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Caliber of the deep veins of the arm in infants and neonates: The VEEIN study (Vascular Echography Evaluation in Infants and Neonates)

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Abstract

Purpose: Ultrasound-guided peripherally inserted central catheters (PICCs) are increasingly used in children, though their insertion may be limited by the small caliber of the deep veins of the arm. Previous studies have suggested to use age or weight as a guide to the feasibility of PICC insertion. We have planned an observational study with the purpose of identifying the actual feasibility of PICC insertion based on the ultrasound evaluation of the deep veins of the arm in groups of children of different weight range.

Methods: We have studied 252 children weighing between 2.5 and 20 kg, divided in five different groups (group 1: 2.5–4 kg; group 2: 4.1–7 kg; group 3: 7.1–10 kg; group 4: 10.1–15 kg; group 5: 15.1–20 kg): the caliber of brachial vein, basilic vein, and cephalic vein at mid-upper arm + the caliber of the axillary vein at the axilla were measured by ultrasound scan.

Results: Veins of caliber >3 mm (appropriate for insertion of a 3 Fr non-tunneled PICC) were found at mid-upper arm in no child of group 1 or 2, in 13% of group 3, in 28% of group 4, and in 54% of group 5. An axillary vein >3 mm (appropriate for insertion of a 3 Fr tunneled PICC) were found in 5.8% of group 1, 30.6% of group 2, 67% of group 3, 82% of group 4, and 94% of group 5.

Conclusions: The age and the weight of the child have a small role in predicting the caliber of the veins of the arm. Veins should be measured case by case through a proper and systematic ultrasound evaluation; however, the clinician can expect that insertion of a 3 Fr PICC may be feasible in one third of children weighing between 4 and 7 kg, and in most children weighing more than 7 kg, especially if adopting the tunneling technique.

Keywords

Pediatric patients, PICC, ultrasound, central venous catheters, diameter of the veins

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What is known

- Ultrasound-guided PICCs are increasingly used in the pediatric populations
- Due to small caliber of the vein, PICC may be associated with thrombosis in children
- Catheter/vein ratio plays a major role as determinant of PICC-related thrombosis

What is new

- Age and weight are not useful for predicting the caliber of the veins of the arm
- The most reasonable approach is to verify the feasibility of PICC insertion by performing a pre-procedural ultrasound scan of the veins of the arm
- Considering 3 Fr catheters and the adoption of the tunneling technique, PICC insertion is feasible in one third of children between 4 and 7 kg and in most children above 7 kg.

Introduction

In all patients, central venous access devices are of paramount importance for safe delivery of intravenous therapies and blood sampling. The use of peripherally inserted central catheters (PICCs) has progressively gained popularity during the last 5 years also in children, mainly because of the safety of their insertion technique if compared to centrally inserted central catheters (CICCs).[1] Current international guidelines[2] recommend the use of ultrasound during any central venous catheterization, for several purposes: preprocedural evaluation, venipuncture, ruling out immediate complications, tip navigation, and tip location. During PICC insertion, ultrasound is particularly important for choosing the best vein to cannulate, since it allows to measure the diameter of the vein and its distance from the skin surface, as well as to rule out the presence of anatomical abnormalities and to evaluate the collapsibility of the vein during breathing.[3] In particular, the measure of the diameter of the vein is probably one of the most critical issues. Nifong and McDevitt[4] have shown that the venous blood flow is decreased by 50%–75% when a catheter occupies 30%–50% of the lumen of the vessel. Therefore, many current protocols for PICC insertion recommend that the diameter of the vein and the size of the catheter should respect a ratio of 3:1 (or higher) to reduce the risk of catheter-related thrombosis (CRT).[3,5]

In previous studies, the choice of the caliber of the catheter before PICC insertion has been guided by the age or weight of the children, based on statistical assumptions of the expected size of veins at different stages of growth of the child.[6]

This prospective observational study was designed to detect the actual diameter of the deep veins of the arm, in different groups of pediatric patients with different range of body weight, as evaluated by ultrasound in two separate zones of the upper arm.

Materials and methods

This was a single center prospective observational study conducted over a period of 15 months in the pediatric intensive care (PICU) of an Italian pediatric hospital ("G. Gaslini" Hospital in Genova). The study—nicknamed VEEIN (Vascular Echography Evaluation in Infant and Neonates)—was approved by the local Ethics Committee and an informed consent was obtained from the guardians and parents of each child. Every patient admitted in the PICU was enrolled in the study. Children with known vascular malformations affecting the upper limb, or with paretic arms, or with ongoing infection, and/or with previous history of upper limb thrombosis were excluded from the study. Neonates weighing less than 2500 g and children weighing more than 20 kg were also excluded.

The children were classified in five groups, according to their weight at the time of the scan: group 1 (2.5–4 kg), group 2 (4.1–7 kg), group 3 (7.1–10 kg), group 4 (10.1–15 kg), and group 5 (15.1–20 kg).

After admission to PICU, as soon as the clinical conditions of the patient had been stabilized, a bilateral scan of the deep vein of the arms was performed according to the Rapid Peripheral Vascular Vein Assessment (RaPeVA)[3] by two different operators equally skilled in ultrasound vascular assessment. The internal diameter of the basilic, brachial, and cephalic veins was measured at mid-arm, in an area corresponding to the middle portion of Dawson's green zone[7] (scan 1) (Figure 1); when more than one brachial vein was visualized, we measured the largest. The internal diameter of the axillary vein was measured at the axilla, in an area corresponding to the proximal portion of Dawson' yellow zone (scan 2) (Figure 2). The brachial artery and the median nerve were also visualized. Ultrasound was performed with high frequency linear transducers: "hockey stick"-shaped probes (10–13 MHz) for group 1 and 2, or standard linear probes with 1-inch footprint (10–15 MHz) for group 3–4–5. The diameter of each vein was measured in the vertical axis, without tourniquet. All scans were performed bedside with the patients in supine position, with the arm placed at 90° with the trunk and the forearm slightly bent on the arm. Both operators used maximal attention in avoiding any excessive pressure by the probe that might have caused distortion of the vein. During the scan, all patients were lightly sedated with midazolam 0.1 mg/kg and monitored by electrocardiogram and peripheral O_2 saturation.

The main anthropometric characteristics of each patient (age, weight, height, body mass index) were recorded.

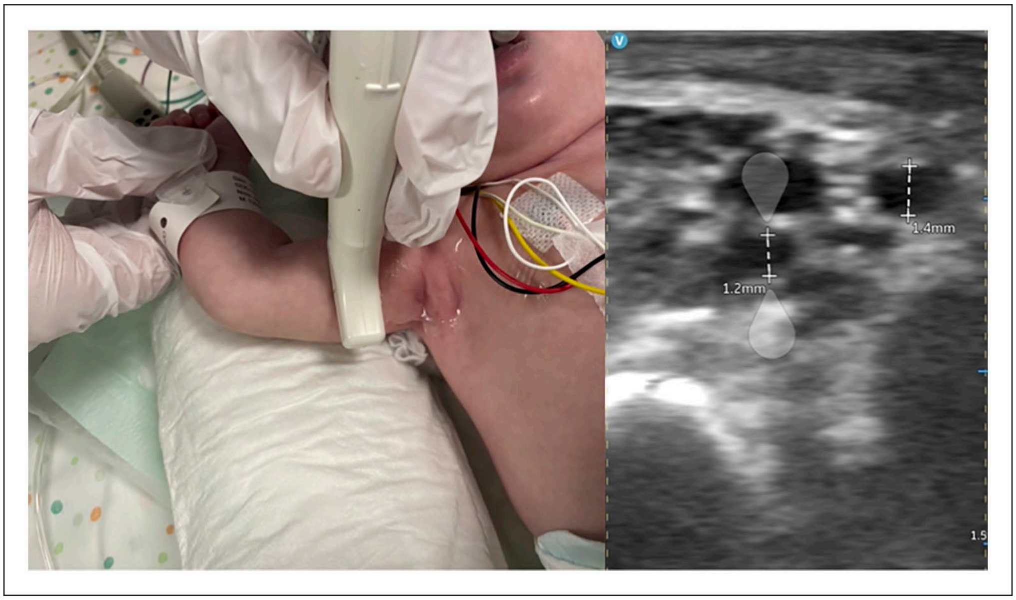

Figure 1. Ultrasound evaluation of deep veins of the arm at the mid-portion of upper arm (green zone according to Dawson) (scan 1): visualization of the brachial vein (diameter 1.2 mm) and of the basilic vein (diameter 1.4 mm).

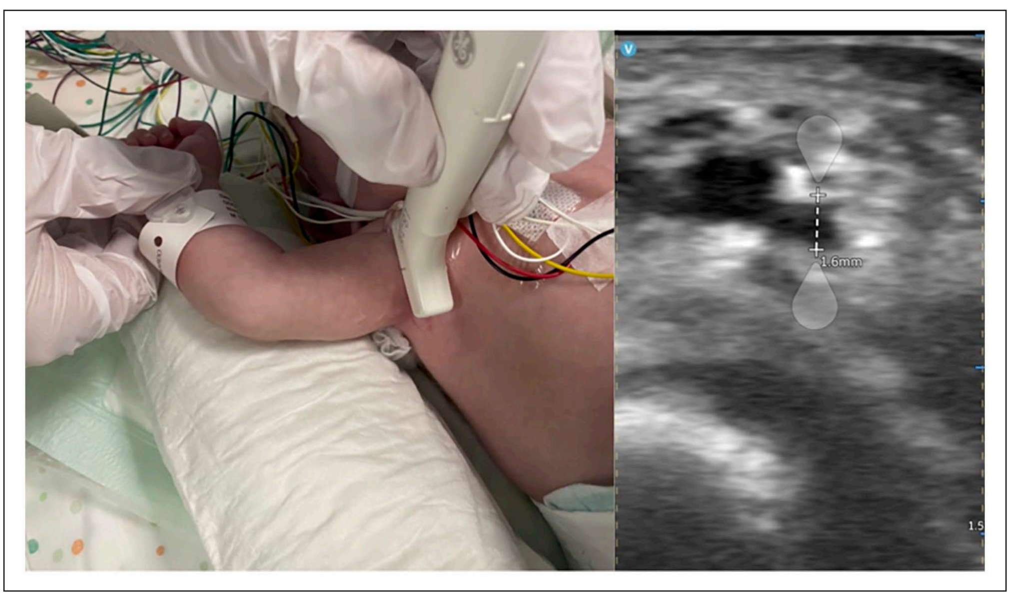

Figure 2. Ultrasound evaluation of deep veins of the arm close to the axilla (yellow zone according to Dawson) (scan 2): visualization of the axillary vein (diameter 1.6 mm).

Statistical analysis

Data were described as means, standard deviation, and medians, quartiles and minimum and maximum values for continuous variables, while absolute and relative frequencies were used for categorical variables.

The Kolmogorov–Smirnov test was used to test the normality of the distribution of the data within the groups. The Wilcoxon signed-rank test was used to compare the difference in paired values between the right and the left side.

Parameters of the study groups were compared using chi-square or Fisher's exact test for categorical variables or Mann–Whitney *U*-test for continuous variables.

Concordance between ultrasound measures interobservers was determined by the Bland-Altmann statistical method.

A p value less than 0.05 was considered statistically significant, and all p values were based upon two tailed tests. Statistical analysis was performed using SPSS for Windows (SPSS Inc, Chicago, IL, USA).

Table 1. Patients included in the study.

	Group 1	Group 2	Group 3	Group 4	Group 5
	2.5–4 kg	4.1–7 kg	7.1–10 kg	10.1–15 kg	15.1–20 kg
Number	51	49	52	50	50
Males/females	38/13	24/25	35/17	38/12	29/21
Age, median (range)	0.56 months (1 day–4.6 months)	3.6 months (0.49–14.8)	16 months (0.2–34.5)	2.6 years (0.62–8.3)	4.8 years (2.7–9.8)
Weight, median (range)	3 kg (2.5–4)	5.6 kg (4.1–7)	10 kg (8–10)	13.2 kg (10.2–15)	18.5 kg (15.3–20)
Height, median (range)	49 cm (36–54)	60 cm (43–74)	82 cm (62–100)	93 cm (79–120)	110 cm (70–140)

Table 2. Internal diameters of the veins (right arm).

	Group 1	Group 2	Group 3	Group 4	Group 5
Brachial vein (scan 1)					
Mean ± SD	1.08 ± 0.31	1.32 ± 0.46	1.64 ± 0.5	1.67 ± 0.43	1.75 ± 0.58
Median (range)	1.05 (0.1–2.3)	1.22 (0.14–2.65)	1.6 (1.05–3)	1.6 (0.8–2.55)	1.62 (0.95–3.45)
Basilic vein (scan 1)					
Mean ± SD	1.36 ± 0.37	1.69 ± 0.51	2.3 ± 0.56	2.58 ± 0.54	3.04 ± 0.65
Median (range)	1.3 (0.1–2.8)	1.6 (0.15–2.75)	2.3 (1.4–4)	2.45 (1.5–3.75)	3 (1.85–4.8)
Cephalic vein (scan 1)					
Mean ± SD	0.99 ± 0.32	1.1 ± 0.32	1.58 ± 0.38	1.61 ± 0.53	1.86 ± 0.49
Median (range)	1.05 (0.07–1.6)	1.15 (0.13–1.65)	1.57 (0.7–2.15)	1.57 (0.2–2.95)	1.77 (1–3.6)
Axillary vein (scan 2)					
Mean ± SD	2 ± 0.52	2.44 ± 0.81	3.4 ± 0.83	3.92 ± 0.92	4.55 ± 0.82
Median (range)	1.95 (0.08–3.05)	2.25 (0.2–4.75)	3.35 (2–5)	4.05 (2.2–6.4)	4.75 (2.75–6.25)

All measurements in millimeters.

Results

During a period of 15 months, 252 children were enrolled (35% females, 65% males). The median age was 1.2 years (range 3 days–9.8 years). The characteristics of the studied population are shown in Table 1.

The brachial artery was of difficult identification in 9.6% of patients (96% of them in group 1). A clear identification of the median nerve was not feasible in 30% of patients (80% of them in group 1 and in group 2).

The diameters of the different veins in the five groups are reported in Table 2 (right arm) and Table 3 (left arm). No significant difference was found in the measurement of the diameter of the veins between male and female patients or between left and right arm. The correlation coefficient between measurements of left and right arm was between 0.96 and 0.99 in all groups.

The correlation coefficients of concordance between the measurements of the two operators were very high (between 0.96 and 0.99 for each vein evaluated).

Also, we found no correlation between the age of the child and the diameter of the deep veins of the arm. A correlation was found between weight of the child and vein diameter, but only in group 4 and 5, that is, in children >10 kg (body weight vs diameter of axillary vein: $r^2 = 0.77$; body weight vs diameter of basilic vein: $r^2 = 0.76$; $p < 0.001$ for both).

Considering that the currently used ultrasound-guided power injectable PICCs have a minimal caliber of 3 Fr—which would require, according to the recommendations of the current protocols,[3] a venous diameter of at least 3 mm—we have studied the prevalence of veins >3 mm in the five groups of children (see Table 4).

As regards the scan at midarm (scan 1), in group 1 and 2, all veins were <3 mm; in group 3, the veins with internal diameter >3 mm were the right basilic vein (13.4% of children) and the left basilic vein (7.6%); in group 4, the veins >3 mm were the right basilic vein (26% of children) and the left basilic vein (28%); in group 5, the veins >3 mm were the right and left basilic veins (54% of children), the right brachial vein (8%), the left brachial vein (16%), the right cephalic vein (10%), and the left cephalic vein (6%).

As regards the scan at the axilla (scan 2), we found an axillary vein >3 mm in 5.8% and 3.9% of patients in group 1 (right and left axillary vein, respectively), in 30.6% and 28.6% of patients in group 2 (right and left axillary vein, respectively), in 67% of patients in group 3 (both right and left axillary vein), in 82% of patients in group 4 (both right

Table 3. Internal diameters of the veins (left arm).

	Group 1	Group 2	Group 3	Group 4	Group 5
Brachial vein (scan 1)					
Mean ± SD	1.06 ± 0.25	1.28 ± 0.46	1.58 ± 0.4	1.76 ± 0.45	1.88 ± 0.8
Median (range)	1.05 (0.12–1.85)	1.2 (0.1–2.6)	1.5 (0.75–2.9)	1.72 (1–2.9)	1.8 (0.1–4.15)
Basilic vein (scan 1)					
Mean ± SD	1.35 ± 0.32	1.62 ± 0.58	2.3 ± 0.47	2.64 ± 0.54	2.96 ± 0.64
Median (range)	1.3 (0.13–2.1)	1.52 (0.12–2.95)	2.3 (1.3–3.3)	2.6 (1.5–3.95)	3 (1.95–4.9)
Cephalic vein (scan 1)					
Mean ± SD	1.03 ± 0.53	1.1 ± 0.32	1.55 ± 0.39	1.59 ± 0.42	1.85 ± 0.51
Median (range)	1.02 (0.08–2.55)	1.15 (0.12–1.85)	1.5 (0.8–2.25)	1.55 (0.9–2.85)	1.8 (0.85–3.55)
Axillary vein (scan 2)					
Mean ± SD	1.97 ± 0.51	2.43 ± 0.91	3.43 ± 0.8	4.02 ± 0.9	4.46 ± 0.78
Median (range)	1.95 (0.15–3)	2.2 (0.14–4.75)	3.45 (2.05–5)	4.17 (2.2–6.2)	4.52 (2.8–6.05)

All measurements in millimeters.

Table 4. Veins with internal diameters >3 mm in the different groups of children.

	Brachial vein (scan 1)		Basilic vein (scan 1)		Cephalic vein (scan 1)		Axillary vein (scan 2)	
	Right	Left	Right	Left	Right	Left	Right	Left
Group 1 (*n* = 51)	–	–	–	–	–	–	3 (5.8%)	2 (3.9%)
Group 2 (*n* = 49)	–	–	–	–	–	–	15 (30.6%)	14 (28.5%)
Group 3 (*n* = 52)	–	–	7 (13.4%)	4 (7.6%)	–	–	35 (67%)	35 (67%)
Group 4 (*n* = 50)	–	–	13 (26%)	14 (28%)	–	–	41 (82%)	41 (82%)
Group 5 (*n* = 50)	4 (8%)	8 (16%)	27 (54%)	27 (54%)	5 (10%)	3 (6%)	47 (94%)	47 (94%)

and left axillary vein), and in 94% of patients in group 5 (both right and left axillary vein).

Discussion

To the best of our knowledge, the present study is the first to investigate systematically, by ultrasound scan, the caliber of the deep veins of the arms in pediatric patients, as well as its relationship with weight and age.

Some of these data may yield interesting considerations that may be useful when planning central venous catheterization in children.

The most important finding is that we found no correlation between the age of the child and the diameter of the deep veins of the arm. A correlation was found between weight of the child and vein diameter, but only for weight >10 kg. This implies that the decision of using a PICC rather than a CICC in a child cannot be based on anthropometric assumptions but only on ultrasound examination of the venous patrimony. As already recommended in the literature,[8] the best venous site for cannulation in children can be determined only after ultrasound examination. Pre-procedural ultrasound vein evaluation allows the clinician to choose the best site for venipuncture as well as the proper catheter size.

The catheter/vein size ratio is probably one of the critical factors determining the long-term outcome of a venous catheter.[4,9] As mentioned above, it is recommended that the diameter of the vein and the size of the cannula should respect a minimum ratio of 3:1 to reduce risk of CRT.[4,9] Maintaining a vein to catheter ratio of 3 to 1 has been of proven efficacy to reduce the risk of thrombotic complications.[5] Since the smallest caliber available for ultrasound guided PICCs is 3 Fr, the diameter of the vein suitable for placement should be at least 3 mm. The results of our study show that a vein >3 mm—suitable for PICC insertion—is available in one third of children weighing between 4 and 7 kg and in most children weighing more than 7 kg.

The appropriate catheter/size ratio as a strategy for reducing the risk of CRT is of great importance in children. Due to the low rate of immediate complications, the use of PICC had been steadily increased in recent years both in adult and in the pediatric population,[10,11] but some pediatric studies have reported a high incidence of late complications, and specifically CRT, in children with PICC.[6,12,13] Though, in many of these studies, PICCs were inserted without ultrasound, which means (a) that venipuncture was performed according to the obsolete technique of direct venipuncture of antecubital veins, and (b) that the operator had no information about the actual caliber of the

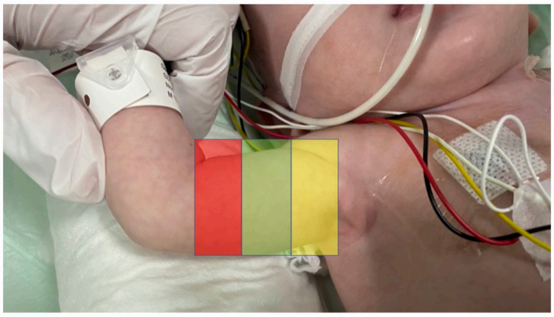

Figure 3. Dawson's zones in the upper arm of a 3.5 kg infant.

vein, so that the choice of the caliber of the catheter was based on the age and weight of the child.[6]

A large study on more than 1100 PICCs in children reported a high incidence of CRT, but no information about the caliber of the vein was provided; though, the authors reported that the ratio between height of the child and diameter of the catheter was found to be an important risk factor for thrombosis.[14]

In another clinical study comparing 1126 PICCs and 1583 CICCs in children, PICCs had a higher risk of CRT; though, the authors offered no details about the technique of PICC insertion or about the catheter/vein ratio or about the criteria for choosing the caliber of the catheter.[13]

A recent study reported a high incidence of CRT (12%) in pediatric patients with Hodgkin lymphoma; though, in this study the catheter-vein ratio was not optimal, since a catheter diameter accounting for 45% of the vein diameter was considered acceptable.[15]

On the contrary, in a very recent prospective study reporting 279 PICC insertion in children (mean age 8.9 ± 5 years), there was no episode of CRT at 2 weeks follow up[5]; notably, in this study all PICCs were inserted according to a well-defined insertion protocol, which included pre-procedural ultrasound evaluation of the veins, catheter-vein ratio 3:1 or higher, and ultrasound guided venipuncture.

In our study, we studied both the deep veins at mid-arm (so-called "green zone" according to Dawson's terminology)[7] (scan 1) and the axillary vein in the proximity of the axilla (so-called "yellow zone" according to Dawson) (scan 2) (Figure 3). Most current protocols of PICC insertion[3] recommend that the exit site of the catheter should be in the green zone, and that if the best available vein is in the yellow zone, the catheter should be tunneled so to have the venipuncture in the yellow zone but the exit site in the green zone. This recommendation is consistent with the RAVESTO protocol (Rapid Assessment of Venous Exit Site and Tunneling Options), recently developed by Ostroff et al.[16] Considering the small caliber of the arm veins in pediatric patients, this would imply a wider adoption of PICC tunneling in children if compared with adults. As discussed in the RAVESTO paper,[16] in some clinical conditions "pseudo-tunneling" (i.e. extended subcutaneous route during venipuncture) may also be an option, particularly in the pediatric population. In the prospective study mentioned above,[5] which reported no episode of CRT, 85 PICCs out of 279 were tunneled.

Considering the results of the present study, a non-tunneled PICC (venipuncture in the green zone) is theoretically possible in no child weighing less than 7 kg, in few children weighing 7–10 kg, in one fourth of children weighing 10–15 kg, and in more than half of children weighing 15–20 kg. On the other hand, according to our data, a tunneled PICC is suitable in few children below 4 kg, but in one third of children weighing 4–7 kg, and in the majority of children weighing more than 7 kg.

Last, one more information drawn from our data is that in children weighing less than 7 kg there may be some risk of accidental injury to the brachial artery or to the median nerve, since these structures may not be easily identified in these patients.

Conclusion

Our prospective study on the diameter of the deep veins of the arm in children weighing less than 20 kg has confirmed that the age and the weight of the patient have a small role in predicting the caliber of the veins of the arm. Veins should be measured case by case through a proper and systematic ultrasound evaluation, using the RaPeVA protocol[3]; at any case, the clinician can expect that insertion of a 3 Fr PICC may be feasible in one third of children weighing between 4 and 7 kg, and in most children weighing more than 7 kg, especially if adopting the tunneling or pseudo-tunneling techniques, as recommended by the current protocols of PICC insertion.[3,16] Also, the clinician should not expect significant difference between female versus male patients or between the left versus the right side.

List of abbreviations

CICC—Centrally Inserted Central Catheter
CRT—Catheter-Related Thrombosis
PICC—Peripherally Inserted Central Catheter
PICU—Pediatric Intensive Care Unit
RaPeVA—Rapid Peripheral Vein Assessment
RAVESTO—Rapid Assessment of Exit Site and Tunneling Options

Author contributions

All authors contributed to the study conception and design. Material preparation, data collection, and analysis were performed by CZ, MB, FB, and LA. The first draft of the manuscript was written by MGA and MP; all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Declaration of conflicting interests

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Ethical approval

The study was approved by the Ethics Committee of the "G.Gaslini" Hospital.

Consent to participate

Written informed consent was obtained from the parents.

Consent to publish

The authors confirm that the parents provided informed consent for publication of the images in Figures 1 to 3.

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