The Michigan Appropriateness Guide for Intravenous Catheters in Pediatrics: miniMAGIC

Amanda J. Ullman, RN, PhD,[a,b,c] Steven J. Bernstein, MD, MPH,[d,e] Erin Brown, PhD,[a,f] Ranjit Aiyagari, MD, FACC,[g] Darcy Doellman, MSN, RN, CRNI, VA-BC,[g] E. Vincent S. Faustino, MD, MHS,[h,i] Beth Gore, PhD,[j] Jeffrey P. Jacobs, MD, FACS, FACC, FCCP,[k] Julie Jaffray, MD,[l] Tricia Kleidon, RN, MNursPrac,[a,c] Prashant V. Mahajan, MD, MPH, MBA,[m] Craig A. McBride, FRACS,[a,c,f] Kayce Morton, DO,[n] Stephanie Pitts, MSN, RN, CPN, VA-BC,[o,p] Elizabeth Prentice, MBBS, FANZCA,[q] Douglas C. Rivard, DO,[r,s] Erin Shaughnessy, MD, MSHCM,[t] Marc Stranz, PharmD,[u] Joshua Wolf, MBBS, PhD, FRACP,[v,w] David S. Cooper, MD, MPH,[x] Marie Cooke, RN, PhD,[a,b] Claire M. Rickard, RN, PhD,[a,b] Vineet Chopra, MD, MSc[d,y]

abstract

OBJECTIVES: Vascular access device decision-making for pediatric patients remains a complex, highly variable process. To date, evidence-based criteria to inform these choices do not exist. The objective of the Michigan Appropriateness Guide for Intravenous Catheters in pediatrics (miniMAGIC) was to provide guidance on device selection, device characteristics, and insertion technique for clinicians, balancing and contextualizing evidence with current practice through a multidisciplinary panel of experts.

METHODS: The RAND Corporation and University of California, Los Angeles Appropriateness Method was used to develop miniMAGIC, which included the following sequential phases: definition of scope and key terms, information synthesis and literature review, expert multidisciplinary panel selection and engagement, case scenario development, and appropriateness ratings by an expert panel via 2 rounds.

RESULTS: The appropriateness of the selection, characteristics, and insertion technique of intravenous catheters commonly used in pediatric health care across age populations (neonates, infants, children, and adolescents), settings, diagnoses, clinical indications, insertion locations, and vessel visualization devices and techniques was defined. Core concepts including vessel preservation, insertion and postinsertion harm minimization (eg, infection, thrombosis), undisrupted treatment provision, and inclusion of patient preferences were emphasized.

CONCLUSIONS: In this study, we provide evidence-based criteria for intravenous catheter selection (from umbilical catheters to totally implanted venous devices) in pediatric patients across a range of clinical indications. miniMAGIC also highlights core vascular access practices in need of collaborative research and innovation.

[a]Alliance for Vascular Access Teaching and Research, Menzies Health Institute Queensland and [b]School of Nursing and Midwifery, Griffith University, Nathan, Queensland, Australia; [c]Queensland Children's Hospital, South Brisbane, Queensland, Australia; [d]Patient Safety Enhancement Program and Center for Clinical Management Research, US Department of Veterans Affairs Ann Arbor Healthcare System, Ann Arbor, Michigan; [e]Divisions of General Medicine and [y]Division of Hospital Medicine, Department of Internal Medicine, [g]Division of Pediatric Cardiology, Department of Pediatrics, and [m]Department of Emergency Medicine and Pediatrics, Medical School, University of Michigan, Ann Arbor, Michigan; [f]Child Health Research Centre, The University of Queensland, Brisbane, Queensland, Australia; [h]Cincinnati Children's Hospital Medical Center, Cincinnati, Ohio; [i]Section of Pediatric Critical Care Medicine, Department of Pediatrics, School of Medicine, Yale University, New Haven, Connecticut; [j]Association for Vascular Access, Herriman, Utah; [k]Southern Thoracic Surgical Association, Chicago, Illinois; [l]Keck School of Medicine, University of Southern California and Children's Hospital Los Angeles, Los Angeles, California; [n]School of Medicine, University of Missouri, Columbia, Missouri; [o]St Joseph's Children's Hospital, Tampa, Florida; [p]B. Braun Medical, Bethlehem, Pennsylvania; [q]Department of Anaesthesia and Pain Management, Royal Children's Hospital, Victoria, Australia; [r]Children's Mercy Hospital, Kansas City, Missouri; [s]School of Medicine, University of Missouri–Kansas City, Kansas City, Missouri; [t]College of Medicine, University of Arizona and Phoenix Children's Hospital, Phoenix, Arizona; [u]Stranz Crossley Inc, Philadelphia, Pennsylvania; [v]Department of Infectious Diseases, St Jude Children's Research Hospital, Memphis, Tennessee; [w]Department of Pediatrics, The University of Tennessee Health Science Center, Memphis, Tennessee; [x]Department of Pediatrics, College of Medicine, University of Cincinnati and Heart Institute, Cincinnati Children's Hospital Medical Center, Cincinnati, Ohio; and

WHAT'S KNOWN ON THIS SUBJECT: Vascular access device decision-making in pediatric patients remains a complex, highly variable process. To date, evidence-based criteria to inform these choices do not exist. Consequently, over- and underuse of available devices is common, frequently resulting in harm to patients.

WHAT THIS STUDY ADDS: In this study, we provide evidence-based criteria for intravenous catheter selection (from umbilical catheters to totally implanted venous devices) in pediatric patients across a range of clinical indications.

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The guidelines/recommendations in this article are not American Academy of Pediatrics policy, and publication herein does not imply endorsement.

The majority of all hospitalized children require placement of a vascular access device (VAD) to receive medications for life-saving therapies and to facilitate blood tests.[1] In addition, many children who are chronically ill are VAD dependent for much of their lives. These devices are required across a continuum of age and acute, subacute, and home care settings.[2] Although vital for treatment, VADs have well recognized insertion morbidity risks (eg, pneumothorax), are costly,[3] and can lead to lethal complications such as thrombosis and bloodstream infection.[4] Even minor VAD-associated adverse events, such as occlusion or dislodgement, can have significant negative sequelae and lead to delays in treatment during acute and chronic illness.[2,5]

When clinicians select a VAD, a number of characteristics are used to determine which device may be optimal for their patient. For example, anticipated duration and frequency of use, complication risk, previous vascular access history, infusate characteristics, vessel health, course and size, and operator availability and skill are factors weighed when making VAD decisions.[4] However, this process is highly variable and often defaults to institutional culture and practice (the way things are done, rather than the way they should be done).[6] Despite the fact that VADs have varying adverse event profiles and treatment capabilities, an evidence-driven standardized process does not exist for the selection of the most appropriate VAD in pediatrics. This uncoordinated approach to VAD decision-making can result in inappropriate device selection. For example, peripheral VADs may be inappropriately chosen for complex long-term therapy,[7] and peripherally inserted central catheters (PICCs) may be unnecessarily used for short-term peripherally compatible therapies.[6] These device-selection decisions potentiate patient harm and inefficient treatment outcomes, adding to health care costs.

In 2015, Chopra et al[8] developed the Michigan Appropriateness Guide for Intravenous Catheters (MAGIC) to aid appropriate VAD decision-making for hospitalized adults. Since publication, MAGIC has been implemented in many hospitals worldwide but particularly in the United States, with evidence suggesting significant reductions in inappropriate VAD use, patient harm, and costs.[9–11] Similar evidence-based VAD appropriateness criteria have not been developed for pediatrics. Therefore, we sought to develop the Michigan Appropriateness Guide for Intravenous Catheters in pediatrics (miniMAGIC), a pediatric-focused version of its adult counterpart, using the RAND Corporation and University of California, Los Angeles (RAND/UCLA) Appropriateness Method[12] to address this knowledge gap.

METHODS

Design

miniMAGIC was developed in accordance with the RAND/UCLA Appropriateness Method.[12] A detailed protocol is available.[13] The study received ethics approval from Griffith University (2018/207) and was deemed exempt from review by the University of Michigan Institutional Review Board (HUMM00144945).

In the RAND/UCLA method a procedure is considered appropriate when the expected health benefits exceed the expected negative consequences (eg, mortality, morbidity, anxiety, and pain) by a sufficiently wide margin such that the procedure is worth doing, exclusive of cost.[12] The method balances the best available evidence with expert judgement to form a statement regarding the appropriateness of individual procedures.[12] Within miniMAGIC, we sought to develop appropriateness criteria for the selection and insertion of VADs for specific populations and indications within pediatrics, regardless of cost.

Following the RAND/UCLA Appropriateness Method, sequential phases were performed to meet this aim. These phases included the following:

1. definition of scope and key terms;
2. information synthesis and literature review;
3. expert panel selection and engagement;
4. case scenario development; and
5. appropriateness ratings by an expert panel via 2 rounds.

Definition of Scope and Key Terms

miniMAGIC defined the appropriateness of VADs commonly used across pediatric health systems (hospitalized and ambulatory care), including management from maternity hospitals or equivalent discharge, until 18 years of age.[14] The objective of miniMAGIC was to provide guidance on important clinical questions (ie, device selection, device characteristics, and insertion technique) for clinicians primarily making decisions regarding VADs in pediatrics (eg, vascular access teams, interventional radiology, anesthesiologists, infectious disease, surgery, and nephrology), contextualizing evidence-based data with current practice with the assistance of a multidisciplinary panel of experts.

Comprehensive definitions of key terms are provided here.[13] These include VAD and infusion catheter types (intraosseous [IO] catheter; peripheral intravenous catheter [PIVC]; midline catheter; umbilical catheter; nontunneled central venous access device [CVAD]; PICC; tunneled, cuffed CVAD; and totally implanted venous device),[8,15,16] insertion locations, population

categories (age [neonates, infants, children, and adolescents]),[17] setting and diagnosis (general hospitalized patients, congenital cardiac disease, critically ill, oncology and hematology, and long-term VAD-dependent conditions),[8,18–21] clinical indications (peripherally compatible and nonperipherally compatible therapy, difficult vascular access, and blood sampling),[8,15,22] and vessel visualization devices and techniques (near infrared light, ultrasound, electrocardiogram tip guidance, fluoroscopy, surgical cutdown, and catheter-to-vessel ratio).[15,19,23]

Information Synthesis and Literature Review

As recommended by the RAND/UCLA Appropriateness Method,[12] we conducted a synthesis of the literature to summarize the evidence regarding pediatric VAD selection, insertion practice, and risk of complications. The methods and results of the literature review are available in this supplement.[24] The final 133 studies and guidelines included were of variable quality, with many that were focused on device performance in specialty populations (eg, hematology and oncology and critical care) and on single interventions (eg, vessel visualization technology and device insertion location). Important gaps in the pediatric literature were observed, especially surrounding neonatal device selection (outside of the NICU), catheter-to-vein ratio, and long-term vascular access–dependent conditions. To bridge these gaps, additional studies from populations outside of pediatrics (eg, NICU and adults) were included to inform appropriateness discussions. Before the appropriateness ratings, the literature review was provided to the expert panel. Findings from the review were also used during the in-person ratings process to inform discussions.

Expert Panel Selection and Engagement

Fourteen clinicians and researchers, representing pediatric health care disciplines typically responsible for decisions about VAD choice, were invited to serve on the panel. Full details on panel members are available.[13] To ensure rigor and inclusion of the patient's voice (especially when the evidence was unclear), we included nonvoting panelists who joined for the meeting and discussions but did not rate or vote on individual scenarios. These panelists included a patient representative and 3 facilitators (including a methodologist).

Case Scenario Development

The clinical scenarios for miniMAGIC were based on the original MAGIC document[8] but were restructured and rewritten to align with the results of the systematic review and panelist expert opinion. We included areas of controversy or ambiguity even if there was limited evidence available because we recognized that clinicians may need guidance when making these decisions. With this framework, the clinical scenarios were divided into the following: (1) device selection (across VAD types), (2) device characteristics (including lumen number, size, and insertion location), and (3) insertion technique (attempts and image guidance). Device selection was further categorized into chapters for age and specific clinical populations.

Appropriateness Ratings by Expert Panel

As per the RAND/UCLA Appropriateness Method, 2 rounds of appropriateness rating of the clinical scenarios were completed. The first-round rating was done independently and performed via paper copy. Individual panelist results were returned electronically (eg, scanned and sent via e-mail) and centrally inputted to create a master ratings document incorporating all panelist responses. The second-round rating occurred after all panelists traveled to Ann Arbor, Michigan, and participated in a group discussion that included a review of all panelist ratings.[12] Appropriateness for each clinical scenario was rated on a scale of 1 to 9, in which 1 indicates "harm outweighs benefit" (highly inappropriate), and 9 signifies "benefit outweighs harm" (highly appropriate). As previously described, the panelists were provided the literature review and instructed to rate each clinical scenario using their best clinical judgement and the evidence in the literature review.[13]

As recommended by the RAND/UCLA method, indications were classified into 3 levels of appropriateness:

1. appropriate: panel median score of 7 to 9, without disagreement;
2. uncertain: panel median score of 4 to 6 or with disagreement regardless of median; and
3. inappropriate: panel median score of 1 to 3, without disagreement.

Disagreement existed if ≥5 panelists rated in each extreme (1–3 and 7–9).[12]

RESULTS

A total of 1234 clinical scenarios were created for review by the panelists. In the first round, panelists rated 424 scenarios as appropriate (34.4%), 492 as inappropriate (39.9%), and 266 as uncertain (21.6%). The panel disagreed on 52 clinical scenarios (4.2%). During the second-round discussion, the panelists removed 481 scenarios because they were considered duplicative (eg, similarity in recommendations for children and adolescents led to a revised category of children and adolescents aged 1–18 years old rather than 2 distinct populations), leaving 753 scenarios to review. In the second round, the panel rated 284 scenarios as appropriate (37.7%), 314 as inappropriate (41.7%), and 137 as uncertain (18.2%) and

disagreed on 18 clinical scenarios (2.4%). Thus, discussions and clarifications in round 2 reduced the proportion of clinical scenarios rated as uncertain and those with disagreement.

The Appropriateness of VAD Selection in Specific Populations

Pediatrics encompasses a heterogeneous population with diverse conditions and includes patients across a range of ages. The venous network matures significantly throughout the first year of life after term delivery.[25] The developing vein structure has a smaller luminal diameter, requiring clinicians to use smaller catheters for both peripheral and central devices, impacting catheter insertion and function.[26] To ensure accuracy, device selection was divided into the following age-based categories: neonates, infants, and children and adolescents, and associated specific clinical contexts (eg, critical illness, cardiac surgery).

The Appropriateness of VAD Selection in Hospitalized Pediatric Patients

Neonates (Birth to 30 Days)

Within this population, the panel considered term neonates who, in the first 30 days of life, are admitted to a pediatric or mixed pediatric-adult facility. Infection and newly diagnosed congenital abnormalities, including cardiac conditions, are a common source of early hospital admission for this population. Reliable access to the vascular system is thus necessary for diagnosis and treatment.

For approximately the first week of life, the umbilical vein is a viable means of venous access. The panel determined that selection of an umbilical catheter should be influenced by the infusate characteristics, therapy duration, and the age of the neonate. The panel rated use of the umbilical catheter as appropriate up to 2 days after birth for peripherally compatible infusates for a therapy duration of ≤14 days. Inserting an umbilical catheter ≥5 days after birth (no matter the therapy duration) was rated as inappropriate. There was disagreement regarding the appropriateness of umbilical catheters for a longer therapy duration (≥15 days) because it was unclear whether the umbilical vascular system and catheter would remain patent for the predicted clinical need.[16,27]

The panel rated umbilical catheters as appropriate for administering nonperipherally compatible infusates (with placement occurring up to 5 days after birth). Central tip positioning of umbilical catheters is frequently problematic, with the catheter tip often moving during treatment, which is related to a small target of safe positioning (due to patient size) and difficult securement.[4,27,28] The panel therefore endorsed frequent assessment of umbilical catheter tip positioning to safely administer nonperipherally compatible infusates. The panel rated it as appropriate to transition to alternative vascular access, from a functioning umbilical catheter, from 8 days after umbilical catheter placement but rated transition before 5 to 7 days after placement as uncertain rather than appropriate.

The miniMAGIC recommendations for appropriate device selection for hospitalized term neonates, across clinical indications and therapy durations, are summarized in Fig 1. PIVCs and midline catheters were rated appropriate for ≤7 days of peripherally compatible therapy; however, the panel rated them as uncertain or inappropriate for more prolonged therapies because of concerns regarding the device reliability. In agreement with the National Association for Neonatal Nurses, PICCs were rated as appropriate for nonperipherally compatible therapies and peripherally compatible therapies of ≥8 days of therapy.[16] Tunneled, cuffed CVADs were rated as appropriate for administration of infusates when therapy was projected to last ≥31 days. The panel deliberated extensively on the selection of an appropriate device for frequent blood draws (more than once per day) because of the risk of catheter occlusion. Ultimately, midline catheters were rated as appropriate for short durations (≤7 days), and PICCs >3F catheter, or ≤20 gauge, were rated as appropriate for ≥8 days of therapy. Tunneled, cuffed CVADs were rated appropriate for all long-term therapies (≥31 days). Totally implanted venous devices were rated as inappropriate for all clinical scenarios for hospitalized neonates, regardless of therapy duration, reflecting difficulty in implanting these devices below the skin and rapid growth impacting tip position in neonates.

Infants (31 Days to 1 year)

Infants require hospitalization for a range of conditions, with respiratory conditions, such as bronchiolitis, being highly prevalent. miniMAGIC recommendations for the selection of VAD for hospitalized infants are presented in Fig 2.

For hospitalized infants, PIVCs were rated as appropriate for ≤14 days of therapy; however, robust evidence with which to rate the appropriate use of midline catheters in this population was lacking. Panelists reported successful use of these devices at some individual hospitals but stressed the necessity for high-quality insertion and maintenance practices to promote safety. Thus, ratings for midline catheters for peripherally compatible infusates lasting ≤7 days were uncertain.

As with hospitalized neonates, PICCs were rated as appropriate for administering nonperipherally compatible infusates, with nontunneled CVADs rated as appropriate for a therapy duration of ≤14 days. The

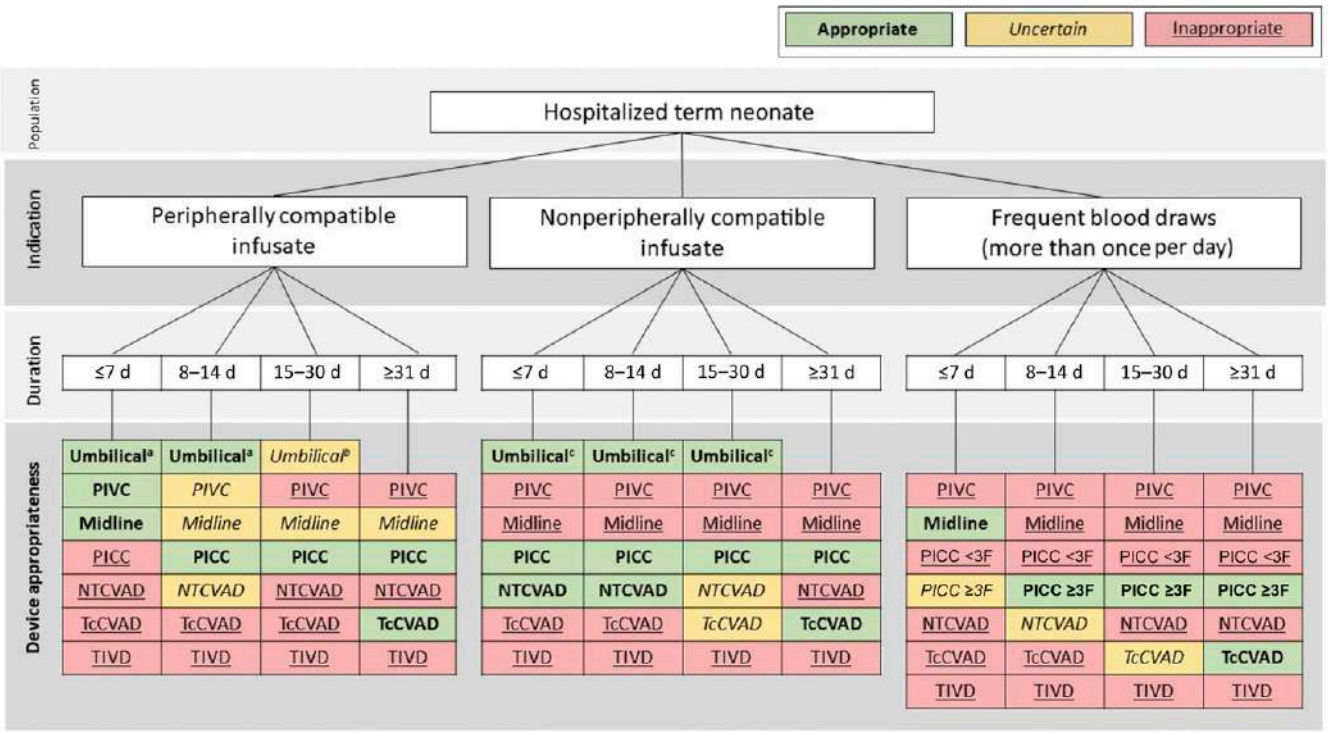

FIGURE 1

miniMAGIC recommendations for appropriate device selection for hospitalized term neonates. [a] Less than or equal to 2 days after birth. [b] All neonatal ages. [c] Less than or equal to 5 days after birth. NTCVAD, nontunneled central venous access device; TcCVAD, tunneled, cuffed central venous access device; TIVD, totally implanted venous device.

panelists again deliberated extensively regarding the appropriateness of device selection for frequent blood draws (more than once per day). The panel rated the appropriateness of PIVCs and midline catheters for ≤7 days as uncertain and rated PICCs as appropriate for ≥8 days if >3F catheter, or ≤20 gauge. The panel discussed the risk/benefit ratio of VADs for this indication, including infection, thrombosis, and repeated procedures.[4] Longer-term devices, including tunneled, cuffed CVADs and totally implanted venous devices, were rated as appropriate for ≥31 days of nonperipherally compatible therapy but as uncertain for other indications.

Children (>1–12 Years) and Adolescents (>12–<18 Years)

Although hospitalized children and adolescents represent a heterogeneous group, overall, the panelists determined that physiologic differences between children and adolescents do not make a clinically meaningful difference when it comes to VAD appropriateness. Thus, these sections were combined when ratings were performed. As displayed in Fig 3, consistent with the adult literature (including MAGIC), midline catheters and PIVCs were rated as appropriate for peripherally compatible infusates for ≤14 days.[8,11] Consequently, PICCs were rated as appropriate for use when ≥15 days of peripherally compatible therapy is planned. PICCs remained appropriate for all durations when nonperipherally compatible infusates are planned. Nontunneled CVADs were rated as appropriate by the panel for nonperipherally compatible therapies of up to 14 days' duration and as uncertain in appropriateness for frequent blood draws of between 8 and 30 days' duration. Tunneled, cuffed CVADs and totally implanted venous devices were rated as appropriate for most indications of ≥31 days.

The Appropriateness of VAD Selection in Special Pediatric Populations

Malignant Hematologic and Oncological Conditions

Compared with general hospitalized pediatric patients, patients with malignant hematologic and oncological conditions are at increased risk of infection and thrombotic complications and adverse sequelae from treatment disruption.[4,5,29] In addition, treatments and supportive therapies are complex and diverse and often require cycles of peripherally and nonperipherally compatible infusates, frequent blood draws, and management across home and health care settings. In agreement with international guidelines,[30] the panel rated tunneled, cuffed CVADs as appropriate across this indication, with totally implanted venous devices also rated appropriate for patients ≥10 kg. The panel rated the appropriateness of PICCs (all ages

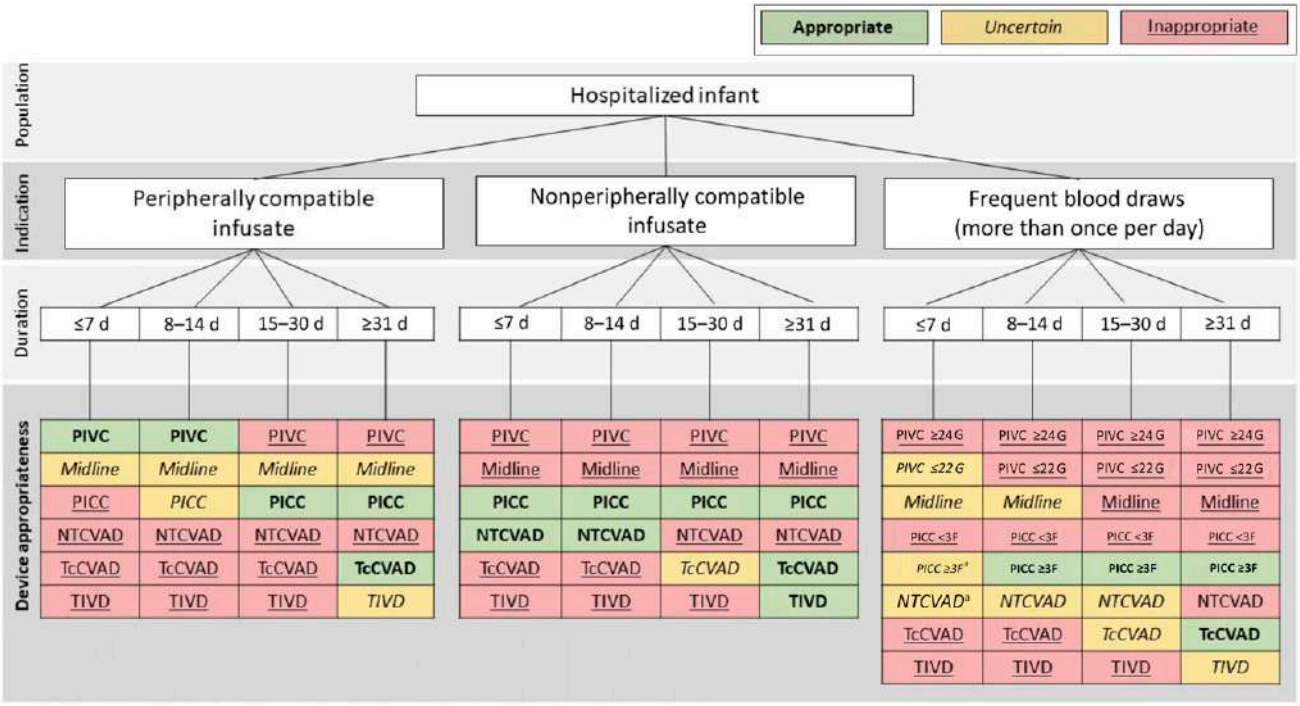

FIGURE 2
miniMAGIC recommendations for appropriate device selection for hospitalized infants. [a] Disagreement. G, gauge; NTCVAD, nontunneled central venous access device; TcCVAD, tunneled, cuffed central venous access device; TIVD, totally implanted venous device.

and weights) and totally implanted venous devices (for patients <10 kg) as uncertain, citing concerns regarding procedural and postinsertion complications such as infection and thrombosis.[30]

The panel rated it appropriate to place a PICC to commence urgent, nonperipherally compatible therapy for cancer and replace this with a definitive device. However, the appropriateness of routinely using this approach was rated as uncertain. When comparing the appropriateness of PICCs versus tunneled, cuffed CVADs, the panel rated it inappropriate to insert a PICC rather than a tunneled, cuffed CVAD for all

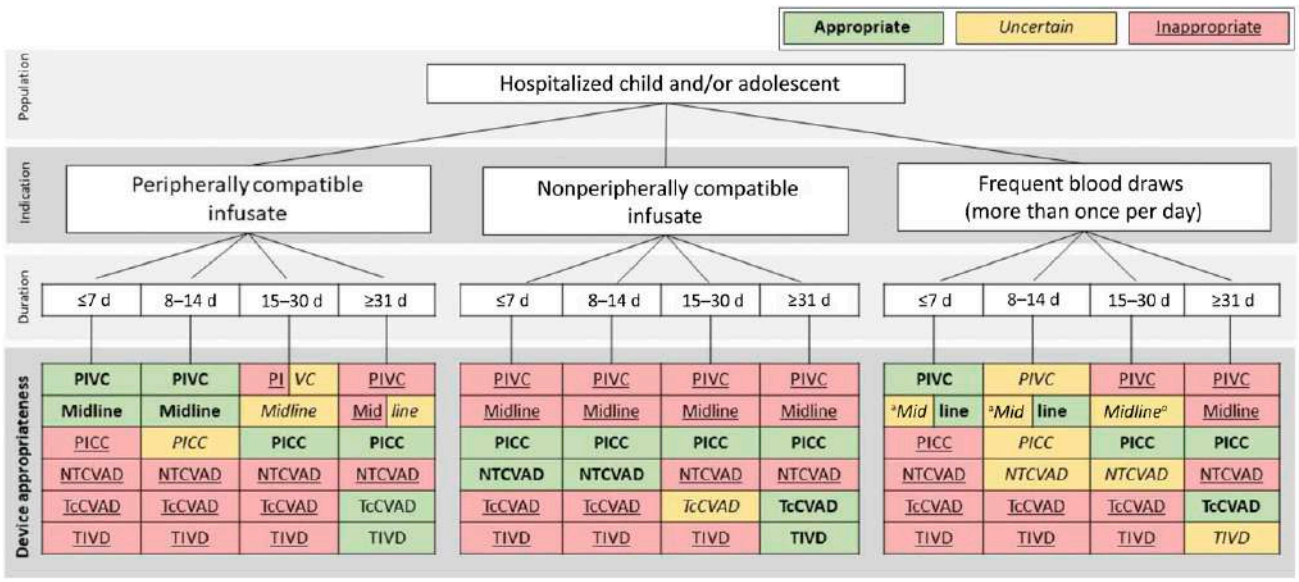

FIGURE 3
miniMAGIC recommendations for appropriate device selection for hospitalized children and adolescents. For boxes with 2 colors, the left is for children (>1–12 years), and the right is for adolescents (>12–<18 years). [a] Disagreement. NTCVAD, nontunneled central venous access device; TcCVAD, tunneled, cuffed central venous access device; TIVD, totally implanted venous device.

aged populations undergoing bone marrow transplant or other treatment of cancer. Similarly, the panel rated insertion of a PICC, rather than a totally implanted venous device, for children and adolescents receiving treatment of active cancer as inappropriate. The panel rated the same comparison as appropriate for neonates and as uncertain for infants.

Patients With Critical Illness

For pediatric patients with critical illness, miniMAGIC panelists recommended VAD selection on the basis of illness severity (ie, physiologically unstable versus stable) rather than setting of care (ie, ICU versus emergency department) or other patient or clinical characteristics. Ratings for patients with critical illness were consistent with existing guidelines[31] with respect to timeliness and importance of early venous access. Displayed in Fig 4, recommendations for a pediatric patient who is stable but critically ill varied on the basis of infusate characteristics and monitoring requirements. Nontunneled CVADs were rated as appropriate for up to 14 days of nonperipherally compatible therapy and for hemodynamic monitoring. Consistent with previous recommendations, PICCs were rated as appropriate for ≥8 days of peripherally compatible therapies and for all durations of nonperipherally compatible therapies. Despite minimal data, midline catheters were rated by the panel as appropriate for all durations of peripherally compatible therapies. For pediatric patients who are stable but critically ill requiring peripherally compatible therapy for ≤14 days, panelists preferred PIVCs over IO catheters. Panelists disagreed on the appropriateness of IO catheter use for managing pediatric patients without hemodynamic compromise without reliable vascular access for ≤7 days. Also displayed in Fig 4 (and in agreement with the American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care),[31] for an unstable pediatric patient, speed of access was first priority. For scenarios with hemodynamic compromise, panelists rated it inappropriate to attempt for PIVC access for ≥120 seconds or ≥2 attempts, instead recommending an IO device to gain intravenous (IV) access, citing how rapidly this can be inserted by clinicians with varying levels of training.[31]

Congenital Cardiac Conditions

For pediatric patients with congenital cardiac conditions, inappropriate VAD selection can directly impact both short- and long-term survival. Damage (thrombotic or stenotic) to key vessels can prevent or complicate future life-saving procedures, including catheterization interventions, palliation of patients with a functionally univentricular heart, and cardiac transplant.[32] Because the implications of vascular access and route of access are highly relevant in decision-making, clinical scenarios for this population were divided into underlying cardiac physiology: univentricular versus biventricular circulation. Across all scenarios there were 2 common recommendations. First, the panel rated totally implanted venous devices as inappropriate regardless of indication because of concerns regarding irreparable vessel damage. Second, the panel rated umbilical catheters as an appropriate access option for neonates because these do not typically result in significant vessel compromise for future procedures.[32]

Congenital cardiac procedures are primarily performed in highly specialized pediatric facilities. miniMAGIC does not include recommendations surrounding the selection of transthoracic intracardiac lines or other specialty cardiac devices (eg, extracorporeal membrane oxygenation catheters). However, the panel recognized that placement of transthoracic intracardiac lines can minimize the need for other types of VADs and thereby minimize the risks associated with percutaneous devices.[33]

For patients with univentricular physiology, miniMAGIC recommendations were based on the patient's stage of cardiac repair (stage 1, 2 or 3)[17] and duration of therapy (Fig 5). Lower-extremity PICCs, umbilical catheters, and femoral CVADs (tunneled, uncuffed and nontunneled) were rated by the panel as appropriate for patients undergoing stage 1 and 2 repair to preserve upper-extremity vein patency for stage 2 and 3 palliation.[32] To facilitate preservation of upper-extremity veins, a slightly varied CVAD insertion technique was included: the tunneled, noncuffed CVAD placed in the femoral vein.[34] After stage 3 repair, appropriateness was similar to recommendations for patients with critical illness. For patients with highly complex, functionally univentricular physiology at any stage of repair, the panel discussed the potential necessity to consider alternatives and recommended that such cases have coordinated, interdisciplinary device planning and consideration of specialist devices (eg, transhepatic CVAD).

For congenital cardiac conditions with biventricular circulation, miniMAGIC recommendations were based on patient age and duration of therapy. Appropriateness ratings were similar to those of pediatric patients who are stable but critically ill, owing to similar physiology and associated risk. The panel rated jugular-placed, nontunneled CVADs and upper extremity–placed PICCs as appropriate. Nontunneled CVADs placed in femoral and subclavian veins were rated as uncertain by the

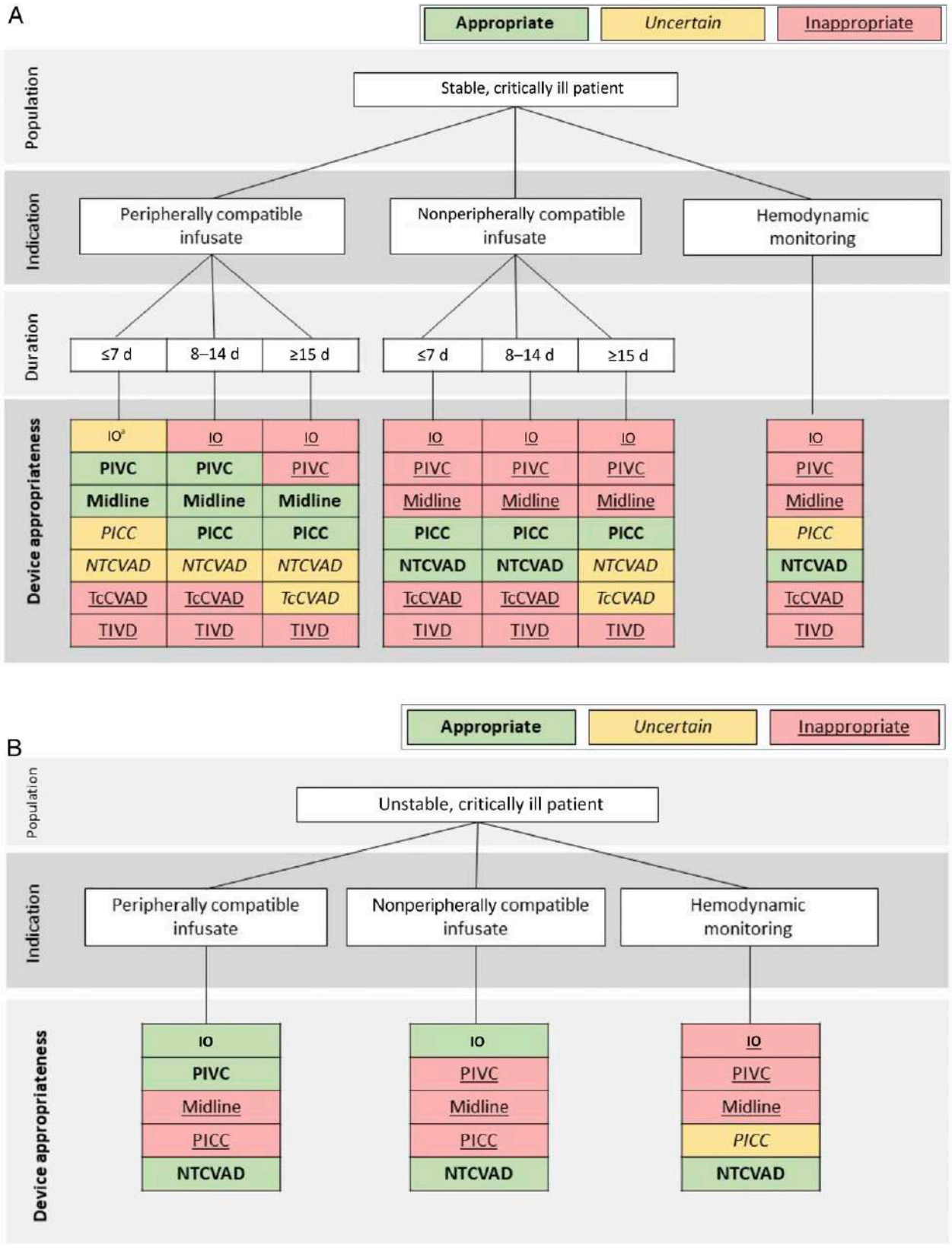

FIGURE 4

miniMAGIC recommendations for pediatric patients who are critically ill. A, stable, critically ill patient. B, unstable, critically ill patient. [a] Disagreement. NTCVAD, nontunneled central venous access device; TcCVAD, tunneled, cuffed central venous access device; TIVD, totally implanted venous device.

panel, reflecting the insertion-related complications associated with subclavian placement (which vary on the basis of operator experience and the use of ultrasound) and infection and thrombotic risk associated with femoral placement.[32] Additionally, femoral vessel preservation was cited as being important for patients with conditions likely to require future transcatheter interventions (eg, patients with tetralogy of Fallot or pulmonary atresia and patients receiving a cardiac transplant who will need multiple myocardial biopsies).

Long-Term Vascular Access Dependent

With evolution in medical therapies, long-term (>2 months) and very long-term (>1 year) vascular access dependency in pediatrics is increasingly common.[2] This prolonged reliance on VADs includes pediatric patients receiving treatment of nonmalignant hematologic (eg, sickle cell), respiratory (eg, cystic fibrosis), gastrointestinal, metabolic, and immunologic conditions. Navigating VAD insertion decisions for children with chronic illness is vital but complex. To this end, our nonvoting patient representative was instrumental in providing context for these ratings. With her input and insight, the panel agreed that defining the appropriateness of basic principles to enable vessel preservation and complication prevention in chronic conditions was necessary. The panel strongly recommended that clinicians partner with the child and family or caregivers when selecting devices to ensure that their immediate and evolving clinical and lifestyle needs are met.

In contrast to MAGIC, the panel did not believe that frequency of hospitalization should be used as a proxy for illness severity or as a defining criterion in pediatric VAD selection. This distinction was made because acute hospitalization was considered an unreliable proxy of disease in pediatric populations with chronic conditions, in whom an emphasis is placed on avoiding hospitalization.[8] Instead, in each of the clinical scenarios, it was recognized that children with long-term vascular access dependency spend time receiving treatment across home and health care facilities. In the scenarios, it was also considered that most children dependent on long-term vascular access are likely to have difficult vascular access, related to previous vessel damage and procedural fear.[2]

The criteria influencing the selection of VADs for this heterogenous population were focused on infusate characteristics (peripheral versus nonperipheral compatibility, including parenteral nutrition [PN]), continuous or intermittent therapies, and treatment duration. Specific recommendations are provided for children requiring long-term PN, and in accordance with the European Society for Parenteral and Enteral Nutrition, the panel rated use of tunneled, cuffed CVADs for all age groups as appropriate. However, the appropriateness of totally implanted venous devices for children and adolescents was rated as uncertain, and there was disagreement regarding the appropriateness of PICCs.[35]

Recommendations for non-PN infusates are displayed in Fig 6. For continuous infusates, appropriateness mirrored PN recommendations, including tunneled, cuffed CVADs for all populations. The panel also rated use of PICCs in infants and children and use of totally implanted venous devices for children and adolescents as appropriate for this indication. For intermittent access, panelists rated PICCs and totally implanted venous devices in neonates and infants as uncertain, but they rated the use of tunneled, cuffed CVADs for all populations and the use of totally implanted venous devices in children and adolescents as appropriate. Peripheral devices, including PIVCs and midline catheters, were rated as being inappropriate across all long-term, complex therapies.

For children and adolescents requiring regular, peripherally compatible intermittent treatments (eg, steroids and antibiotics) for short durations (<7 days), the panel rated PIVCs and totally implanted venous devices as appropriate. The panel rated the use of midline catheters and PICCs as uncertain, owing largely to a lack of credible evidence supporting this practice. Although some panelists had substantial experience in using midline catheters for this purpose and reported few untoward events, the lack of evidence to support this practice and the potential risk of complications limited recommendations. When considering medium-duration (8–14 days) treatment, PICCs; tunneled, cuffed CVADs; and totally implanted venous devices were rated as appropriate.

Difficult Venous Access

Difficult venous access is caused by a variety of factors in pediatrics, including physiology, pathology, VAD damage, and clinician procedural skill.[36] Appropriateness criteria for difficult venous access are focused on the number of insertion attempts, intramuscular (IM) therapy substitution, and escalation of VAD types. Each of these criteria provided a pathway to minimize vessel damage and patient distress without impacting treatment provision.

In agreement with the Infusion Nurses Society guidelines, the panel rated ≥3 attempts at PIVC insertion by a single clinician as inappropriate.[15] In parallel, the panel rated 0 to 2 attempts by one individual as appropriate but recommended early escalation to a more experienced PIVC inserter

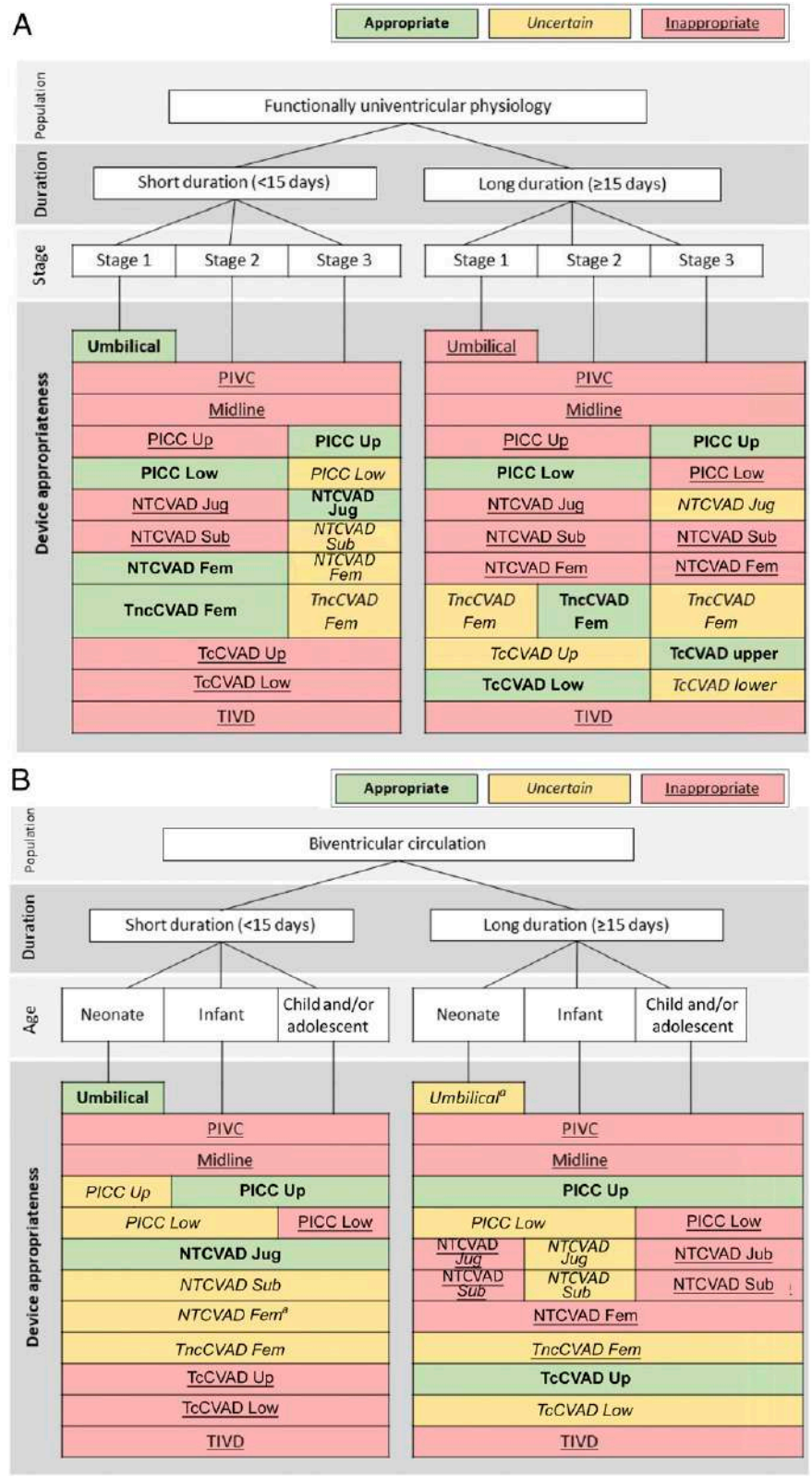

FIGURE 5

miniMAGIC recommendations for congenital cardiac conditions in pediatric patients. A, Functionally univentricular physiology. B, Biventricular circulation. [a] Disagreement. Fem, femoral; Jug, jugular; Low, lower body; NTCVAD, nontunneled central venous access device; Sub; subclavian; TcCVAD, tunneled, cuffed central venous access device; TIVD, totally implanted venous device; TncCVAD, tunneled, noncuffed central venous access device; Up, upper body.

for children with difficult venous access.

It is not uncommon in pediatrics for a child to need an additional day of IV treatment only to lose reliable IV access. In such situations, the panel rated it appropriate to substitute an antibiotic that may be delivered via alternative routes (eg, IM ceftriaxone) with a non-IV injection on the final day of therapy when advanced insertion staff are not available or after ≥2 insertion attempts are unsuccessful. The panel rated this approach as uncertain with 0 to 1 attempts but also indicated that it was reasonable to attempt to insert a PIVC for completion of IV therapy. Underlying the panel's recommendation was the understanding (1) that the efficacy of IV and IM administration for the antibiotic in question is similar and (2) that IM injections can be painful, and often multiple doses are required, thus making it less ideal.[37] When transitioning from IV to IM treatment, consultation with an infectious diseases specialist was recommended. Additionally, the panel advised considering oral antibiotic therapy in all such situations, including before IV therapy is commenced.[38]

The panel rated placement of a PICC as appropriate for a child who does not need central access or access for extended periods but who, despite appropriate escalation with skilled inserters and technology (eg, ultrasound), has required ≥2 PIVC insertion attempts. For this indication, the panel balanced the risk associated with delays to treatment and distressing repeated PIVC insertion procedures with device complications and sequelae.

The Appropriateness of Device Characteristics

The appropriateness of device characteristics, such as size and

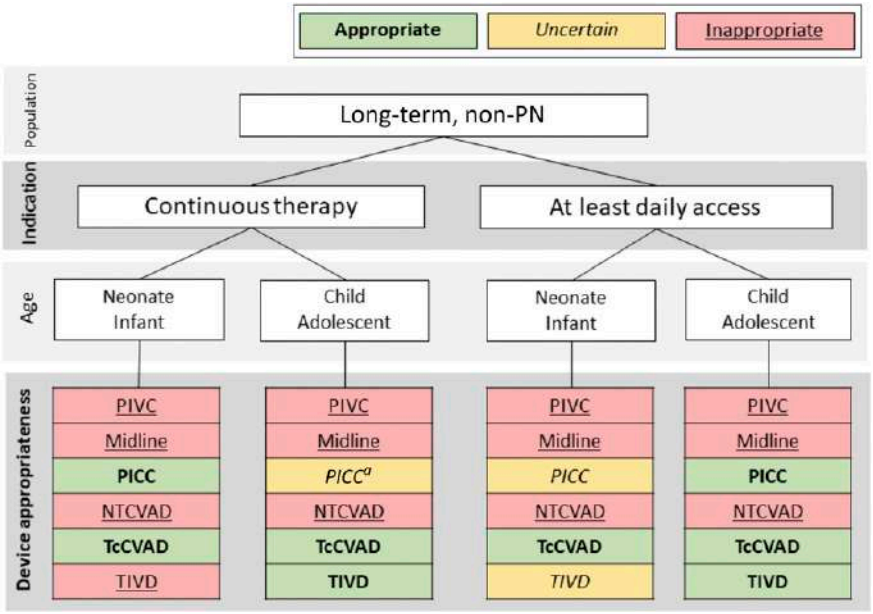

FIGURE 6

miniMAGIC recommendations for pediatric patients with non–PN-related long-term VAD dependency. [a] Disagreement. NTCVAD, nontunneled central venous access device; TcCVAD, tunneled, cuffed central venous access device; TIVD, totally implanted venous device.

number of lumens, risk of complications, device performance, and successful completion of intended therapy, was also rated. The panel considered these characteristics broadly, across all indications rather than for specific populations or clinical factors driving treatment.

Catheter-to-Vein Ratio

Although thrombosis risk is generally considered to be lower in pediatrics than in adults, the size of the vessel should be considered carefully when choosing the size of a catheter.[16] In agreement with the Infusion Nurses Society guidelines and adult literature, the panel rated a catheter-to-vein ratio of ≤45% as appropriate for PIVCs and PICCs. The panel rated a catheter-to-vein ratio of 50% as uncertain and a ratio of ≥60% as inappropriate.[15,23] For nontunneled CVADs, tunneled CVADs, and totally implanted venous devices, the panel's catheter-to-vessel ratio of appropriateness ratings were more conservative, with ≤40% appropriate, 45% to 50% uncertain, and ≥60% inappropriate. Although the panel recognized the lack of pediatric-specific literature in this area of practice, these ratings were an instance in which findings from the adult literature were felt to be applicable to pediatric patients. The panel did recommend this a priority for future inquiry.

Device Lumens

In agreement with MAGIC[8] and multiple national and international guidelines,[15,30,39] the panel rated it appropriate to routinely place a single-lumen device, unless there were specific reasons for a multilumen device (eg, incompatible infusions that could not be separated in time).[8,30] Within this domain, the panel also rated it inappropriate to place a multilumen device with dedicated lumens for blood transfusions and sampling. However, the appropriateness of dedicating lumens for lipid emulsions and PN was rated as uncertain. This rating reflected a lack of evidence regarding risks and benefits with respect to infectious complications from PN and lipid emulsions versus risks and benefits with respect to a multilumen device. Therefore, the panel recommended collaboration with a pharmacist and/or VAD insertion clinician to ensure device characteristic suitability (ie, lumen number and size) as appropriate.

The Appropriateness of the Insertion Procedure

Insertion Locations

The locations into which VADs are inserted directly impact the success of the procedure and risk of complications.[15,39–41] Vessels suitable for VAD insertion in a neonate may become difficult and/or inappropriate to access (eg, scalp vessels) or lead to an increased risk of complications (eg, lower-body PICCs in a mobilizing patient) later in life. Devices inserted into areas of flexion are associated with an increased risk of postinsertion complications, including infiltration, phlebitis, and thrombosis.[42] Recommendations for the appropriateness of VAD insertion vessels and sites are described in Fig 7.

Vessel Visualization

Vessel visualization technologies, such as ultrasound, near infrared light, and fluoroscopy, are used with increasing frequency in pediatric clinical practice.[43] High-quality evidence is available to support the use of vessel visualization techniques during the insertion of several devices, including PIVCs, PICCs, and nontunneled CVADs, to promote insertion success and prevent insertion and postinsertion complications.[43–46] In agreement with previous guidelines,[15,43] panelists rated it appropriate to insert all devices by using ultrasound guidance. Similarly, panelists rated placement of PIVCs in patients with difficult venous access and placement

of nonemergent central devices without image guidance as inappropriate. The appropriateness of near infrared light to guide PIVC and midline catheter insertion was rated as uncertain because of limited evidence. Similarly, electrocardiographically guided insertion of PICCs across populations was rated as uncertain because (unlike in the adult population) the evidence in pediatrics for a benefit of this technology is limited. Evaluation of the venous anatomy using ultrasound before placement of all central devices, and placement of VADs in neonates and pediatric patients with long-term vascular access–dependent conditions, was rated as appropriate by the panel.

DISCUSSION

Appropriate VAD selection and insertion influences a child's clinical management and outcome, reducing pain, complications, length of stay, and costs and increasing overall safety and treatment success.[4,5,36] Following the RAND/UCLA Appropriateness Method,[12] the miniMAGIC recommendations from a panel of interdisciplinary clinicians provide guidance to improve everyday VAD selection and insertion decisions. The method balances contemporary literature with the pragmatic clinical experience of the expert panelists, ensuring the recommendations are realistic and reliable.

miniMAGIC is the first time the breadth of pediatric VAD selection and insertion practices have been thoroughly evaluated and critiqued. miniMAGIC also includes recommendations encompassing the broad and unique populations within pediatrics. Findings from this work stand to improve decisions for clinically challenging patients across a broad range of VADs. Because many recommendations were grounded in evidence aimed at reducing harm, these appropriateness criteria should also help reduce complications related to poor device-selection decisions. Evidence of inappropriate use of VADs and consequential harm in pediatrics and other populations is rising,[47,48] including inappropriate PICC use for short-duration, peripherally compatible therapy.[6] miniMAGIC fills this evidence-practice gap and offers a pragmatic and novel way to reduce patient harm.

As is common in pediatric health care, many aspects of VAD practice had not been evaluated rigorously, so the panel recommendations were necessarily conservative. Consequently, important differences between miniMAGIC and MAGIC (for hospitalized adults) were observed. These included uncertainty regarding the role of midline catheters, the inappropriateness of totally implanted devices in neonates, and the appropriateness of PICCs in subspecialty populations. Scenarios classified as uncertain and with disagreement reveal opportunity for research and innovation. For example, midline catheter use; device selection for blood sampling; the use of PICCs in malignant hematology, oncology, and PN; totally implanted venous devices for children and adolescents requiring long-term PN; and insertion locations for PIVCs and nontunneled CVAD are areas in dire need of more evidence. Because these gaps span many health disciplines, collaborative and interdisciplinary research that includes intensivists, infectious disease physicians, hospitalists, nurses, oncologists, surgeons, anesthesiologists, interventional radiologists and cardiologists, and pharmacists is necessary. To improve pediatric health outcomes and health care services, funding for these research questions from foundations, national institutes, and invested stakeholders is needed.

miniMAGIC aims to broadly support the current diverse clinician inserter workforce but does not diminish the

Device	Clinical indication	Population	Appropriateness		
			Appropriate	Uncertain	Inappropriate
PIVC	Not difficult or urgent	Neonates	Forearm, hand, foot, scalp	Antecubital	
		Infants	Forearm, hand, foot	Antecubital, scalp	
		Children and adolescents	Forearm, hand	Antecubital	Scalp, foot
	Difficult	Neonates	Forearm, hand, foot, scalp, antecubital		
		Infants	Forearm, hand, foot, antecubital	Scalp	
		Children and adolescents	Forearm, hand, antecubital	Scalp, foot	
	Urgent	Neonates	Forearm, hand, foot, scalp, antecubital		
		Infants	Forearm, hand, foot, scalp, antecubital		
		Children and adolescents	Forearm, hand, foot, antecubital		Scalp
PICC		Neonates	Vessel: Basilic, brachial, cephalic, greater saphenous, axillary, mid-thigh femoral Location: Above the antecubital		Location: At the antecubital
		Infants	Vessel: Basilic, brachial, cephalic, greater saphenous, axillary Location: Above the antecubital	Vessel: Mid-thigh femoral	Location: At the antecubital
		Children and adolescents	Vessel: Basilic, brachial, cephalic Location: Above the antecubital	Vessel: Greater saphenous, axillary Location: At the antecubital	
Nontunneled CVAD	Not urgent	Neonates and infants	Femoral, internal jugular	Subclavian[a]	
		Children and adolescents	Internal jugular	Femoral, subclavian[a]	

FIGURE 7
Summary of miniMAGIC recommendations for the appropriate VAD insertion vessel and/or site in pediatric patients. [a]Disagreement.

need for vascular access experts, especially for complex cases. In this context, processes and recommendations to improve VAD selection for patients with long-term and very long-term VAD dependency, including those with congenital cardiac conditions relying on intact vessels for procedures, are especially important. A siloed approach without a dedicated expert can result in poor decisions regarding device selection, placement, and management without consideration of long-term vessel health and preservation.[49] Coordination, communication, and planning across disciplines within the art and science of vascular access is necessary to ensure that vessel damage does not occur and that the patient's and family's health goals are considered.

The implementation of miniMAGIC into practice will require further collaboration and innovation. Like its adult counterpart, the study team plans to develop a mobile health application to operationalize the panel recommendations for use at point of care. Following the RAND/UCLA Appropriateness Method,[12] miniMAGIC should also be used to evaluate historical, current, and planned VAD selection and insertion decisions in pediatric health care. The recommendations can first be used to motivate practice change and then be used as a benchmark, with retrospective and prospective audits to monitor adoption. With implementation, health care institutions can examine and celebrate corresponding improvements in patient and health services outcomes, such as reductions in central line–associated bloodstream infections, thrombosis, readmissions, and length of stay.

Our study has limitations. First, the recommendations largely rely on the quality of the evidence on which they have been generated. Many aspects of pediatric vascular access have poor-quality evidence, which means the recommendations were often reliant on clinical practice guidelines and the expert opinion of the panel. However, the recommendations of miniMAGIC are not permanent. As new evidence is generated, miniMAGIC recommendations should be revised. Second, the panel members were from the United States and Australia. Health services in other countries can be vastly different, including practitioner training and resource availability. As with MAGIC, we strongly recommend local contextualization of the recommendations before wide implementation. Finally, not all subspecialty populations were considered when creating miniMAGIC. This limitation is most evident for children with long-term vascular access–dependent conditions. For this population we have provided appropriateness criteria for practice principles; however, coordinated case management and patient- and family-centered care are vital.

CONCLUSIONS

Coordinated, appropriate VAD selection and insertion decisions can change a child's life. miniMAGIC provides robust appropriateness criteria for VADs in commonly occurring, sometimes complex, pediatric clinical indications. Interdisciplinary clinicians with a range of expertise and training can use this resource to reduce VAD-associated harm and accompanying health care resources and to improve treatment. miniMAGIC has also drawn attention to priority areas for research, innovation, and patient safety across pediatric disciplines. The findings stand to challenge and improve current pediatric vascular access practice and outcomes.

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ABBREVIATIONS

CVAD: central venous access device
IM: intramuscular
IO: intraosseous
IV: intravenous
MAGIC: Michigan Appropriateness Guide for Intravenous Catheters
miniMAGIC: Michigan Appropriateness Guide for Intravenous Catheters in pediatrics
PICC: peripherally inserted central catheter
PIVC: peripheral intravenous catheter
PN: parenteral nutrition
RAND/UCLA: RAND Corporation and University of California, Los Angeles
VAD: vascular access device

Drs Ullman and Chopra conceptualized and designed the study, drafted the initial manuscript, reviewed the data, and reviewed and revised the manuscript; Dr Bernstein assisted with designing the study and with protocol development and reviewed and revised the manuscript; Dr Brown, designed the data collection instruments, collected data, conducted the initial analyses, and reviewed and revised the manuscript; Dr Aiyagari provided expertise for vascular access devices in pediatric cardiology patients and reviewed and revised the final manuscript; Drs Cooper and Mahajan provided expertise for vascular access devices in critically ill

neonatal and pediatric patients and reviewed and revised the final manuscript; Ms Doellman provided expertise for vascular access devices in the neonatal and pediatric patient and reviewed and revised the final manuscript; Dr Gore provided patient and caregiver perspective and reviewed and revised the final manuscript; Dr Jacobs provided expertise for vascular access devices in pediatric cardiac surgery patients and reviewed and revised the final manuscript; Dr Jaffray provided expertise for vascular access devices in pediatric hematology, oncology, and bone marrow transplant patients and reviewed and revised the final manuscript; Ms Kleidon assisted in drafting case scenarios and funding applications, in protocol development, and in revision of the final manuscript; Mr McBride provided content expertise in pediatric surgery and surgically inserted devices, assistance in drafting case scenarios, and reviewed and revised the final manuscript; Drs Morton and Shaughnessy provided expertise in pediatric hospital medicine and reviewed and revised the manuscript; Ms Pitts supported the protocol development and review, case scenario review, and panel recruitment and reviewed and revised the final manuscript; Ms Prentice provided content expertise in pediatric surgery and surgically inserted devices and reviewed and revised the final manuscript; Dr Stranz provided content expertise in pediatric pharmacology and reviewed and revised the final manuscript; Dr Wolf provided expertise in pediatric infectious diseases and pediatric hematology and oncology and reviewed and revised the manuscript; Dr Rivard provided expertise in pediatric interventional radiology and image-guided insertion of vascular access devices in the neonatal and pediatric patient and reviewed and revised the final manuscript; Drs Rickard and Cooke assisted with funding applications, protocol development, and revision of the final manuscript; and all authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

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Address correspondence to Amanda J. Ullman, RN, PhD, School of Nursing and Midwifery and Menzies Health Institute Queensland, Griffith University, 140 Kessels Rd, Nathan, QLD 4111, Australia. E-mail: a.ullman@griffith.edu.au

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The Michigan Appropriateness Guide for Intravenous Catheters in Pediatrics: miniMAGIC

Amanda J. Ullman, Steven J. Bernstein, Erin Brown, Ranjit Aiyagari, Darcy Doellman, E. Vincent S. Faustino, Beth Gore, Jeffrey P. Jacobs, Julie Jaffray, Tricia Kleidon, Prashant V. Mahajan, Craig A. McBride, Kayce Morton, Stephanie Pitts, Elizabeth Prentice, Douglas C. Rivard, Erin Shaughnessy, Marc Stranz, Joshua Wolf, David S. Cooper, Marie Cooke, Claire M. Rickard and Vineet Chopra

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The Michigan Appropriateness Guide for Intravenous Catheters in Pediatrics: miniMAGIC

Amanda J. Ullman, Steven J. Bernstein, Erin Brown, Ranjit Aiyagari, Darcy Doellman, E. Vincent S. Faustino, Beth Gore, Jeffrey P. Jacobs, Julie Jaffray, Tricia Kleidon, Prashant V. Mahajan, Craig A. McBride, Kayce Morton, Stephanie Pitts, Elizabeth Prentice, Douglas C. Rivard, Erin Shaughnessy, Marc Stranz, Joshua Wolf, David S. Cooper, Marie Cooke, Claire M. Rickard and Vineet Chopra

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