

See discussions, stats, and author profiles for this publication at: <https://www.researchgate.net/publication/382817567>

A narrative review on tip navigation and tip location of central venous access devices in the neonate: Intracavitary ECG or real time ultrasound?

Article in *The Journal of Vascular Access* · August 2024

DOI: 10.1177/11297298241259247

CITATION

1

READS

27

5 authors, including:



Gina Ancora

AUSL Romagna Infermi Hospital Rimini

106 PUBLICATIONS 3,133 CITATIONS

[SEE PROFILE](#)



Vito D'Andrea

Policlinico Universitario Agostino Gemelli

71 PUBLICATIONS 874 CITATIONS

[SEE PROFILE](#)



Giovanni Barone

Catholic University of the Sacred Heart

79 PUBLICATIONS 1,879 CITATIONS

[SEE PROFILE](#)

A narrative review on tip navigation and tip location of central venous access devices in the neonate: Intracavitary ECG or real time ultrasound?

Miria Natile¹, Gina Ancora¹, Vito D'Andrea² ,
Mauro Pittiruti³  and Giovanni Barone¹ 

The Journal of Vascular Access
1–8

© The Author(s) 2024

Article reuse guidelines:

sagepub.com/journals-permissions

DOI: 10.1177/11297298241259247

journals.sagepub.com/home/jva



Abstract

The proper location of the tip of a central venous access device plays a crucial role in minimizing the risks potentially associated with its use. Recent guidelines strongly recommend preferring real-time, intra-procedural methods of tip location since they are more accurate, more reliable and more cost-effective than post-procedural methods. Intracavitary electrocardiography and real time ultrasound can both be applied in the neonatal setting, but they offer different advantages or disadvantages depending on the type of central venous access device. Reviewing the evidence currently available about the use of these two methods in neonates, in terms of applicability, feasibility and accuracy, it can be concluded that (a) real time ultrasound is the only acceptable methodology for tip navigation for any central venous access device in neonates, (b) intracavitary electrocardiography is the preferred method of tip location for central catheters inserted by ultrasound-guided cannulation of the internal jugular vein or the brachiocephalic vein, and (c) real time ultrasound is the preferred method of tip location for umbilical venous catheters, epicutaneo-cava catheters, and central catheters inserted by ultrasound-guided cannulation of the common femoral vein.

Keywords

Real time ultrasound, central venous access, patient safety, umbilical venous catheter, epicutaneo-cava catheter, intracavitary ECG

Date received: 26 March 2024; accepted: 19 May 2024

Introduction

Central venous access devices (CVADs) are often required in Neonatal Intensive Care Unit (NICU) for several purposes. For any CVAD, the proper location of the tip is crucial to minimize the risks potentially associated with the use of the device. Current methods for accurate and safe tip location of CVADs include intracavitary electrocardiography (IC-ECG)^{1,2} and ultrasound-based tip navigation/tip location (ECHOTIP).^{1,3} Unfortunately, tip location is still assessed by radiological methods (chest and abdominal X-rays) in most neonates; several surveys found out that such practice is still used in up to 80% of NICUs.^{4,5}

It is nowadays recognized that conventional radiology should be avoided for several reasons. First, because it is inaccurate. In fact, plain X-rays do not allow the direct visualization of the vasculature (veins, atrium or cava-atrial

junctions), so that location of the tip is estimated on the basis of radiological landmarks such as the vertebral bodies, the cardiac silhouette, or the diaphragmatic contour: this estimate is purely based on statistical inference and often does not correspond to the actual anatomical position of the tip.^{1,3,6–12} Also, since fluoroscopy is hardly if ever

¹Neonatal Intensive Care Unit, Infermi Hospital, AUSL della Romagna, Rimini, Italy

²Neonatal Intensive Care Unit, Fondazione Policlinico Universitario A. Gemelli IRCCS, Rome, Italy

³Department of Surgery, Fondazione Policlinico Universitario A. Gemelli IRCCS, Rome, Italy

Corresponding author:

Giovanni Barone, Neonatal Intensive Care Unit, Infermi Hospital Rimini, Via Settembrini 2, Rimini, Romagna 47923, Italy.

Email: gbarone85@yahoo.it

adopted in NICU, radiological methods are always post-procedural: this implies that they might be used only for tip location (i.e. assessment of the final position of the tip of the catheter) and not for tip navigation (i.e. real-time assessment of the proper direction of the catheter during placement).¹ As for any post-procedural method, there is inevitably some delay in reporting the result; also, there is sometimes the need to reposition the device, which means additional manipulations of the CVADs, increased stress and discomfort for the patient and potentially increased risk for infection.¹³ Last, radiology-based tip location is not harmless, since it exposes the neonate to ionizing radiations, which might ultimately be associated with long term consequences.^{14–16}

For these reasons, all recent guidelines strongly recommend preferring real-time, intra-procedural, non-radiological methods of tip location such as IC-ECG and real time ultrasound,^{1,17,18} since they are more accurate, more reliable and more cost-effective than radiology.¹ Being intraprocedural methods, they shorten the delay between device insertion and device utilization, allowing a more rapid start of the therapy (which is very important, especially in critically ill neonates).^{1,13}

Both IC-ECG and ultrasound offer several advantages but they also have some limitations in the neonatal setting. The aim of this paper is to review all the evidence available about IC-ECG and ultrasound in the neonatal setting and to describe how these two methods might integrate for tip navigation and location in NICU. After a brief overview of these methods applied on the neonatal population, we will discuss separately the main CVADs used in NICU: umbilical venous catheters (UVC); epicutaneous-cava catheters (ECC); CVADs inserted by ultrasound-guided venipuncture of deep veins, that is, centrally inserted central catheters (CICC) and femorally inserted central catheters (FICC).

Literature search

The literature search was performed using PubMed, EMBASE, Google Scholar, as well as the Cochrane Central Register of Controlled Trials.

Terms used in the search included “ultrasound,” “USG,” “point-of-care ultrasound,” “POCUS,” “Intracavitary ECG,” “NICU,” “central line,” “umbilical line,” “umbilical catheter,” “umbilical venous catheter (UVC),” “PICC,” “epicutaneous-cava catheter (ECC),” “CICC,” “FICC,” “internal jugular vein,” “subclavian vein,” “brachiocephalic vein,” and “femoral vein,” all of them matched with the terms “infant,” “neonate,” “newborn”; the search included papers published in the past 20 years, from 1/1/2004 to 1/1/2024. No language restrictions were applied, and we included all trials, case reports, and case series; the articles were filtered by reviewing the abstract.

The method of intracavitary electrocardiography for tip location

IC-ECG is a non-invasive, safe, inexpensive, and accurate method for intraprocedural verification of the correct position of the tip of the catheter.² In adults and in children, IC-ECG is currently regarded as the gold standard for tip location because it is intra-procedural, accurate, safe, cost-effective, easy to use and easy to learn.^{19–27} The IC-ECG method is based on the use of the catheter tip as a “traveling intracavitary electrode.” The vector of the lead II of the ECG is approximately co-axial to the vector of the atrial depolarization, so that the ECG trace shows a progressive increase in the height of the P wave, which reaches its peak as the intracavitary electrode (i.e. the tip of the catheter) is at the cava-atrial junction.²¹ Though, IC-ECG is not always easily feasible in newborns, particularly when using small caliber central venous catheters as 1 Fr ECCs.²⁸ Also, umbilical venous catheters (UVC) are often inserted in emergency, and/or in settings where IC-ECG might be logistically difficult to use.²⁹ Furthermore, while IC-ECG is highly accurate for detecting the position of the tip at the junction between superior vena cava (SVC) and right atrium (RA) (peak of P wave), or in the middle of the RA (biphasic P wave), it cannot accurately detect the position of the tip at the junction between inferior vena cava (IVC) and RA (the ideal position for UVC). Last but not least, IC-ECG is not useful for tip navigation, at least in neonates.

Real time ultrasound for tip navigation and tip location

Ultrasound represents the most promising method for both tip navigation and tip location during insertion of CVADs in NICU,^{17,30} because of its many advantages: it is accurate, consistently applicable and feasible, easy to perform (as ultrasound visualization of the vasculature is optimal in neonates), intraprocedural, non-invasive, absolutely safe, rapidly available, and appropriate for both tip navigation and tip location. On the other hand, learning this method requires a longer and more structured training if compared to the IC-ECG method.^{31,32} In this regard, a recent paper has offered a standardized protocol for tip navigation and tip location of all CVADs in NICU³—the Neo-ECHOTIP protocol—which should be used in the near future as an effective strategy to standardize the methodology, facilitate learning, and implement training programs focused on US based tip navigation and tip location in neonates.

The umbilical venous catheter

UVC is a very common CVAD in neonates, because is easy to insert at birth, and appropriate for the management of the critically ill, since it can be used for any type of

infusion, including inotropes and parenteral nutrition, as well as for blood sampling.^{29,33} On the other hand, UVC may be associated with severe complications if the tip is not placed in the appropriate location.³

Safe position of the tip of umbilical venous catheters

The correct position for the tip of UVCs is at the IVC/RA junction: this location of the tip appears to be associated with the minimal incidence of UVC-related complications (pleural and cardiac effusion, cardiac tamponade, endocarditis, arrhythmias, liver lesions, portal vein thrombosis, and portal hypertension).^{29,34–37}

IC-ECG for UVC

Three studies have explored the use of IC-ECG for tip location of UVCs.^{38–40} The two main limitations of these studies are the small number of neonates enrolled and the method used for comparison (X-rays). Furthermore, UVC is sometimes inserted in emergency and/or in settings where the use of IC-ECG might be logistically difficult. Also, as mentioned above, IC-ECG is not accurate in the detection of the IVC/RA junction. When the tip is in the IVC below the diaphragm, the amplitude of the P-wave and of the QRS complex is low; as the catheter tip approaches the RA, the amplitude of the QRS complex increases but the amplitude of the P wave does not follow a reliable pattern; as the tip gets to the middle of the RA, the P-wave becomes biphasic. At this point, the catheter should be retracted for an undetermined length so to reach again the IVC/RA junction.⁴¹ In short, this maneuver is not really accurate, since IC-ECG identifies the SVC/RA junction or the mid-atrium, but it cannot directly identify the IVC/RA junction. Last, IC-ECG cannot be used for tip navigation, which is crucial during UVC insertion.^{3,42}

Ultrasound for tip navigation/location of UVC

Many recent clinical studies have evaluated the accuracy of ultrasound during UVC placement.^{43–52} Ultrasound is feasible in any setting, and it is relatively easy to teach, and to learn. As a tip location method, it is more accurate, faster, safer and less expensive than conventional radiology; according to most authors, the method is consistently applicable and feasible, and the tip can be successfully located in 95%–100% of patients.⁵³ During UVC insertion, ultrasound is also extremely useful for tip navigation, and not only for tip location: primary malpositions with the catheter tip caught in the right or left portal vein branch are quite common if ultrasound is not utilized (up to 50% of the cases).²⁹ Ultrasound guidance facilitates the progression of the catheter in the desired direction, toward the ductus venosus: in fact, exerting a small pressure with the

probe, the umbilical vein becomes aligned with the ductus venosus. Tip navigation by ultrasound reduces significantly the incidence of errors in the progression of the catheter, thus reducing primary malposition and the incidence of related complications.^{3,42,54,55} The procedure of ultrasound-based tip navigation and tip location of UVCs has been properly described and standardized—in terms of probes and acoustic windows – as part of the previously quoted Neo-ECHOTIP protocol.

Summary: tip navigation/location of UVC

Analyzing the available evidence and the pro and cons of the two methods, it is reasonable to prefer ultrasound to IC-ECG, and consider ultrasound as the gold standard for both tip navigation and tip location of UVC in terms of applicability, feasibility, and accuracy; the intraprocedural ultrasound based tip navigation is particularly important, since it reduces dramatically the incidence of primary malpositions.⁵⁵ As regards tip location of UVCs, ultrasound is simple to learn, so that it can be easily introduced in the daily clinical practice⁵⁶; proper training may be facilitated by adopting standardized procedural protocols such as the Neo-ECHOTIP.³

The epicutaneo-cava catheter

Epicutaneo-cava catheter (ECC) is the most common CVAD used in NICU to administer parenteral nutrition and drugs not suitable for the peripheral veins; though, ECC is not appropriate for blood sampling or blood transfusion because of its small caliber; also, its use is somehow limited by the low flow (max 1–2 ml/min).^{28,33} In most NICUs, tip location of ECCs is performed by post-procedural chest X-ray; as explained above, X-rays offer only a very rough estimation of the tip location, based on relatively unreliable radiological landmarks^{4,5}; also, current guidelines recommend intra-procedural and not post-procedural methods.

Safe position of the tip of epicutaneo cava-catheters

The location of the tip depends on the insertion site of the ECC. For catheters inserted in veins of the upper limb or of the scalp, the tip should be located at the SVC/RA junction or in the upper third of the RA. For ECCs inserted in veins of the lower limb, the tip should be located either at IVC/RA junction or in the IVC above the level of renal veins and below the hepatic veins.^{1,57}

IC-ECG for ECC: Evidence from the literature

Several studies have explored the applicability, the feasibility, and the accuracy of IC-ECG for ECC inserted in

veins of the upper limbs or the scalp.^{58–62} Though, only in one study IC-ECG has been applied to small-caliber 1 Fr catheters, which are the most common ECCs used in NICU.⁵⁸ Furthermore, until now, this aforementioned study is the only one comparing the accuracy of IC-ECG to ultrasound-based tip location. Unfortunately, it is a very small study, which included only 26 patients. Due to this scarce evidence, IC-ECG cannot be recommended as first choice for intraprocedural tip location of ECCs inserted in the upper limbs. Two other studies evaluated the IC-ECG method for 2 Fr ECCs inserted in veins of the lower limbs, using as comparison conventional radiology.^{63,64} The results of these studies are limited by the consideration that IC-ECG—as already mentioned—is quite inaccurate in detecting the IVC/RA junction.

Ultrasound for ECC: Evidence from the literature

In the last decade, many clinical studies have investigated ultrasound as a tool for tip location for ECCs.^{3,13,31,48,53,65–68} In these studies, the tip was successfully located in a variable percentage of cases. The success of tip location is maximal when the operator is properly trained and a standardized protocol is adopted.^{32,53,65} Ultrasound-based tip location of ECCs requires a more advanced training if compared to UVCs. As for UVCs, also for ECCs ultrasound has the additional value of being useful for tip navigation, which should be performed preferably adopting standardized protocols of systematic ultrasound evaluation of the deep veins,^{3,69} such as the Rapid Central Vein Assessment⁷⁰(RaCeVA), the Rapid Peripheral Vein Assessment⁷¹ (RaPeVA), and the Rapid Femoral Vein Assessment (RaFeVA).⁷² Ultrasound can be used for tip location of ECCs inserted either in the upper limbs or in the lower limbs. The Neo-ECHOTIP protocol³ provides a standardized and easy guide for choosing the appropriate probe and the appropriate acoustic window in each situation. For catheters inserted in the lower limbs, a new acoustic window has been proposed recently, the so-called transhepatic view.⁷³ This approach is particularly useful for ECCs inserted in the lower limbs, since it allows to visualize the tip in the tract of IVC between hepatic veins and renal veins.

Summary: Tip navigation/location of ECCs

If ECCs are inserted in the upper limbs, both ultrasound and IC-ECG are theoretically applicable for tip location, but the feasibility of IC-ECG may be limited because of interferences derived from the movements of the non-sedated or mildly sedated neonate, and because of poor conductivity of the signal through small caliber 1 Fr catheters. Also, data supporting IC-ECG as the only technique for tip location are scarce, while ultrasound-based

tip location is supported by a significant amount of data. Last, ultrasound can be used for tip navigation, in contrast to IC-ECG. Nonetheless, appropriate training is of paramount importance. If ECCs are inserted in the lower limbs, ultrasound is the only appropriate method for both tip navigation and tip location, since the IVC/RA cannot be accurately detected by IC-ECG. Ultrasound-based tip navigation/location may not be easy for ECCs and requires proper training, which may be facilitated by adopting standardized procedural protocols such as the Neo-ECHOTIP.³

Ultrasound-guided CVADs

In neonates, most ultrasound-guided CVADs are power-injectable, 3–4 Fr polyurethane catheters inserted by ultrasound guided puncture either of the internal jugular or of the brachio-cephalic vein (CICC), or of the common femoral vein (FICC). CICCs and FICCs are especially appropriate for the management of critically ill neonates, since these CVADs allow high flow infusions (1ml/s), hemodynamic monitoring (central venous pressure and oxygen saturation of mixed venous blood), easy blood sampling, and administration of blood products.^{33,74,75}

Safe position of the tip of CICCs and FICCs

For CICCs, the tip should be located at the SVC/RA junction or in the upper third of the RA.^{1,57} For FICCs, the tip should be located either at the IVC/RA junction (if the device is meant to be used also for hemodynamic monitoring) or in the tract of IVC between renal and hepatic veins (if the device is meant to be used only for infusion not suitable for the peripheral route and blood sampling).^{33,73}

IC-ECG for CICCs and FICCs: Evidence from the literature

Several studies have investigated the IC-ECG method for tip location of CICCs and FICCs, demonstrating that it is widely applicable and feasible in the neonatal population.^{19,26,74,76–79} In the largest study currently available,⁷⁸ including 105 CICC insertions in neonates, the applicability of IC-ECG (i.e. evidence of P-wave on the surface ECG) was 100%, and its feasibility (i.e. detection of an increased P-wave on the intracavitary ECG) was also 100%. The accuracy was 100%, since there was a perfect match between tip location by IC-ECG and tip location by ultrasound. There were no adverse events directly or indirectly related to the IC-ECG technique. IC-ECG may also be applicable and feasible for FICCs, with the main limitation that the method is accurate in the detection of the tip in mid-atrium (biphasic P wave) but it is not accurate to locate the IVC/RA junction or the subdiaphragmatic IVC.

Table 1. Tip location by intracavitary ECG.

Vascular Access Device	Applicability	Feasibility	Accuracy
UVC	Applicable, but not recommended	Yes	Low
ECC – upper limbs	Applicable, but not recommended	Not always feasible	High
ECC – lower limbs	Not always applicable	Not always feasible	Low
CICC	Applicable and highly recommended	Yes	High
FICC	Not always applicable	Not always feasible	Low

IC-ECG = never applicable for tip navigation.

Table 2. Tip location by real time ultrasound.

Vascular Access Device	Applicability	Feasibility	Accuracy
UVC	Applicable, highly recommended	Yes	High
ECC – upper limbs	Applicable, recommended	Yes	High
ECC – lower limbs	Applicable, recommended	Yes	High
CICC	Applicable	Yes	High
FICC	Applicable, recommended	Yes	High

Real time ultrasound = always applicable for tip navigation.

Ultrasound for CICCs and FICCs: Evidence from the literature

Ultrasound, particularly if adopting the Neo-ECHOTIP protocol, is certainly applicable, feasible and accurate for tip location of CICCs, though few published studies are available on this specific topic. Ultrasound-based tip location of FICCs is also particularly easy and accurate for any desired position of the tip, either at the IVC/RA junction or in the subdiaphragmatic IVC. For both CICCs and FICCs, real time ultrasound is also very useful for tip navigation. The above mentioned Neo-ECHOTIP protocol³ provides a standardized and easy guide for choosing the appropriate probe and the appropriate acoustic window not only during UVC and ECC insertion, but also during CICC and FICC insertion.

Summary: Tip navigation/location of CICCs and FICCs

IC-ECG is the gold standard for tip location during CICC insertion since it is applicable, feasible, accurate, cost effective, and—most interestingly—requires only a minimal training. During CICC insertion, the infant is fully sedated, and the ECG trace is not exposed to interference. Also, the caliber of the CICC is appropriately large so to guarantee an optimal conductivity of the ECG signal. IC-ECG tip location has the advantage that it can be performed by a single operator, with no need of additional probes, as required by ultrasound-based tip location.⁷⁸ Though, even if using IC-ECG, ultrasound can be very useful during CICC insertion, because it accounts for an accurate tip navigation and because it identifies easily any primary malposition. Furthermore, there are some rare

situations where the IC-ECG may not be applicable (e.g. newborns with atrial flutter) while ultrasound-based tip location is applicable in 100% of cases. As regards FICC insertion, tip location by ultrasound is to be preferred, since it is the only accurate method for detecting the tip inside the IVC or at the IVC/RA junction.

Conclusions

The main limitation of the present paper is that it' is not a systematic review however it offers a comprehensive overview of tip navigation and tip location for all CVADs used in NICU.

CVADs are often required in neonates admitted to the NICU. The position of the tip of the CVAD is often assessed by post-procedural radiography, but this strategy should be discouraged because inaccurate, expensive, unsafe, and time-consuming. Since recent guidelines strongly recommend intra-procedural methods for tip location, the only acceptable strategies for tip location are either ultrasound or IC-ECG (see Tables 1 and 2).

IC-ECG can be theoretically applicable for tip location of ECCs, UVCs, and FICCs, but its actual applicability, feasibility and accuracy are limited by several factors: the small caliber of some ECCs; the interferences due to movements of awake or lightly sedated infants; the absence of a clear electrophysiological correlate of the IVC/RA junction.

On the other hand, during CICCs insertion, IC-ECG should be regarded as the gold-standard, although integration with ultrasound is recommended in some special situations.

Last, as regards tip navigation of CVADs, IC-ECG is not useful; the only methods theoretically useful are

fluoroscopy and ultrasound, and the latter is obviously the only option in neonates, since fluoroscopy-based tip navigation is inaccurate, unsafe, expensive, and logistically difficult or impossible.

Author contributions

MN, GB and MP made a substantial contribution to the concept or design of the work; MN drafted the article and GB, GA, MP revised it critically for important intellectual content. GA and VD revised and approved the final version of the manuscript improving significantly the intellectual content.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

Ethics/Informed consent statement

Not applicable

ORCID iDs

Vito D'Andrea  <https://orcid.org/0000-0002-0980-799X>

Mauro Pittiruti  <https://orcid.org/0000-0002-2225-7654>

Giovanni Barone  <https://orcid.org/0000-0002-8015-7299>

References

- Nickel B, Gorski L, Kleidon T, et al. *Infusion therapy standards of practice*, 9th ed. *J Infus Nurs* 2024; 47: S1–S285.
- Pittiruti M, Pelagatti F and Pinelli F. Intracavitary electrocardiography for tip location during central venous catheterization: a narrative review of 70 years of clinical studies. *J Vasc Access* 2021; 22: 778–785.
- Barone G, Pittiruti M, Biasucci DG, et al. Neo-ECHOTIP: a structured protocol for ultrasound-based tip navigation and tip location during placement of central venous access devices in neonates. *J Vasc Access* 2022; 23: 679–688.
- Sharpe E, Pettit J and Ellsbury DL. A national survey of neonatal peripherally inserted central catheter (PICC) practices. *Adv Neonatal Care* 2013; 13: 55–74.
- Ben Fadel N, Pulgar L and Khurshid F. Point of care ultrasound (POCUS) in Canadian neonatal intensive care units (NICUs): where are we? *J Ultrasound* 2019; 22: 201–206.
- Albrecht K, Breitmeier D, Panning B, et al. The carina as a landmark for central venous catheter placement in small children. *Eur J Pediatr* 2006; 165: 264–266.
- Hirschl JR, Gadepalli SK, Derstine BA, et al. CT validation of SVC-RA junction location for pediatric central line placement: is vertebral bodies below the carina accurate? *Pediatr Surg Int* 2020; 36: 1055–1060.
- Yoon SZ, Shin JH, Hahn S, et al. Usefulness of the carina as a radiographic landmark for central venous catheter placement in paediatric patients. *Br J Anaesth* 2005; 95: 514–517.
- Inagawa G, Ka K, Tanaka Y, et al. The carina is not a landmark for central venous catheter placement in neonates. *Paediatr Anaesth* 2007; 17: 968–971.
- Gupta R, Drendel AL, Hoffmann RG, et al. Migration of central venous catheters in neonates: a radiographic assessment. *Am J Perinatol* 2016; 33: 600–604.
- Ahn S and Chung JH. Proper tip position of central venous catheter in pediatric patients. *J Vasc Access* 2015; 16: 399–402.
- Gorski LA, Hadaway L, Hagle ME, et al. Infusion therapy standards of practice, 8th ed. *J Infus Nurs* 2021; 44: S1–S224.
- D'Andrea V, Cascini V, Russo R, et al. The role of ultrasound in epicutaneo-caval catheter insertion in neonates: systematic review, meta-analysis and future perspectives. *Diagnostics (Basel)* 2023; 13: 20230903.
- Escourrou G and De Luca D. Lung ultrasound decreased radiation exposure in preterm infants in a neonatal intensive care unit. *Acta Paediatr* 2016; 105: e237–e239.
- Scott MV, Fujii AM, Behrman RH, et al. Diagnostic ionizing radiation exposure in premature patients. *J Perinatol* 2014; 34: 392–395.
- Kleinerman RA. Cancer risks following diagnostic and therapeutic radiation exposure in children. *Pediatr Radiol* 2006; 36(Suppl. 2): 121–125.
- Lamperti M, Bodenham AR, Pittiruti M, et al. International evidence-based recommendations on ultrasound-guided vascular access. *Intensive Care Med* 2012; 38: 1105–1117.
- Lamperti M, Biasucci DG, Disma N, et al. European Society of Anaesthesiology guidelines on peri-operative use of ultrasound-guided for vascular access (PERSEUS vascular access). *Eur J Anaesthesiol* 2020; 37: 344–376.
- Rossetti F, Pittiruti M, Lamperti M, et al. The intracavitary ECG method for positioning the tip of central venous access devices in pediatric patients: results of an Italian multicenter study. *J Vasc Access* 2015; 16: 137–143.
- Baldinelli F, Capozzoli G, Pedrazzoli R, et al. Evaluation of the correct position of peripherally inserted central catheters: anatomical landmark vs. electrocardiographic technique. *J Vasc Access* 2015; 16: 394–398.
- Pittiruti M, La Greca A and Scoppettuolo G. The electrocardiographic method for positioning the tip of central venous catheters. *J Vasc Access* 2011; 12: 280–291.
- Bloemen A, Daniels AM, Samyn MG, et al. Electrocardiographic-guided tip positioning technique for peripherally inserted central catheters in a Dutch teaching hospital: feasibility and cost-effectiveness analysis in a prospective cohort study. *J Vasc Access* 2018; 19: 578–584.
- Li W, Xu R and Fan D. Clinical application of electrocardiogram-guided tip positioning in peripheral inserted central catheters placement. *J Cancer Res Ther* 2018; 14: 887–891.
- Li A, Jiao J, Zhang Y, et al. A randomized controlled study of bedside electrocardiograph-guided tip location technique & the traditional chest radiography tip location technique for peripherally inserted central venous catheter in cancer patients. *Indian J Med Res* 2018; 147: 477–483.
- Liu G, Hou W, Zhou C, et al. Meta-analysis of intracavitary electrocardiogram guidance for peripherally inserted central catheter placement. *J Vasc Access* 2019; 20: 577–582.

26. Pittiruti M, Salerno G, Mancino A, et al. Ultrasound versus intracavitary electrocardiography for intraprocedural tip location during central venous catheterization in infants and children: a prospective clinical study. *J Vasc Access* 2022; 11297298221132415. 774–778.
27. Yuan L, Li R, Meng A, et al. Superior success rate of intracavitary electrocardiogram guidance for peripherally inserted central catheter placement in patients with cancer: a randomized open-label controlled multicenter study. *PLoS One* 2017; 12: e0171630.
28. Barone G and Pittiruti M. Epicutaneo-caval catheters in neonates: new insights and new suggestions from the recent literature. *J Vasc Access* 2020; 21: 805–809.
29. D'Andrea V, Prontera G, Rubortone SA, et al. Umbilical venous catheter update: a narrative review including ultrasound and training. *Front Pediatr* 2021; 9: 774705.
30. Pittiruti M. Ultrasound guided central vascular access in neonates, infants and children. *Curr Drug Targets* 2012; 13: 961–969.
31. Grasso F, Capasso A, Pacella D, et al. Ultrasound guided catheter tip location in neonates: a prospective cohort study. *J Pediatr* 2022; 244: 86–91 e82.
32. Barone G, Pittiruti M and D'Andrea V. Ultrasound-guided catheter tip location in neonatal central venous access. Focus on well-defined protocols and proper ultrasound training. *J Pediatr* 2022; 247: 181.
33. Barone G, D'Andrea V, Ancora G, et al. The neonatal DAV-expert algorithm: a GAVeCeLT/GAVePed consensus for the choice of the most appropriate venous access in newborns. *Eur J Pediatr* 2023; 182 (8): 3385–3395.
34. Campbell RE. Roentgenologic features of umbilical vascular catheterization in the newborn. *Am J Roentgenol Radium Ther Nucl Med* 1971; 112: 68–76.
35. Oestreich AE. Umbilical vein catheterization—appropriate and inappropriate placement. *Pediatr Radiol* 2010; 40: 1941–1949.
36. Abiramalatha T, Kumar M and Shabeer MP. Pleural effusion caused by a malpositioned umbilical venous catheter in a neonate. *BMJ Case Rep* 2015; 2015: 20151030.
37. Weber AL, DeLuca S and Shannon DC. Normal and abnormal position of the umbilical artery and venous catheter on the roentgenogram and review of complications. *Am J Roentgenol Radium Ther Nucl Med* 1974; 120: 361–367.
38. Biban PC, Santuz P, Soffiati M, et al. Positioning of umbilical vein catheter with ECG-guided technique: randomized study. *Acta Biomed Ateneo Parmense* 2000; 71: 647–650.
39. Tsui BC, Richards GJ and Van Aerde J. Umbilical vein catheterization under electrocardiogram guidance. *Paediatr Anaesth* 2005; 15: 297–300.
40. Wu L, Peng M, Cao T, et al. Application of a modified electrocardiogram-guided technique for umbilical venous catheterisation in neonates: a retrospective trial. *J Paediatr Child Health* 2020; 56: 716–720.
41. Annetta MG, Marche B, Dolcetti L, et al. Ultrasound-guided cannulation of the superficial femoral vein for central venous access. *J Vasc Access* 2022; 23: 598–605. 20210321.
42. Kishigami M, Shimokaze T, Enomoto M, et al. Ultrasound-guided umbilical venous catheter insertion with alignment of the umbilical vein and ductus venosus. *J Ultrasound Med* 2020; 39: 379–383.
43. Greenberg M, Movahed H, Peterson B, et al. Placement of umbilical venous catheters with use of bedside real-time ultrasonography. *J Pediatr* 1995; 126: 633–635.
44. Simanovsky N, Ofek-Shlomai N, Rozovsky K, et al. Umbilical venous catheter position: evaluation by ultrasound. *Eur Radiol* 2011; 21: 1882–1886.
45. Karber BC, Nielsen JC, Balsam D, et al. Optimal radiologic position of an umbilical venous catheter tip as determined by echocardiography in very low birth weight newborns. *J Neonatal Perinatal Med* 2017; 10: 55–61.
46. Froehlich CD, Rigby MR, Rosenberg ES, et al. Ultrasound-guided central venous catheter placement decreases complications and decreases placement attempts compared with the landmark technique in patients in a pediatric intensive care unit. *Crit Care Med* 2009; 37: 1090–1096.
47. Fleming SE and Kim JH. Ultrasound-guided umbilical catheter insertion in neonates. *J Perinatol* 2011; 31: 344–349.
48. Katheria AC, Fleming SE and Kim JH. A randomized controlled trial of ultrasound-guided peripherally inserted central catheters compared with standard radiograph in neonates. *J Perinatol* 2013; 33: 791–794.
49. Pulickal AS, Charlagorla PK, Tume SC, et al. Superiority of targeted neonatal echocardiography for umbilical venous catheter tip localization: accuracy of a clinician performance model. *J Perinatol* 2013; 33: 950–953.
50. Ades A, Sable C, Cummings S, et al. Echocardiographic evaluation of umbilical venous catheter placement. *J Perinatol* 2003; 23: 24–28.
51. Franta J, Harabor A and Soraisham AS. Ultrasound assessment of umbilical venous catheter migration in preterm infants: a prospective study. *Arch Dis Child Fetal Neonatal Ed* 2017; 102: F251–F255.
52. Hoellering AB, Koorts PJ, Cartwright DW, et al. Determination of umbilical venous catheter tip position with radiograph. *Pediatr Crit Care Med* 2014; 15: 56–61.
53. Nguyen J. Ultrasonography for central catheter placement in the neonatal intensive care unit: a review of utility and practicality. *Am J Perinatol* 2016; 33: 525–530.
54. Kozyak BW, Fraga MV, Juliano CE, et al. Real-time ultrasound guidance for umbilical venous cannulation in neonates with congenital heart disease. *Pediatr Crit Care Med* 2022; 23: e257–e266. 20220307.
55. Barone G, Pittiruti M, Prontera G, et al. A novel neonatal protocol for Safe Insertion of Umbilical Venous Catheters (SIUVeC): Minimizing complications in placement and management. *J Vasc Access* 2024; 11297298241236220.
56. Rubortone SA, Costa S, Perri A, et al. Real-time ultrasound for tip location of umbilical venous catheter in neonates: a pre/post intervention study. *Ital J Pediatr* 2021; 47: 68.
57. Pittiruti M and Lamperti M. Late cardiac tamponade in adults secondary to tip position in the right atrium: an urban legend? A systematic review of the literature. *J Cardiothorac Vasc Anesth* 2015; 29: 491–495.
58. Capasso A, Mastroianni R, Passariello A, et al. The intracavitary electrocardiography method for positioning the tip of epicutaneous cava catheter in neonates: Pilot study. *J Vasc Access* 2018; 19: 542–547.
59. Ling Q, Chen H, Tang M, et al. Accuracy and safety study of intracavitary electrocardiographic guidance for peripherally

- inserted central catheter placement in neonates. *J Perinat Neonatal Nurs* 2019; 33: 89–95.
60. Xiao AQ, Sun J, Zhu LH, et al. Effectiveness of intracavitary electrocardiogram-guided peripherally inserted central catheter tip placement in premature infants: a multicentre pre-post intervention study. *Eur J Pediatr* 2020; 179: 439–446.
 61. Tang BZ, Chen CH, Chen H, et al. [RCT of reduction in catheter-related complications by using intracavitary electrocardiogram-assisted guidance in neonatal PICC Placement]. *Sichuan Da Xue Xue Bao Yi Xue Ban* 2021; 52: 497–502.
 62. Yang L, Bing X, Song L, et al. Intracavitary electrocardiogram guidance for placement of peripherally inserted central catheters in premature infants. *Medicine (Baltimore)* 2019; 98: e18368.
 63. Zhang S, Zhu Y, Du Y, et al. The positioning of the catheter tip with an intracavitary electrocardiogram in epicutaneous catheter placement via lower limbs in newborns: a retrospective study. *J Vasc Access* 2024; 25: 119–124.
 64. Zhou LJ, Xua HZ, Xu MF, et al. An accuracy study of the intracavitary electrocardiogram (IC-ECG) guided peripherally inserted central catheter tip placement among neonates. *Open Med (Wars)* 2017; 12: 125–130.
 65. Tauzin L, Sigur N, Joubert C, et al. Echocardiography allows more accurate placement of peripherally inserted central catheters in low birthweight infants. *Acta Paediatr* 2013; 102: 703–706.
 66. Oleti T, Jeeva Sankar M, Thukral A, et al. Does ultrasound guidance for peripherally inserted central catheter (PICC) insertion reduce the incidence of tip malposition? – a randomized trial. *J Perinatol* 2019; 39: 95–101. 20181022.
 67. Sharma D, Farahbakhsh N and Tabatabaie SA. Role of ultrasound for central catheter tip localization in neonates: a review of the current evidence. *J Matern Fetal Neonatal Med* 2019; 32: 2429–2437.
 68. Rossi S, Jogeesvaran KH, Matu E, et al. Point-of-care ultrasound for neonatal central catheter positioning: impact on X-rays and line tip position accuracy. *Eur J Pediatr* 2022; 181: 2097–2108.
 69. Barone G, D'Andrea V, Vento G, et al. A systematic ultrasound evaluation of the diameter of deep veins in the newborn: results and implications for clinical practice. *Neonatology* 2019; 115: 335–340.
 70. Spencer TR and Pittiruti M. Rapid central vein assessment (RaCeVA): a systematic, standardized approach for ultrasound assessment before central venous catheterization. *J Vasc Access* 2019; 20: 239–249.
 71. Brescia F, Pittiruti M, Spencer TR, et al. The SIP protocol update: Eight strategies, incorporating Rapid Peripheral Vein Assessment (RaPeVA), to minimize complications associated with peripherally inserted central catheter insertion. *J Vasc Access* 2024; 25: 5–13.
 72. Brescia F, Pittiruti M, Ostroff M, et al. Rapid femoral vein assessment (RaFeVA): a systematic protocol for ultrasound evaluation of the veins of the lower limb, so to optimize the insertion of femorally inserted central catheters. *J Vasc Access* 2021; 22: 863–872.
 73. Annetta MG, Marche B, Giarretta I, et al. Applicability and feasibility of intraprocedural tip location of femorally inserted central catheters by transhepatic ultrasound visualization of the inferior vena cava in adult patients. *J Vasc Access* 2024; 25: 651–657.
 74. Barone G, Pittiruti M, Ancora G, et al. Centrally inserted central catheters in preterm neonates with weight below 1500 g by ultrasound-guided access to the brachio-cephalic vein. *J Vasc Access* 2021; 22: 344–352.
 75. Lamberti G, Domenichelli V, Straziuso S, et al. Use of the dialkylcarbonylchloride dressing in the care of central venous access exit site in a pediatric and neonatal population. *Diagnostics (Basel)* 2023; 13: 20230423.
 76. Mastroianni R, Capasso A and Ausanio G. The intracavitary electrocardiography method for tip location of jugular internal vein access device in infants of less than 5 kg: A pilot study. *J Vasc Access* 2018; 19: 639–643.
 77. Pittiruti M, Celentano D, Barone G, et al. A GAVeCeLT bundle for central venous catheterization in neonates and children: a prospective clinical study on 729 cases. *J Vasc Access* 2022; 11297298221074472.
 78. D'Andrea V, Pezza L, Prontera G, et al. The intracavitary ECG method for tip location of ultrasound-guided centrally inserted central catheter in neonates. *J Vasc Access* 2023; 24: 1134–1139.
 79. Weber MD, Himebauch AS and Conlon T. Use of intracavitary-ECG for tip location of femorally inserted central catheters. *J Vasc Access* 2022; 23: 166–170.