone[1], Mauro Pittiruti[2], Gina Ancora[1], Giovanni Vento[3], Francesca Tota[4] and Vito D'Andrea[3]

Abstract

Objective: Central venous access in critically ill newborns can be challenging. Ultrasound-guided brachio-cephalic vein catheterization is a relatively new procedure, recently introduced in several neonatal intensive care units. The aim of this study is to evaluate the safety and feasibility of such a technique in preterm babies.
Design: Retrospective analysis of prospectively collected data on ultrasound-guided central venous catheter insertion in preterm neonates.
Setting: Neonatal intensive care unit.
Patients: Critically ill preterm neonates with weight below 1500 g requiring a central access.
Interventions: Ultrasound-guided brachio-cephalic vein catheterization.
Main Results: Thirty centrally inserted catheters were placed in 30 neonates. The success rate of the procedure was 100%. No case of accidental arterial or pleural puncture was registered during the study period.
Conclusion: The brachio-cephalic vein can be safely catheterized in preterm newborns requiring intensive care after appropriate training.

Keywords

Newborn, central access, critical ill newborn, neonatal intensive care, ultrasound guidance, central venous catheterization

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Introduction

Critically ill newborns admitted to a neonatal intensive care unit (NICU) often require a central line for hemodynamic monitoring, repeated blood sampling, infusion of high volumes of fluids, and/or infusions of drugs and solutions that are not appropriate for the peripheral route.

An umbilical venous catheter (UVC) is often the first choice, but the use of this line is limited for three main reasons: (a) the closure of the umbilical vein in the first few hours of life makes this line unfeasible after the first day; (b) a UVC cannot be placed when there are abdominal malformations (e.g. exomphalos); (c) the 2016 Standards of the Infusion Nursing society[1] suggest to limit the dwell time to 7–14 days, since the risk of infection increases after this period of time. Removal of the UVC is often followed by the insertion of an epicutaneo-caval catheter (ECC). ECCs are small bore silicone or polyurethane catheters (1–2.7 Fr) inserted via superficial veins of the limbs and the scalp,

[1]Neonatal Intensive Care Unit, Ospedale Infermi, Rimini, Italy
[2]Department of Surgery, Catholic University Hospital "A.Gemelli," Rome, Italy
[3]Neonatal Intensive Care Unit, Catholic University Hospital "A.Gemelli," Rome, Italy
[4]Neonatal Intensive Care Unit, Ospedale S. Chiara, APSS, Trento, Italy

Corresponding author:
Giovanni Barone, Neonatal Intensive Care Unit, Ospedale Infermi di Rimini, Viale Luigi Settembrini, 2, 47923 Rimini, Italy.
Email: gbarone85@yahoo.it

which may sometimes not completely fulfill the need of a critical ill neonate. In these situations, the placement of a large bore polyurethane catheter (3–4 Fr) in the brachiocephalic vein (BCV; centrally inserted central catheters (CICC)) can be more appropriate.[2–6]

The aim of this study is to describe our experience with CICC insertion in preterm neonates with a weight below 1500 g.

Methods

Setting

The study was conducted over 12 months in the NICUs of three different Italian hospitals (Catholic University Hospital "A.Gemelli," Rome; Ospedale Infermi, Rimini; Ospedale S. Chiara, Trento).

Study population

Ultrasound-guided BCV catheterization was performed only in preterm neonates admitted to NICUs and thought to be eligible according to one of the following criteria: expected duration of parenteral nutrition > 14 days; impending emergency surgery; acute respiratory insufficiency defined as the need for mechanical ventilation at day 7 of life; complex malformations; gastrointestinal emergencies; hemodynamic instability; and other severe acute conditions requiring a central catheter appropriate for high flow infusions, blood withdrawal, hemodynamic monitoring, and blood transfusions, according to the judgment of the attending physicians. The collection of data was approved by the local Ethics Committee of Catholic University Hospital "A.Gemelli," and the parents of each patient provided written informed consent.

Procedure

The catheters were placed in the three hospitals using exactly the same procedure, that is, a well-defined insertion bundle. The very first CICCs were placed by one physician (M.P.), specifically trained in ultrasound-guided central catheter placement in neonates and infants; this same physician subsequently trained the other clinicians (G.B., V.D., and F.T.) by appropriate practice on simulators, clinical tutoring, and a course of supervised procedures. We used exclusively power-injectable, non-valved catheters—3 Fr single lumen or 4 Fr double lumen—made of new-generation polyurethane, currently available from many different companies.

All CICCs were inserted according to our insertion bundle for neonatal/pediatric central lines:

Pre-operative ultrasound scan of all central veins (so-called "RaCeVA": rapid central vein assessment);[7]

Maximal barrier precautions;

Skin antisepsis with 2% chlorhexidine in 70% isopropyl alcohol;

Ultrasound-guided venipuncture of the BCV by the supraclavicular approach (visualization in the long axis: in-plane puncture);

Vein cannulation using the modified Seldinger technique and a micro-introducer kit;

Ultrasound assessment of the direction of the guidewire into the vasculature (ultrasound-based tip navigation);

Tip location by intracavitary echocardiography (ECG) and/or transthoracic ECG;

Tunneling of the catheter to the infraclavicular area;

Securement by the sutureless device;

Cyanoacrylate glue for the closure of the puncture site and for the sealing of the exit site;

Coverage of the exit site with a semipermeable transparent membrane.

All procedures were performed at bedside, that is, in the incubator or in an open cot, according to the weight and postnatal age of the baby. Each patient was placed in a supine position, with a rolled sheet placed under the shoulders; the neck was in extension and the head turned slightly toward the opposite side of the chosen BCV. With this position, we were able to get a clear view of the BCV in all infants. During the procedure, the incubator was kept fully opened and the main operator was at the right or left corner (according to the venipuncture site); a second operator was usually placed next to the main operator at the head of the baby managing the airways, especially if the baby was not intubated. A Neopuff Infant T-Piece Resuscitator was used if the baby became apneic during the deep sedation. A ultrasound screen was placed in front of the main operator at the opposite site of the incubator.

Ultrasound imaging was performed by L8-18i-D Intraoperative 8–18 MHz High Frequency Ultrasound Transducer "hockey stick" Probe (GE Healthcare, Little Chalfont, United Kingdom) connected to a LOGIQ E9 Ultrasound Unit (GE Healthcare, Little Chalfont, United Kingdom). The depth was adjusted as needed according to the depth of the vein itself; no Doppler or Zoom function was used.

Pre-operative ultrasound scan of central veins (RaCeVA) was performed using the linear "hockey stick" probe; the goal of RaCeVA is to identify the best spot and position for the venipuncture and to assess the diameter of the vessel (Figure 1). The internal jugular vein (IJV) was identified by placing the probe perpendicularly at the middle neck in the transverse position. The IJV was distinguished from the

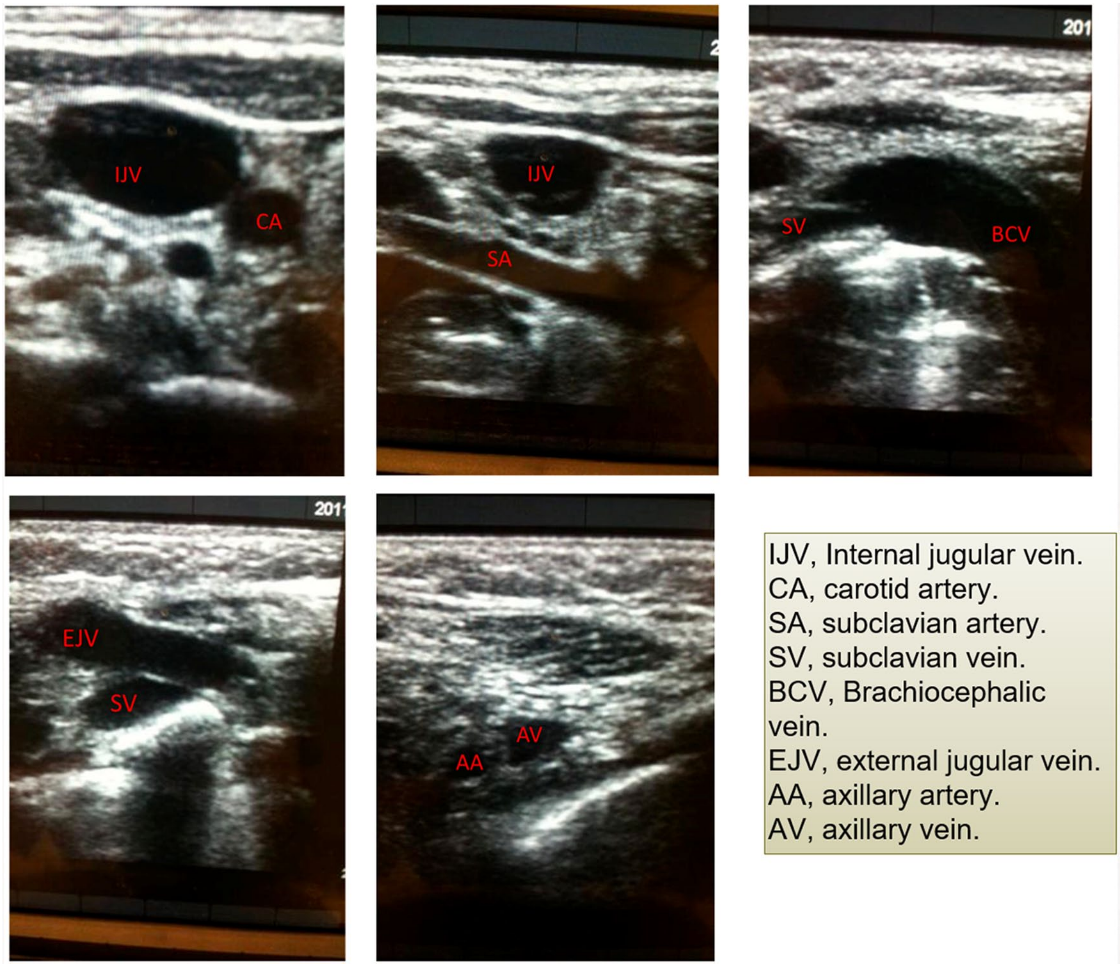

Figure 1. Pre-operative ultrasound scan of central veins (RaCeVA: rapid central vein assessment).
IJV: internal jugular vein; CA: carotid artery; SA: subclavian artery; SV: subclavian vein; BCV: brachio-cephalic vein; EJV: external jugular vein; AA: axillary artery; AV: axillary vein.

carotid artery by its compressibility. The IJV was followed downward by sliding the ultrasound probe to the clavicle, always visualizing the IJV in the short axis. The probe was progressively tilted to a frontal plane, so as to visualize the BCV and the subclavian vein.

Skin antisepsis was performed with 2% chlorhexidine in 70% isopropyl alcohol. Maximal barrier precautions were used, including appropriate hand hygiene, non-sterile cap and mask, sterile gloves and gown, wide sterile field, long sterile cover over the probe, and sterile gel over the skin.

The BCV was visualized in the long axis and punctured in-plane, so that the needle was under constant ultrasound control (Figure 2). Ultrasound-guided venipuncture was performed with a 21G echogenic needle using the same "hockey stick" linear probe. The needle was a 7 cm 21 gauge with a hyperechogenic tip. Figure 3 shows ultrasound image showing the puncture needle (not the guidewire) inside the BCV in two very low weight babies. After assessing the correct intravascular position of the needle by ultrasound visualization and by blood withdrawal, a 0.018″ floppy straight tip nitinol micro-guidewire was introduced through the needle. Ultrasound assessment of the direction of the micro-guidewire into the vasculature (tip navigation) was also performed using the hockey stick probe. The catheter was then inserted with the modified Seldinger technique using micro-introducer dilators of appropriate caliber (3.5 Fr or 4.5 Fr). The exit site was placed in the infraclavicular area after tunneling the catheter through 14G or 16G needle cannulas (Figure 4).

The central position of the tip was assessed by intracavitary ECG using a standard ECG monitor and a dedicated sterile ECG cable (Vygocard, Vygon), considering

Figure 2. Ultrasound-guided venipuncture using a modified Seldinger technique by micro-introducer and ultrasound assessment of the direction of the guidewire into the vasculature.

the maximum amplitude of the P wave as a reliable landmark of the cavo-atrial junction. In a few cases, the tip location was also confirmed by transthoracic ECG using a micro-convex or sectorial probe.

All catheters were secured by subcutaneously anchored sutureless devices (Securacath, Interrad Medical). N-butyl-cyanoacrylate glue was applied at the end of the procedure to close the puncture site and to seal the exit site. Semipermeable transparent membranes were used to cover the puncture site and the exit site (Figure 5).

The overall insertion bundle we adopted is summarized in Table 1.

ECCs, if present, were left in situ during the procedure and removed after securement of CICCs.

Endpoint

The primary endpoint was to evaluate the feasibility of our insertion bundle for CICC insertion in preterm neonates with a weight below 1500 g in NICUs. Secondary endpoints were the number of early and late complication related to such a catheter in infants admitted to NICUs.

Data collection

We recorded many patient data, including age and weight, as well as relevant data concerning the procedure (type of catheter, whether the operator was expert

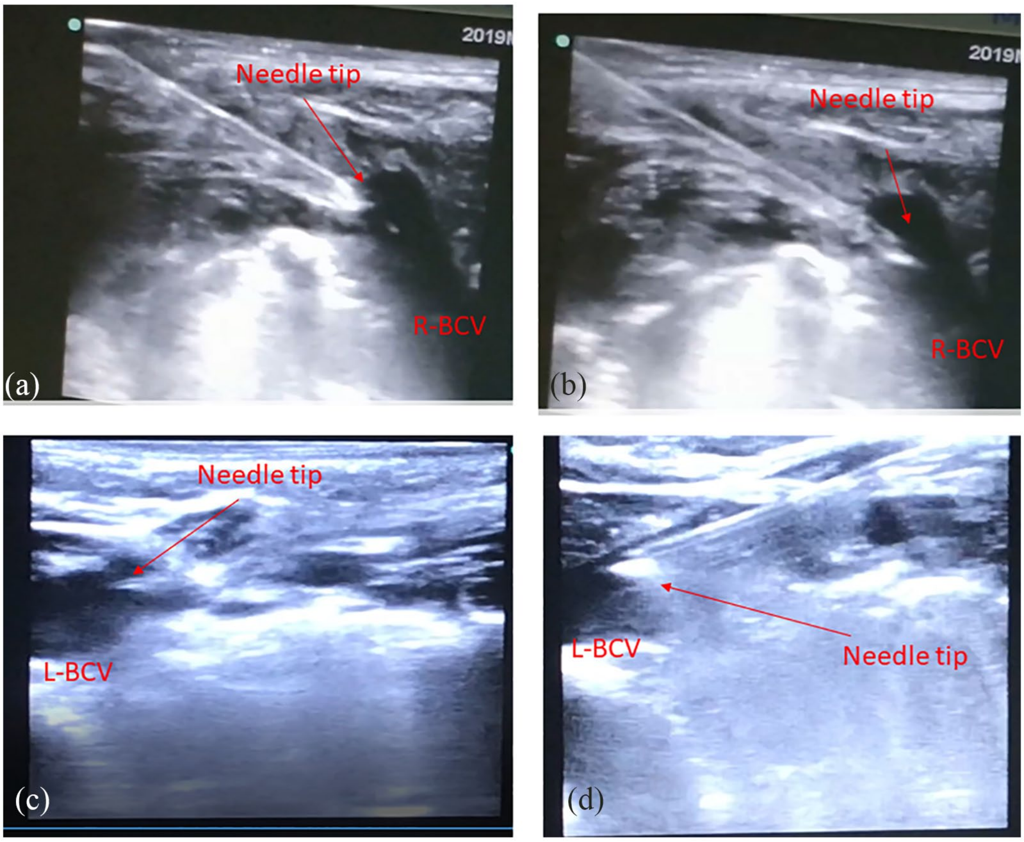

Figure 3. Figure 3 shows the ultrasound image showing the puncture needle (not the guidewire) inside the BCV in two very low-weight babies. (a) Needle tip clearly visualized at the wall of the right BCV vein in a preterm infant of 650 g. (b) Needle tip advanced into the vein. (c) Needle tip at the wall of the left BCV vein in a preterm infant of 580 g. (d) Needle tip advanced into the vein.

or beginner, number of venipuncture, etc.), and also the clinical outcome—success of catheterization, intra-procedural complications (arterial puncture, pneumothorax, malposition, etc.), and late complications (catheter malfunction, catheter-related bloodstream infection, catheter-related thrombosis, etc.). Catheter malfunction was defined as persistent difficulty in infusion and/or withdrawal. Catheter-related blood stream infection (CRBSI) was defined according to the criteria of IDSA (Infective Diseases Society of America) and—if clinically suspected—was ruled out by the method of delayed time to positivity (DTP). Catheter-related thrombosis was ruled out by ultrasound scan of the central veins; ultrasound scan was not carried out routinely, but only (a) if thrombosis was clinically suspected and (b) before removal of the catheter. The electronic database was used to record all data (Excel 2018).

Statistical analysis

The D'Agostino Pearson test was performed in order to assess the variables for normality. Continuous variables that were found to be normally distributed were expressed as mean ± SD. Variables that were not were expressed as median ± SEM.

Results

Study population and relevant information on the catheter choice

Thirty CICCs were inserted in 30 neonates during the study period. The patients' characteristics are summarized in Table 2. All catheters were inserted according to our insertion bundle (see above), with no exception. The right BCV was the preferred site for cannulation (87%); this is likely due to its larger size and clear view even in small infants. The BCV diameter ranged from 2.7 to 4.4 mm. We used more 3 Fr single lumen (n = 25) than 4 Fr double lumen catheters (n = 5), the latter being inserted only if the BCV diameter was 4 mm or larger. In all patients, the tip location was identified successfully by the intracavitary ECG method; in 20% of patients, the central position of the tip was additionally confirmed by ECG.

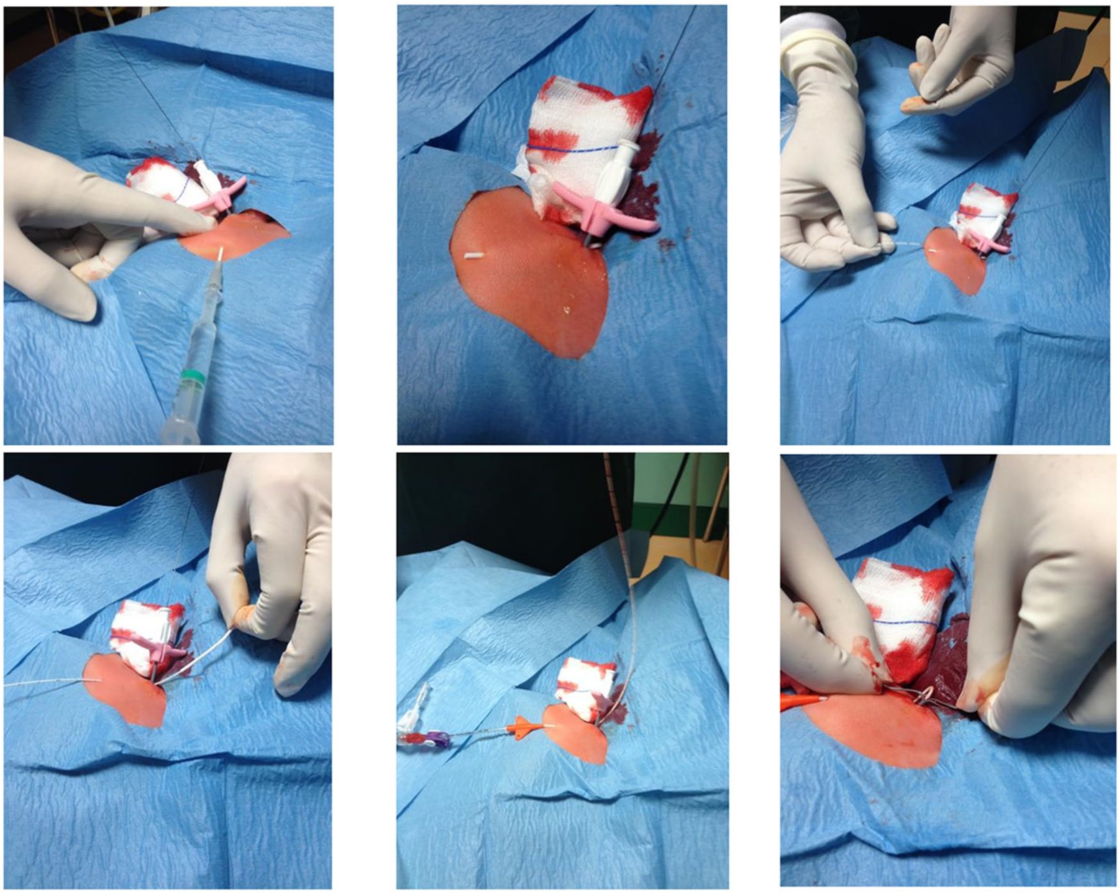

Figure 4. Tunneling of the catheter to the infraclavicular area.

Figure 5. Cyanoacrylate glue for the closure of the puncture site and for the sealing of the exit site; securement by the sutureless device; coverage of the exit site with a semipermeable transparent membrane.

Table 1. Our insertion bundle.

Ultrasound pre-puncture evaluation of central veins (RaCeVA)
Hand hygiene and maximal barrier precautions
Skin antisepsis with 2% chlorhexidine in alcohol
Ultrasound-guided venipuncture
Tip location by intracavitary echocardiography and/or echocardiography
Tunneling the catheter so as to obtain an exit site in the infraclavicular area
Securement with the sutureless device
Sealing of the exit site with glue
Coverage with transparent semipermeable dressing

RaCeVA: rapid central vein assessment.

Table 2. Patients' data, expressed as mean ± standard deviation and range or number and percentage.

Day of life at the insertion (days) (mean ± SD; min–max)	5 ± 7 (2–30)
Gestational age at birth (weeks) (mean ± SD; min–max)	26 ± 2 (23–32)
Birth weight (g) (mean ± SD; min–max)	848 ± 200 (370–1240)
Postmenstrual age at insertion (weeks) (mean ± SD; min–max)	27 ± 2 (24–32)
Weight at the time of insertion (g) (mean ± SD; min–max)	923 ± 205 (350–1500)
Sex (male:female)	17:13
Number of patients intubated at placement	18 (60%)
Number of infants needing inotropes at the placement	6 (20%)

SD: standard deviation.

Cannulation success

Twenty-eight catheters were successfully inserted at the very first venipuncture. Only two infants required a second attempt performed on the same vein. Guidewire was easily inserted in all cases. Overall, the success rate of the procedure was 100%. Importantly, no cases of accidental arterial puncture or of pleural injury were registered during the study period. There were no insertion-related complications. Preferred drugs for sedation included Fentanyl, Ketamine, and Midazolam.

Outcome for the catheter

All catheters were successfully used for high flow infusion, blood sampling, and hemodynamic monitoring. No catheter was removed because of complications. We had no episode of dislocation or CRBSI or venous thrombosis during the study period. No major episodes of transient or persistent catheter malfunction were reported (see Table 3).

Table 3. Catheters' data, expressed as median ± SEM and range or number and percentage.

Dwell time; days ± SD (min–max)	37 ± 21 (2–95)
Elective removal	30 (100%)
CRBSI	0
Catheter-related thrombosis	0
Catheter malfunction	0

CRBSI: catheter-related blood stream infection; SD: standard deviation.

Discussion

Subclavian or BCV cannulation has been reported to be both safe and relatively easy in pediatric and NICUs;[4,5,8–13] in particular, ultrasound-guided catheterization of the BCV is currently seen as a very promising technique in neonates.

Our study reports a number of successful BCV catheterizations in preterm neonates—some with a weight below 1 kg at the time of placement—with no complications during the procedure. This 100% success rate and the absence of intra-procedural complications are probably due to our solid insertion bundle. In particular, we avoided any risk of puncture-related complications by keeping the needle under constant ultrasound vision ("in plane" technique).

Also, we had no late complications (infection, thrombosis, dislocation, and catheter malfunction). Such absence of late complications is secondary to the consistent adoption of a well-defined insertion bundle, designed to minimize the risk of CRBSI (maximal barrier precautions, skin antisepsis with 2% chlorhexidine in alcohol, tunneling of the catheter, application of glue, and coverage with transparent membranes), to minimize the risk of venous thrombosis (ultrasound-guided venipuncture with a small gauge needle and accurate intra-procedural tip location by IC-ECG and ECG), and to minimize dislocations (subcutaneously anchored securement).

Another interesting novelty of our experience is that we consistently used power-injectable polyurethane catheters (3–4 Fr); we think that the high performance of these catheters in terms of flow and blood withdrawal offers several advantages when compared to ECC catheters, so as to make them the central line of choice in severely ill newborns (Table 4).

This consideration brings us to a very important point: which might be the criteria for choosing an ultrasound-guided CICC rather than an UVC or an ECC in NICUs?

In most NICUs, the choice of the vascular device currently relies upon the operator's experience and preferences, though we believe that it would be more appropriate to take into account the different performances of such devices. In particular, if we consider the advantages of CICCs due to their power injectability, they obviously

Table 4. Differences between epicutaneo-caval catheters (ECCs) and central inserted central catheters (CICCs).

	CICC	ECC
Venipuncture	Deep veins	Superficial veins
Ultrasound guidance	Yes	No
Catheter diameter	3–4 Fr	1–2.7 Fr
Sedation required	Yes	No
Power injectability	Yes	No
Maximal flow rate	60 mL/min	1 mL/min
Infusion of blood products	Yes	No
Monitoring of central venous pressure	Yes	No
Monitoring of SvO_2	Yes	No
Blood sampling	Yes	No
Tunneling	Yes	No
Tip location by intracavitary ECG	Yes	Yes
Limited dwell time	No	Yes
Possibility of CRBSI diagnosis by DTP	Yes	No

CRBSI: catheter-related blood stream infection; DTP: delayed time to positivity; ECG: echocardiography.

offer several advantages when compared to ECCs (see Table 4). When clinicians choose the type of central vascular access device, the first issue to consider is whether the baby is stable or unstable. In our opinion, unstable newborns that might benefit from CICCs include (a) infants with hemodynamic instability who require inotropes and frequent hemodynamic assessment such as measurement of central venous pressure or of oxygen saturation in mixed venous blood; (b) infants that need multiple lumens for continuous infusion of different and incompatible drugs; (c) infants affected by major congenital malformations (gastroschisis, exomphalos, congenital diaphragmatic hernia, etc.); (d) newborns that need surgery (due to necrotizing enterocolitis, gastrointestinal perforation, etc.); (e) previously preterm babies affected by severe bronchopulmonary dysplasia, still ventilated and needing IV infusion; and (f) infants with no superficial veins available for cannulation. In all these conditions, the choice of a power-injectable CICC rather than ECC offers many advantages: high flow (1 mL/s), easy infusion of blood products, easy blood sampling, and possibility of hemodynamic monitoring (central venous pressure and oxygen saturation of mixed venous blood).

Another factor to consider is the expected duration of the intravenous treatment. Peripheral cannulas are appropriate when the infusion will not exceed 6 days.[14] There is a certain grade of uncertainty regarding the duration of ECCs, but several reports suggest that at least in preterm neonates, the risk of infective and mechanical complications of ECCs increases enormously after 14 days.[15–19] Therefore, for infusion expected to last more than 14 days, we suggest placing a CICC rather than several consecutive ECCs. This contention is somehow confirmed by our findings. In fact, we were able to reach the target of zero infection even in preterm infants with a weight below 1500 g. This is extremely important especially considering the mean dwell time of such catheters.

However, our study opens two main issues that need to be answered in future prospective studies. The first one is about the sedation: CICC placement requires a deep sedation that might be quite difficult to achieve in preterm babies. We were able to place a CICC also in all babies that were extubated, keeping them off ventilators throughout the procedure but in the literature a standardized and safe protocol for deep sedation is missing. The second open issue is about the training of the operator. At this moment, the specific training program is not standardized and the minimum number of procedure apt to demonstrate the proficiency of the operator is still unknown.

Conclusion

While ECCs may still be appropriate in neonates requiring only hydration and parenteral nutrition, critically ill preterm neonates requiring emergency surgery or admitted to the NICU for acute severe cardiorespiratory conditions would rather benefit from ultrasound-guided CICCs. Power-injectable 3–4 Fr polyurethane catheters (single or double lumen) have the best performance in this regard. The placement of such catheters can be safely performed by adopting an appropriate insertion bundle after appropriate training.

To our knowledge, this is the first report of ultrasound-guided insertion of power-injectable CICCs in preterm neonates with weight below 1500 g; also, it is the first clinical study to propose a very solid insertion bundle for CICCs tailored to neonates and reaching the target of zero complication.

Declaration of conflicting interests

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ORCID iDs

Giovanni Barone https://orcid.org/0000-0002-8015-7299
Mauro Pittiruti https://orcid.org/0000-0002-2225-7654
Vito D'Andrea https://orcid.org/0000-0002-0980-799X

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