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REVIEW

The neonatal DAV-expert algorithm: a GAVeCeLT/GAVePed consensus for the choice of the most appropriate venous access in newborns

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Abstract

In most NICUs, the choice of the venous access device currently relies upon the operator's experience and preferences. However, considering the high failure rate of vascular devices in the neonatal population, such clinical choice has a critical relevance and should preferably be based on the best available evidence. Though some algorithms have been published over the last 5 years, none of them seems in line with the current scientific evidence. Thus, the GAVePed—which is the pediatric interest group of the most important Italian group on venous access, GAVeCeLT—has developed a national consensus about the choice of the venous access device in the neonatal population. After a systematic review of the available evidence, the panel of the consensus (which included Italian neonatologists specifically experts in this area) has provided structured recommendations answering four sets of questions regarding (1) umbilical venous catheters, (2) peripheral cannulas, (3) epicutaneo-cava catheters, and (4) ultrasound-guided centrally and femorally inserted central catheters. Only statements reaching a complete agreement were included in the final recommendations. All recommendations were also structured as a simple visual algorithm, so as to be easily translated into clinical practice.

Conclusion: The goal of the present consensus is to offer a systematic set of recommendations on the choice of the most appropriate vascular access device in Neonatal Intensive Care Unit.

Keywords Neonatal intensive care unit · Vascular access devices · Umbilical venous catheter · Ultrasound-guided catheter · Central venous catheter · Indications

Abbreviations

CRBSI	Catheter-related bloodstream infection
CICC	Centrally inserted central catheter
ECC	Epicutaneo-cava catheter
FICC	Femorally inserted central catheter
LPC	Long peripheral cannula
NICU	Neonatal intensive care unit
PN	Parenteral nutrition
PICC	Peripheral inserted central catheter
RaCeVA	Rapid central vein assessment
RaSuVa	Rapid superficial vein assessment
SPC	Short peripheral cannula
UVC	Umbilical venous catheter
VAD	Vascular access device

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Introduction

The choice of the most appropriate venous access device (VAD) is particularly difficult in neonates. In fact, in this population, though a reliable venous access is often indispensable for the infusion of drugs, fluids, parenteral nutrition, and blood products, the venous patrimony is limited, and all devices are prone to frequent complications. In the last decade, three algorithms [1–3] have been published about the choice of VADs in the neonatal population. However, all of them have relevant limitations.

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1. The algorithms proposed by Ullman et al. [1] and by Osmond et al. [2] do not consider preterm neonates. This is a major limitation, since preterm neonates account for most of the admission to NICU, and they inevitably require a VAD for hydration, nutrition, and drug infusion.
2. In both papers by Ullman et al. [1] and by Osmond et al. [2], the authors perpetuate the confusion of terminology between epicutaneo-cava catheter (ECC) and peripherally inserted central catheters (PICC). The 1–2.7 Fr ECCs used in neonates are completely different from the ultrasound-guided 3–5 Fr PICCs used in children and adults. ECCs and PICCs are associated with different techniques of insertion, different clinical performances, and different incidences of complications. If compared to ECC, PICCs are appropriate for blood sampling, for high flow infusion (up to 1 ml/sec), for hemodynamic monitoring, and for infusion of blood products, and they have extended dwell time (even months) [4].
3. In the algorithms proposed by Ullman et al. [1] and by Van Rens et al. [3], the authors do not differentiate between critical (unstable) vs. stable neonates. This is a major limitation, since many recent studies suggest that the approach to VAD selection should be different in unstable, critically ill patients, as these neonates require hemodynamic monitoring, high-flow infusion, blood sampling, and so on [4–6].
4. In the paper by Ullman et al. [1], the authors suggest the placement of "PICC > 3 Fr" in neonates that need frequent blood sampling. This suggestion is not clear and probably dangerous. To the best of our knowledge, no study has proven the presence of a vein of adequate diameter for a 3 Fr catheter in the arms or the limbs of neonates [5]. On the contrary, ultrasound-guided placement of 3–4 Fr catheters in the deep veins of neck (centrally inserted central catheters (CICC)) and groin (femorally inserted central catheters (FICC)) has been recently reported to be safe and relatively easy in term and preterm infants [6–8].
5. In the paper by Osmond et al. [2], the authors suggest using central lines inserted by surgical cutdown. Even though such practice was very common in the past, nowadays, it is antiquated and should be completely abandoned, considering the body of evidence available on ultrasound-guided cannulation.
6. In the paper by Van Rens et al. [3], the authors do not consider the use of ultrasound-guided central VADs, which represents probably the most important novelty in the care of critically ill neonates [6, 7, 9–16].

As none of these algorithms was fully satisfying, the GAVePed (which is the pediatric interest group of the most important Italian group on venous access: GAVeCeLT) decided to develop a new algorithm called "Neonatal DAV-Expert."

Methods

Considering the impact of this topic on the daily clinical practice and the lack of evidence from high.quality studies, a consensus was thought to be the most appropriate tool for providing robust recommendations. The consensus was promoted and coordinated by two members of GAVePed (GB and MP). A panel of experts was identified. Some panelists were members of GAVePed; some were members of the special interest group in vascular access devices founded inside the Italian Society of Neonatology; some panelists were chosen on the basis of their expertise in the field of neonatal vascular access or neonatal parenteral nutrition. All the panelists have published papers on neonatal vascular access in the last few years and/or participated as speakers in conferences on this topic.

The consensus was structured in different steps, mainly using web-based meetings. Initially, a literature search was performed independently by three panelists (GB, VDA, and MP) using PubMed, OVID, Elsevier, and Cochrane Library, evaluating all randomized and observational studies on neonatal VADs published in the English language from January 2000 to December 2022. Keywords such as "venous catheter," "central venous catheter" "umbilical venous catheter" "tunneled catheter" "peripheral venous catheter," "centrally inserted central catheter" "femorally inserted central catheter," "critically ill neonates" "neonatal parenteral nutrition" "short peripheral cannula" "long peripheral cannula" "neonatal PICC line," and "epicutaneo-cava catheter" "NICU" were used. References of articles, previous reviews, and meta-analyses were also analyzed, so as not to miss relevant papers. The consensus process was carried out according to the RAND/University of California at Los Angeles (UCLA) Appropriateness Methodology as a three-step consensus process [17]. The method is a modification of the Delphi method, a structured process for collecting knowledge from groups of experts through a series of questionnaires.

First, the two coordinators of the panel proposed to develop the document as answers to four sets of questions: (1) which are the appropriate indications for the use of umbilical venous catheters (UVC)? (2) Which are the appropriate indications for the use of a short peripheral cannula (SPC)? (3) Which are the appropriate indications for the use of epicutaneo-cava catheter (ECC)? (4) Which are the appropriate indications for the use of centrally inserted central catheters (CICC) and femorally inserted central catheters (FICC)? After a first email-based discussion, the whole panel agreed to structure the recommendations as answers to these four questions.

Based on the collected literature—which had been previously shared with the whole panel—the two coordinators wrote a preliminary draft of statements. This preliminary

document was e-mailed to the whole panel. Each panelist was asked to state her/his level of agreement with each statement (disagree, uncertain, agree) and to provide additional comments, especially in cases of uncertainty or disagreement. After collecting the answers of each member of the panel, a web-based meeting was organized, and all the controversies were discussed collegially. At this point, a second document was customized, modifying the statements according to the suggestions of the panel, and presented to the panel for final approval. After a second web-based meeting, the final statements were defined, and the algorithm was developed in its final form. After the meeting, the recommendations, a summary of the consensus, and the final manuscript were e-mailed to the whole panel for review and final approval. Only statements supported by the agreement of the whole panel were included in the final recommendations. The panel decided to exclude statements addressing a few special vascular devices used infrequently in the neonatal population—such as dialysis catheters, ECMO cannulas, and catheters for extracorporeal blood purification—considering that the available literature and experience are still scarce in this regard.

The results of the consensus are presented in the following section, question by question, offering the background knowledge behind each question, the recommendations of the panel, plus some special additional considerations that the panel considered relevant for the proper translation of the recommendations into clinical practice.

Results

(Q1) Which are the appropriate indications for the use of umbilical venous catheters (UVC)?

Background

UVC is one of the most used central lines in neonates, since it is fast and easy to insert and provides a stable central access in critically ill infants requiring advanced resuscitation in the delivery room or needing medications, fluids, frequent blood sampling, and parenteral nutrition during the first days of life [18–20]. However, the use of UVCs is not free from risk. Primary and secondary malposition [21], infection [22], thrombosis [23], and hepatic injury are among the most common complications related to UVCs [19, 24–32].

Over the last 50 years, a significant overuse of UVCs has been reported in several NICUs. In a quality improvement document aiming to reduce unnecessary placement of UVCs, Shahid et al. [33] developed consensus guidelines providing indications for UVC placement on the basis of gestational age, the severity of illness, and the availability of peripheral veins. Our panel judged that their approach is rational and evidence-based, and it may reduce the complications related to the unnecessary use of UVC.

Though not inside the goals of the consensus, the panel unanimously recommended to verify the tip of the catheter using real-time ultrasound, according to the Neo-ECHOTIP protocol [34]. Ultrasound may effectively reduce UVC malposition, which is associated with serious complications [20, 32]. In this regard, prompt removal of the UVC should be considered when the tip is not properly located at the junction between the IVC and the RA [20, 34, 35].

UVCs are made of polyurethane; UVCs made of polyurethane treated with silver ions might reduce the risk of catheter-related bloodstream infections (CRBSI), especially in newborns with a gestational age less than or equal to 30 weeks, as suggested by the results of a single randomized controlled study [36]. The use of UVCs treated with silver ions has also been recommended by SHEA guidelines in 2014 and 2022 for the prevention of CRBSI in preterm infants [37, 38]. However, considering the Cochrane analysis published in 2015 [39], it seems reasonable to recommend these catheters only in preterm infants with an expected long dwelling time of UVC (more than 7 days). In fact, the Kaplan–Meier curve clearly shows that the differences in the risk of CRBSI between conventional vs and antimicrobial-impregnated UVCs are clinically relevant only for dwelling times longer than 7 days.

The UVC should be promptly removed when no longer needed. It is also reasonable to limit the UVC dwelling time to 7 days to reduce the risks of infectious and thrombotic complications. If a central access is still required, early removal of UVC (i.e., at 4 days) should be followed by the insertion of a new central line [18, 40–42].

Panel recommendations.

1. Appropriate indications for UVC include (a) preterm infants born at or less than 28 weeks of gestation at the time of birth; (b) neonates with severe respiratory distress (intubated or on non-invasive ventilation with FiO2 > 40%), or with hemodynamic instability, or with difficulty in finding peripheral venous access at the time of birth; (c) neonates affected by asphyxia requiring therapeutic hypothermia.
2. UVCs should be in polyurethane.
3. Silver-coated polyurethane UVCs should be considered in selected cases of preterm infants which are expected to require a prolonged dwelling time of the device.
4. Double lumen UVCs should be preferred (a) in infants requiring repeated blood samples; (b) in infants requiring multiple continuous infusions; (c) in infants simultaneously requiring parenteral nutrition (PN) + intravenous drugs not compatible with PN.

5. UVCs should be preferably removed early (within 4–5 days), for the purpose of reducing infective and thrombotic complications.

Special considerations.

- The use of UVC should also be considered in neonates who need PN at birth but are not included in the categories mentioned above [43, 44], such as preterm infants with severe growth restriction and abnormal antenatal Doppler.
- The UVC should also be inserted in neonates which soon require at birth the infusion of non-peripherally compatible solutions (as for instance IV solutions with pH < 5 or > 9; drugs with osmolarity > 600 mOsm/L; vesicant drugs, drugs potentially associated with endothelial damage) [45–47].
- Even though multiple continuous infusions can be administered sometimes through a single lumen, the risk of inadvertent boluses must be considered, especially in preterm neonates receiving inotropic drugs, since blood pressure fluctuations might have long-term neurological consequences [48–51].
- Longer dwelling time of UVC might be considered in babies with severe skin disease such as infants with collodion baby syndrome or harlequin ichthyosis.

(Q2) Which are the appropriate indications for the use of a short peripheral cannula (SPC)?

Background

Danski et al. [52] reported that almost all NICU patients have a VAD, and this is an SPC in approximately half of the cases; however, SPCs are particularly prone to complications (63.15% of SPCs are removed because of complications). According to Legemaat et al. [53], 62% of SPC are placed after the unscheduled removal of a previous SPC. Infiltration (i.e., extravascular leakage of non-vesicant solutions) is the most common complication of SPCs [54] (23–78%). Another common complication (11–23%) [55] is extravasation (i.e., the extravascular leakage of vesicant solutions). Even though this issue has never been specifically addressed in the literature, many SPC-related complications are probably secondary to an erroneous choice of the VAD and/or to an inappropriate choice of the vein [56]. Considering their mean dwelling time, SPC should not be used when the expected intravenous treatment is likely to exceed 6 days [57], as recommended by the Centers for Disease Control and Prevention Healthcare Infection Control Practices Advisory Committee [58].

A recent paper suggested that long peripheral cannulas (LPCs) may be considered as a valid alternative to SPC in neonates that require infusions compatible with peripheral access for more than 3 days [59].

Panel recommendations.

1. Indications for SPCs include (a) stable preterm newborns with less than 7 days of the expected duration of PN; (b) stable newborns with venous access required for less than 7 days. LPCs may be considered when more than 3 days of IV infusions are expected.
2. SPCs should be made of polyurethane; the caliber should be 24G-26G (depending on the size of the vein).

Special considerations.

- In recent years, "integrated" SPCs and LPCs are becoming particularly interesting in adults and children [60], though data about the neonatal population are still scarce. However, considering the short duration of SPCs in NICU [53] (48 h), these devices might offer a theoretical advantage, prolonging the mean dwelling time of peripheral VADs in neonates.

(3) Which are the appropriate indications for the use of an epicutaneo-cava catheter (ECC)?

Background

Epicutaneo-cava catheters (ECCs) are often called "PICCs," and this is not incorrect, because they are central VADs and because they are inserted in "peripheral," superficial veins. Nonetheless, the term "PICC" as referred to ECC in neonates has been a constant source of confusion in the scientific literature, since the ECCs inserted in neonates are completely different from the PICCs inserted in children and in adults. For this reason, the World Conference on Vascular Access (WoCoVA) Foundation—which is the recognized global network of all associations of vascular access—has recently recommended to adopt a new terminology, differentiating ECCs from ultrasound-guided PICCs [4].

While SPCs are appropriate if the infusion does not exceed 6 days [57], there is a certain grade of uncertainty regarding the optimal duration of ECCs, though several reports suggest that the risk of infective and mechanical complications of ECCs increases enormously after 14 days [4, 61–64], at least in preterm neonates. If the expected duration of IV infusion exceeds 14 days, probably a different central VAD should be preferred.

The diameter of ECC ranges from 1 to 2.7 Fr. The size of the ECC and the number of lumens are commonly chosen based on the clinical conditions, the weight of the baby, or the required length of the catheter. This clinical practice is not optimal. The size of the catheter should be decided after

studying the diameter of the veins. In adult and pediatric populations, the current international guidelines—such as the WoCoVA-GAVeCeLT-WINFOCUS consensus [65]—recommend measuring the diameter of the vein before the insertion of any catheter, since matching the vein diameter with the catheter caliber reduces the risk of venous thrombosis [65]. It is recommended that the external diameter of the catheter should not exceed one-third of the internal diameter of the vein [66]. This is particularly difficult to achieve in ECCs, and thus, their rate of local thrombosis/thrombophlebitis is high, ranging from 2.2 to 33.6% [67–69]. A recent paper [5] showed that measurement of the diameter of deep veins is feasible even in preterm infants. Pre-procedural scan of the veins should be performed for two main reasons: (1) to choose the catheter of the appropriate caliber for the vein diameter, thus reducing the risk of thrombosis; (2) to collect useful information about the state of the vessels before central catheterization. The vein should be chosen considering the status of all available veins. In this regard, the RaSuVA protocol [56] (rapid superficial vein assessment) may be useful. The RaSuVA implies a systematic examination of the superficial veins of the newborn, from the foot to the head, first on the right side and then on the left side, evaluating the seven sites where it is most likely to identify a superficial vein: (1) medial malleolus, (2) lateral malleolus, (3) retro popliteal area, (4) hand and wrist, (5) antecubital area, (6) preauricular zone, and (7) post-auricular zone.

In infants with the exhaustion of superficial veins (as evident from RaSuVA) or in newborns in which the insertion of ECC is difficult or impossible, the insertion of a CICC or a FICC may be indicated.

Panel recommendations.

1. ECCs are indicated in stable preterm newborns with an expected duration of PN of more than 7 days. If PN is expected to last more than 14 days, a tunneled CICC or FICC should be preferred.
2. ECCs should be in polyurethane; 1-Fr catheters should be preferred in infants below 2 kg, so to reduce the risk of thrombosis.
3. Double lumen ECCs are indicated when an infusion of multiple continuous non-compatible drugs is required if a 2 Fr ECC is esteemed to be appropriate for the diameter of the vein.

Special considerations.

- ECCs coated with rifampicin (antibiotic) and miconazole (antifungal) are now available on the market, though a recent randomized controlled trial proved that the use of such antimicrobial ECCs does not reduce the risk of central-line-associated bloodstream infection [70, 71].

(4) Which are the appropriate indications for the use of centrally inserted central catheters (CICC) and femorally inserted central catheter (FICC)?

Background

Critically ill newborns admitted to 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 compatible with the peripheral route. ECCs are small bore catheters (1–2.7 Fr) and do not completely fulfill the needs of a critically ill neonate [4]. In these situations, the insertion of a large bore (3–4 Fr) polyurethane catheter in the brachiocephalic vein or in the internal jugular vein (CICC) or in the common femoral vein (FICC) may be more appropriate [6, 72].

The evidence about the advantages of CICCs in preterm neonates is rapidly emerging [6, 7, 16, 72–75]. The easiest and safest supra-clavicular vein available for ultrasound-guided puncture and cannulation in the newborn is usually the brachio-cephalic vein. Even in premature infants, the caliber of this vein is 3 mm or larger, which allows the placement of a 3Fr power injectable polyurethane catheter [5, 76]. The GAVeCeLT protocol for central venous catheterization in neonates and children has been extensively used and published [6, 9, 10, 72, 75, 77]. This insertion protocol includes the following: ultrasound evaluation of all central veins (rapid central vein assessment (RaCeVA)) [78]; maximum barrier precautions; skin antisepsis with chlorhexidine 2% in alcohol; ultrasound-guided venipuncture (in the case of the brachiocephalic vein: visualization in long axis and "in plane" puncture); tip navigation by supra-clavicular ultrasound scan; tip location by intracavitary ECG technique and/or echocardiography; sutureless securement; coverage of the exit site with cyanoacrylate glue and transparent semipermeable dressing with high transpirability. Furthermore, in the newborn, it is always preferable to tunnel the catheter to the infra-clavicular area. For this purpose, the off-label use of central catheters marketed as PICC (3 Fr single lumen or 4 Fr double lumen) offers extra advantages because these catheters are made of power injectable polyurethane which allows high flow and high resistance, and the insertion technique is based on the modified Seldinger technique (which makes the tunneling easier).

CICCs and FICCs are appropriate not only for normal infusions, but also for high-flow infusions, for blood transfusions, for blood sampling, and for hemodynamic monitoring (if the tip is positioned in the right atrium) [6, 46].

FICCs may be a secondary option compared to CICCs, since in most newborns the femoral venipuncture is more difficult than the puncture of the brachio-cephalic vein (especially because of the caliber of the two veins: the common femoral vein is much smaller) [5]. If the caliber of the

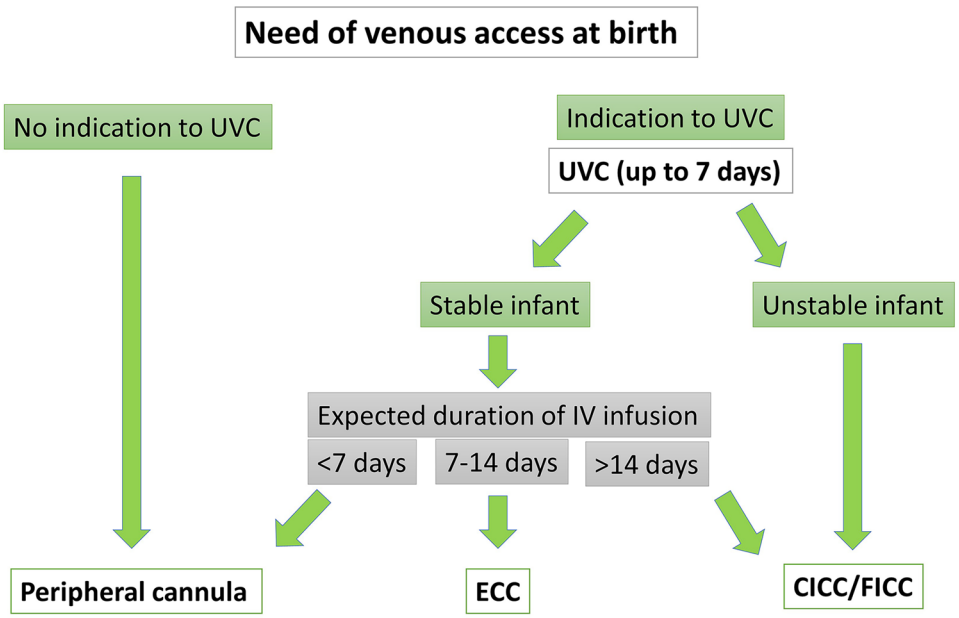

Fig. 1 Algorithm for the choice of the vascular access device at birth

femoral vein is 3 mm or more, a 3Fr power injectable polyurethane catheter can be inserted; a 2 Fr—available in different lengths—can be used in smaller veins (2 mm) [8]. FICCs should be tunneled to the mid-thigh, so to obtain an exit site far from the inguinal fold and from the diaper.

Some FICCs may have the tip in the inferior vena cava (as verified by ultrasound) and can be used for infusions of any type and for blood sampling; other FICCs may have the tip in the right atrium tip (as verified with intracavitary ECG or echocardiography), and they can be used not only for infusion and sampling, but also for hemodynamic monitoring.

Panel recommendations.

1. Indications for ultrasound-guided CICCs or FICCs include the following: (a) newborns (at any gestational age) with hemodynamic instability developed after the first 24 h of life, or even within the first 24 h of life, if UVC insertion is not feasible or if the UVC cannot be placed in a proper position; (b) newborns who need or might need rapid fluid repletion (in emergency and/or before major surgery); (c) newborns with major malformation pathologies requiring surgery (e.g., major exomphalos; esophageal atresia); (d) stable newborns requiring a central line, if ECC cannot be placed in a proper position; (e) newborns requiring repeated blood samplings; (f) newborns requiring multiple transfusions; (g) CICCs or FICCs should also be considered in stable preterm newborns with an expected duration of PN longer than 2 weeks.

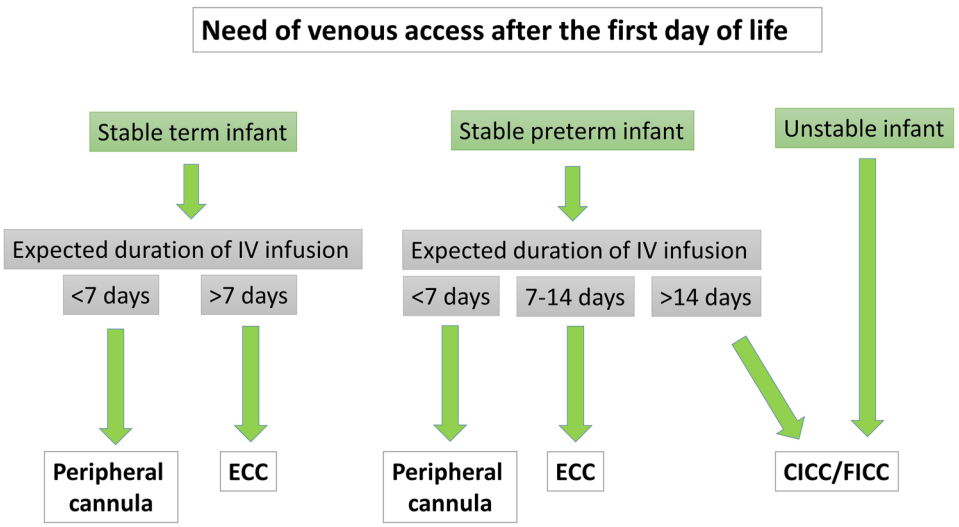

Fig. 2 Algorithm for the choice of the vascular access device at birth after the first day of life

Table 1 Summary of the panel recommendations

Which are the appropriate indications for the use of umbilical venous catheters (UVC)?
1. Appropriate indications for UVC include (a) preterm infants born at or less than 28 weeks of gestation at the time of birth; (b) neonates with severe respiratory distress (intubated or on non-invasive ventilation with FiO2 > 40%), or with hemodynamic instability, or with difficulty in finding peripheral venous access at the time of birth; (c) neonates affected by asphyxia requiring therapeutic hypothermia.
2. UVCs should be in polyurethane.
3. Silver-coated polyurethane UVCs should be considered in selected cases of preterm infants which are expected to require a prolonged dwelling time of the device.
4. Double lumen UVCs should be preferred (a) in infants requiring repeated blood samples; (b) in infants requiring multiple continuous infusions, and (c) in infants simultaneously requiring parenteral nutrition (PN) + intravenous drugs not compatible with PN.
5. UVCs should be preferably removed early (within 4–5 days), for the purpose of reducing infective and thrombotic complications.
Which are the appropriate indications for the use of a short peripheral cannula (SPC)?
1. Indications for SPCs include (a) stable preterm newborns with less than 7 days of the expected duration of PN; (b) stable newborns with venous access required for less than 7 days. LPCs may be considered when more than 3 days of IV infusions are expected.
2. SPCs should be made of polyurethane; the caliber should be 24 G–26 G (depending on the size of the vein).
Which are the appropriate indications for the use of epicutaneo-cava catheter (ECC)?
1. ECCs are indicated in stable preterm newborns with an expected duration of PN of more than 7 days. If PN is expected to last more than 14 days, a tunneled CICC or FICC should be preferred.
2. ECCs should be in polyurethane; 1 Fr catheters should be preferred in infants below 2 kg, so to reduce the risk of thrombosis.
3. Double lumen ECCs are indicated when an infusion of multiple continuous non-compatible drugs is required if a 2 Fr ECC is esteemed to be appropriate for the diameter of the vein.
Which are the appropriate indications for the use of centrally inserted central catheters (CICC) and femorally inserted central catheters (FICC)?
1. Indications for ultrasound-guided CICCs or FICCs include: (a) newborns (at any gestational age) with hemodynamic instability developed after the first 24 h of life, or even within the first 24 h of life, if UVC insertion is not feasible or if the UVC cannot be placed in a proper position; (b) newborns who need or might need rapid fluid repletion (in emergency and/or before major surgery); (c) newborns with major malformation pathologies requiring surgery (e.g., major exomphalos; esophageal atresia); (d) stable newborns requiring a central line, if ECC cannot be placed in a proper position; (e) newborns requiring repeated blood samplings; (f) newborns requiring multiple transfusions; (g) CICCs or FICCs should also be considered in stable preterm newborns with an expected duration of PN longer than 2 weeks.
2. Ultrasound-guided CICCs and FICCs should be preferably power injectable and made of polyurethane. Calibers between 3 and 4Fr are usually appropriate, depending on the size of the vein being cannulated.
3. Consider the benefit of tunneling all ultrasound-guided CICC/FICC, especially in elective conditions.

2. Ultrasound-guided CICCs and FICCs should be preferably power injectable and made of polyurethane. Calibers between 3 and 4Fr are usually appropriate, depending on the size of the vein being cannulated.
3. Consider the benefit of tunneling all ultrasound-guided CICC/FICC, especially in elective conditions.

Special considerations.

- Even though is always advisable to tunnel the catheter, in some situations, this maneuver can be impractical, for example, because of the limited duration of sedation in extremely low birth weight infants, or because of the difficulty of using the modified Seldinger technique in babies weighing less than 750 g, or because of insufficient training of the operator.
- Neonates, especially preterm ones, might need repeated peripheral venous cannulations sometimes this leads to a progressive exhaustion of available veins. In this context, an ultrasound-guided CICC or FICC might be considered even though a central line is not strictly indicated.

Summary of the panel recommendations

All the recommendations made by the panel have been summarized in the form of an algorithm, addressing separately the neonate needing venous access at birth (Fig. 1) and after the first days after birth (Fig. 2). The panel recommendations are reported in Table 1. The neonatal DAV-expert algorithm, as developed by this GAVeCeLT/GAVePed consensus, is currently part of the DAV-Expert algorithm (available in five languages at the permanent link http://davexpert.gavecelt.it/).

The neonatal DAV-expert algorithm is the first algorithm developed using a modification of the Delphi method and fully focused on neonates. Even though the Mini-Magic[1] was developed using the RAND/UCLA appropriateness method, the clinical scenarios including neonates are very scarce and its general recommendations are not in line with the recent evidence from the literature. The present algorithm, instead, reflects the most recent literature and fully explores the different and complex clinical conditions that neonatologists must face in NICUs.

Conclusions

The goal of the present consensus is to offer a systematic set of recommendations on the choice of the most appropriate VAD in the NICU. The neonatal DAV-expert algorithm, however, should not be considered as a reference guideline, nor as a shortcut for an automatic clinical choice; instead, it should be regarded as a tool to facilitate clinical reasoning in potentially complex situations, in which we must keep in mind all the possible solutions and the pros and cons of each choice. In fact, we do believe that the selection of the most appropriate VAD will always be a clinical decision that the healthcare professional (physician or nurse) must take on a case-by-case basis, after assessing the needs of the individual patient and the resources of the local NICU.

Last, the neonatal DAV-expert algorithm is conceived as an open system. Since the field of venous accesses is constantly evolving, the algorithm should not be interpreted as a static dogma but rather as a dynamic and evolving instrument, up to date with the international literature that continually proposes new solutions, new devices, and new evidence.

Authors' contributions All authors contributed to the study's conception and design. GB, VDA, and MP performed the literature research. All authors had an active part in the construction of the recommendations of the present paper. The first draft of the manuscript was written by GB and MP. All authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Declarations

Ethical approval Not applicable.

Competing interests The authors declare no competing interests.

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