Indications for peripheral, midline and central catheters: summary of the MAGIC recommendations

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ABSTRACT

Patients admitted to acute care frequently require intravenous access to effectively deliver medications and prescribed treatment. For patients with difficult intravenous access, those requiring multiple attempts, those who are obese, or have diabetes or other chronic conditions, determining the vascular access device (VAD) with the lowest risk that best meets the needs of the treatment plan can be confusing. Selection of a VAD should be based on specific indications for that device. In the clinical setting, requests for central venous access devices are frequently precipitated simply by failure to establish peripheral access. Selection of the most appropriate VAD is necessary to avoid the potentially serious complications of infection and/or thrombosis. An international panel of experts convened to establish a guide for indications and appropriate usage for VADs. This publication summarises the work and recommendations of the panel for the Michigan Appropriateness Guide for Intravenous Catheters (MAGIC).

Key words: Central venous catheters ■ Peripheral catheters ■ Midline catheters ■ Peripherally inserted central catheters ■ Central line associated bloodstream infections ■ Thrombosis

Intravenous access is a necessary component of the delivery of medical treatment in hospitals. More than 60% of patients in acute care worldwide, and higher percentages in the USA, require a vascular access device (VAD) (Alexandrou, 2015). Central venous access devices (CVADs) exceed 7 million units per year in the USA and 10 million worldwide (iData Research, 2014), and while necessary in most cases, each CVAD carries significant risk to the patient (Napalkov et al, 2013; Chopra et al, 2012a; 2012b). Recent concerns over serious complications of infection and thrombosis require closer scrutiny of CVAD use with particular emphasis on applying evidence-based indications and avoiding potential overuse of peripherally inserted central catheters (PICCs) (Maki et al, 2006; Chopra et al, 2012b; 2013a; 2013b; 2014; Hammes et al, 2015; Carr and Rippey, 2015). Due to increasing popularity, ease of insertion, low insertion related complications, reduced cost and placement primarily by vascular access teams, PICCs now comprise nearly half of all CVADs currently used in the USA (iData Research, 2014). Despite the advantages and safety in terms of insertion, PICCs are prone to occlusion and venous thrombosis, by a factor of more than 2 in comparison with other CVADs (Moureau et al, 2002; Spencer et al, 2007; Evans et al, 2010; Saber et al, 2011; Marnejon et al, 2012; Chopra et al, 2013a; Evans et al, 2013). PICC venous thrombosis is known to also impact the risk of lower-extremity thrombosis and potentially contribute to incidence of pulmonary emboli (Greene et al, 2015; Kaplan et al, 2015). Selecting the intravenous device with the lowest risk that most effectively supports the patient's treatment plan should be performed based on available evidence and specified indications.

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Method

Recognising the need to establish evidence-based indications for intravascular devices and specifically PICCs, an international group of expert physicians, clinicians and one patient was selected to work together as part of a University of Michigan/Society of Hospital Medicine-funded initiative. In this initiative, the RAND/UCLA Appropriateness Method (Fitch et al, 2001) was applied to develop criteria for the selection of the best VAD for each patient. A systematic literature review was performed and disseminated to the 15-member panel for evaluation with the 665 patient scenarios. To determine the effect on clinical decision-making, devices including peripheral intravenous catheters, ultrasound-guided peripheral intravenous catheters, midline catheters, non-tunnelled central venous catheters (CVCs), tunnelled CVCs, and ports, were compared with PICCs. Additionally, scenarios evaluating the appropriateness of individual devices were also created. Each scenario was rated based on appropriateness of PICC or other VAD usage. The RAND/UCLA Appropriateness Method incorporated information synthesis, panelist selection, patient scenarios, a rating process and analysis of results all specific to VADs.

Table 1. Peripheral catheter indications

- Peripheral intravenous catheter treatment involves the infusion of peripherally compatible solutions for 5 days or less
- Patient has adequate veins to accommodate catheter size and length
- Emergent use with placement in the external jugular or foot veins (emergent or less than 4 days)
- Cyclic or episodic chemotherapy (non-vesicant) treatment for less than 3 months

Table 2. Ultrasound-guided peripheral catheter indications

- Use visualisation technology to establish peripheral access using longer catheters for the purpose of intravenous treatment less than 5 days or more than 15 days (with transition to midline or PICC)
- For patients with one or more failed attempts, inability to identify veins visually or those identified as difficult intravenous access (DIVA) commonly inserted in the forearm, antecubital fossa or upper arm
- For contrast based radiological studies requiring upper extremity access in larger veins with 20-, 18- or 16-gauge catheter (where visible veins to accommodate catheter size are not present)

Table 3. Midline catheter indications

- Treatment involves peripherally appropriate solutions that will likely exceed 6 days
- Preferred for patients requiring infusions of up to 14 days
- Patients with difficult intravenous access (DIVA) despite ultrasound-guided peripheral catheter attempts
- Single-lumen midline is placed unless specific indication for dual lumen with compatible infusions

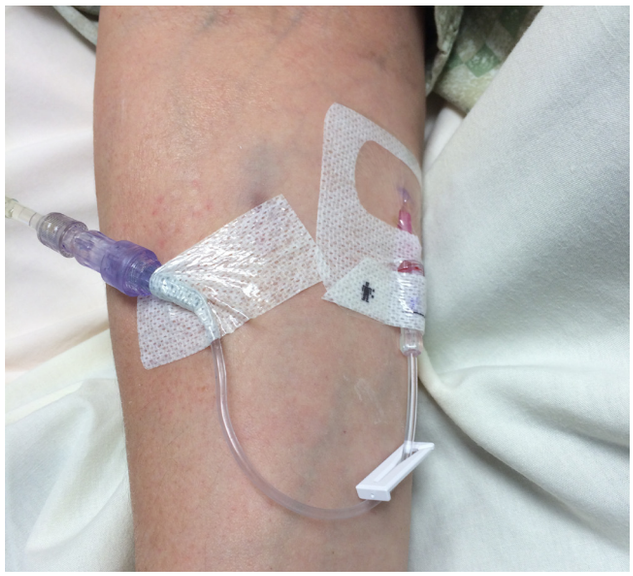

Figure 1. Ultrasound-guided peripheral catheter in the forearm (used with permission from PICC Excellence, Inc.)

Results

The results of the review by the Michigan Appropriateness Guide for Intravenous Catheters (MAGIC) panel included ratings from 391 unique indications of appropriateness or inappropriateness for PICCs and other VADs with two rounds of in-person rating scenarios by the panel (Chopra et al, 2015a). The final results established 38% of these indications as appropriate, 43% as inappropriate and 19% neutral or uncertain for the 665 scenarios. Details for each device are summarised in the following sections.

Peripheral access (PIV, USGPIV)

Peripheral catheters establish access into the veins and arteries of the arms and, less frequently, legs or other paediatric or neonatal applications of the scalp (Rickard et al, 2012; McCay, 2014). They are inserted using a direct visual approach or with visualisation devices such as infra-red or ultrasound technology. Peripheral access is considered less invasive than central access and has a lower risk of infection (0.5/1000 catheter days) (Maki et al, 2006; Hadaway, 2012). Peripheral catheters are considered appropriate for treatment of peripherally compatible medications and solutions (less than 900 mOsm/litre, not vesicant or irritant) when the duration of treatment is 6 days or less (*Table 1*) with transition to midline or PICC when duration is extended (Periard et al, 2008; Gorski et al, 2016).

When multiple peripheral catheter attempts fail, the designation of difficult intravenous access (DIVA) may lead to assessment and access with ultrasound or other forms of visualisation technology (*Figure 1*). Success is enhanced with deeper ultrasound-guided access and the use of longer peripheral catheters (Chinnock et al, 2007; Elia et al, 2012; Liu et al, 2014; Stolz et al, 2015). For all patients considered DIVAs, those with one or more failed attempts, inability to identify veins visually or with a history of difficult access, use of ultrasound or other visual technologies is recommended to help obtain the preferred peripheral intravenous access (Gorski et al, 2016). Ultrasound-guided peripheral access (USGPIV), commonly inserted in the veins of the forearm, antecubital fossa or upper arm, is indicated for treatment duration less than 6 days or up to 15 days with a transition to midline catheter or PICC if treatment continues. USGPIV is also recommended for contrast-based radiographic studies requiring upper-extremity veins with larger catheters, 20–16 gauge, where visible veins to accommodate the size are not available (*Table 2*). Evidence supports greater success with ultrasound-guided peripheral catheter access after training (Schoenfeld et al, 2011). Greater success with these procedures results in reduced need and avoidance of CVADs (Gregg et al, 2010; Au et al, 2012; Shokoohi et al, 2013).

Current research and guidelines support maintaining peripheral catheters until no longer clinically indicated or until a complication develops (Rickard et al, 2012; Gorski et al, 2012; Loveday et al, 2014; Tuffaha et al, 2014; Wallis et al, 2014; Bolton, 2015). Insertion of peripheral catheters into external jugular or leg veins is considered appropriate in emergent situations with verified inserter training prior to the insertion and treatment is 4 days or less (Chopra et al, 2015a). Peripheral catheters in the hand or distal portion of the upper extremity are the preferred choice when chronic kidney disease (CKD) is present and glomerular filtration rate (GFR) is less than 44 ml/minute, stage 3b or greater, with a focus on preserving peripheral and central veins for haemodialysis, fistula or grafts (Chopra et al, 2015a).

Peripheral catheters are the preferred access for all patients where no indication is present for central venous access (Chopra et al, 2015a). Increasing clinical skill with vein selection and access through the use of ultrasound and other visual aids facilitates the goal of avoiding CVADs when no indication

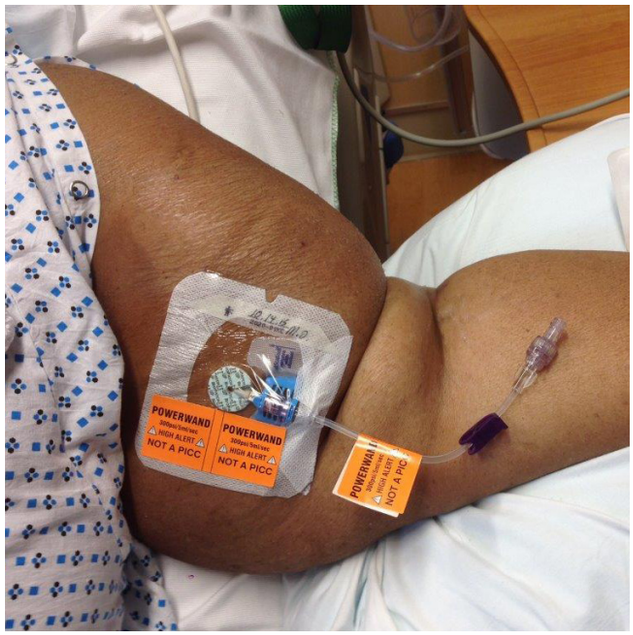

Figure 2.Midline for patient with difficult intravenous access (used with permission from Matthew Ostroff)

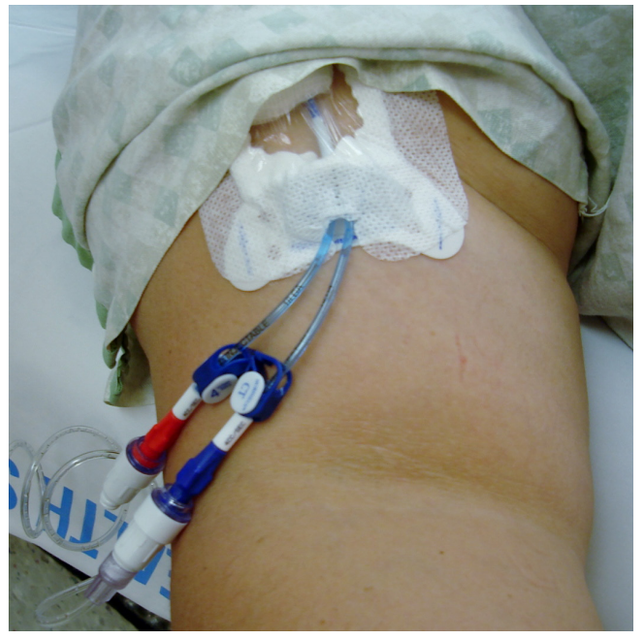

Figure 3 Peripherally inserted central catheter (PICC) (Used with permission from PICC Excellence, Inc.)

Table 4. PICC indications

- Patient requires intravenous access for longer than 14 days. For proposed treatment of 6 or more days ultrasound-guided or midline catheter preferred over PICC
- Clinically stable patient requiring intravenous therapy with peripherally incompatible solutions. Haemodynamically unstable patients where cardiac monitoring or use of vasopressors is necessary in cases less than 14 days and more than 15 days (CVCs favoured over PICCs)
- PICC is preferred to CVAD for critically ill patients with bleeding disorders for 14 days or less and those requiring 15 or more days of treatment
- For use with continuous infusions of vesicant, parenteral nutrition, chemically irritating or non-peripherally compatible solutions for any duration. For cyclic chemotherapy with active cancer where treatment is more than 3 months. Consideration given to discontinuation of PICC when each cycle complete (peripheral catheter preferred when less than 3 months)
- Use with patients receiving frequent phlebotomy of every 8 hours or more often with duration of 6 days or more
- For burn patients where early implementation of PICC decreases risk of bacteraemia
- For use with chronic or lifelong access populations (sickle cell, cystic fibrosis, short gut) or those hospitalised more frequently than 6 times per year (tunnelled catheter preferred)
- For use in patients in palliative treatment, actively dying or in hospice requiring intravenous solutions
- For skilled nursing facilities when duration of treatment is more than 14 days
- Prior nephrology approval if glomerular filtration rate (GFR) less than 30 or creatinine more than 2.0
- Single-lumen PICCs preferred unless specific indication for additional lumen. Use smaller gauge PICC with fewer lumen to reduce risk of deep vein thrombosis (DVT) (Grove and Pevec, 2000; Evans et al, 2013). Measure vein size to establish appropriate catheter size of less than 45% of vein diameter (Sharp et al, 2015). Position of terminal tip of PICC in lower third of the superior vena cava, cavoatrial junction or right atrium

exists for these devices. Many hospitals have incorporated vascular access teams to insert and maintain both peripheral and central catheters with positive outcomes (Hawes, 2007). The added expertise and skill of these team members supports the longer use of peripheral catheters.

Midline catheters

Midline catheters are experiencing a resurgence of attention with great usage owing to improvements in catheter materials and products. The two most recent midline catheters are 8–10 cm in length utilising the insertion technique referred to as accelerated Seldinger (AST) (Access Scientific, Bard Access Systems, Teleflex). These all-in-one devices with the modified Seldinger technique (MST) have the needle, wire and introducer in a combined unit for ease and speed in access. The evidence supporting midlines is growing with a variety of publications demonstrating positive outcomes (Anderson et al, 2004; Griffiths, 2007; Alexandrou et al, 2011; Cummings et al, 2011; Warrington et al, 2012; Dawson and Moureau, 2013; Caparas and Hu, 2014; Moureau et al, 2015). Midline catheters have lower phlebitis rates than peripheral catheters and lower rates of infection than other central catheters. Midlines are considered appropriate for patients with peripherally compatible solutions or medications where treatment will likely exceed 6 days. Midlines are preferred for patients requiring infusions up to 14 days, but may be used in a manner consistent with the clinically indicated removal of peripheral catheters (O'Grady et al, 2011; Caparas and Hu, 2014) (*Table 3*). When patients are considered DIVAs and ultrasound-guided peripheral access has failed, midlines are preferred (*Figure 2*). As with all vascular access devices, single lumen midline catheters are placed unless a specific indication for dual lumen is needed (only single and dual-lumen midlines are currently available).

Peripherally inserted central catheters (PICC)

PICCs have provided a reliable bridge between shorter peripheral catheters and chest-inserted central venous catheters (CICC) for more than 20 years (*Figure 3*). There is reduced risk of pneumothorax, haemothorax, nerve damage, stenosis and other

Table 5. Inappropriate PICC

- Placement of PICC for any non-central indication
- Insertion of a PICC primarily for the purpose of establishing intravenous access when the duration of treatment is unknown
- Use with any infusion other than non-peripherally compatible infusates
- Placement of a PICC with confirmed PICC-related bloodstream infection without documented clearance of infection (line-free interval of 48–72 hours with negative blood cultures)
- Avoid PICC use for inappropriate indications, or for patients with history of thrombosis, hypercoagulability or decreased venous flow to extremities; consider alternative devices and remove PICC when no longer needed
- For renal failure stage 3b or greater chronic kidney disease with GFR of less than 44 ml/minute or for patients currently receiving any renal replacement therapy
- Insertion for infrequent phlebotomy, less than 3 times daily
- Medical, nursing or patient/family request without central indication, actively dying/hospice or other appropriate criteria for PICC
- Urgent or 'STAT' request for PICC for a haemodynamically unstable or critical patient
- Placement of PICC on the basis of arm dominance
- Removal or replacement of PICC that is clinically necessary without evidence of bloodstream infection or other complication
- Advancement of PICC or other dislodged vascular access device in the case of migration of the catheter

Table 6. Non-tunnelled catheter indications

- Unstable patients requiring haemodynamic monitoring, multiple medications, large fluid infusions, blood or blood products or continuous parenteral nutrition
- Short-term critical access. Non-tunnelled CVCs are preferred over PICCs for access up to 14 days
- Chemotherapy treatment anticipated for more than 3 months
- Antimicrobial non-tunnelled catheters are often used for these critical patients to reduce the risk of infection by approximately 40%

Table 7. Tunnelled catheter indications

- Patients receiving treatment exceeding 31 days
- Infusion of vesicant, irritant, parenteral nutrition or chemotherapeutic agents regardless of duration
- Patients likely to receive cyclic or intermittent ongoing therapy exceeding 31 days
- Patients with more than than 6 hospitalisations annually with expected duration of therapy longer than 15 days per hospitalisation

Table 8. Totally implanted subcutaneous port indications

- Patients with expected treatment longer than 6 months (neutral rating for 3–6 month duration of treatment)
- Patients requiring intermittent or cyclic infusion treatment, rather than continuous, for more than 6 months

more serious CVAD-related complications with PICC placement. Indications for PICCs (*Table 4*) include any patient requiring peripherally incompatible infusions or for intravenous treatment more than 14 days (Chopra et al, 2015a). Expanded nursing roles support safe placement of PICCs by specially trained teams of nurses (Robinson et al, 2005; Falkowski, 2006; Simcock, 2008). Increased awareness of PICCs has reduced the number of other CVAD placements. Bedside nurses are more likely to request a PICC order after having difficulty establishing peripheral access rather than considering all options and appropriateness of central access (Chopra et al, 2015b; Helm et al, 2015; Woller et al, 2015).

With rising concerns over the incidence of thrombosis with PICCs and the relationship of thrombosis to infection, closer evaluation of each PICC request is necessary to evaluate the need for central versus peripheral access for each patient (Marschall et al, 2014; Chopra et al, 2015a). Measuring the vein diameter and choosing a catheter–to–vein ratio of 45% or less may reduce thrombosis risk in PICCs and midlines (Nifong and McDevitt, 2011; Sharp et al, 2015; Gorski et al, 2016). Use of antimicrobial PICCs may reduce risk and was statistically significant in reducing the level of infection by a factor of 4 in one hospital study (Rutkoff, 2014). In *Tables 4* and *5* a list of appropriate and inappropriate indications for PICCs is provided based on MAGIC (Chopra et al, 2015a).

Non-tunnelled central venous catheters

Non-tunnelled CVCs are commonly used for internal jugular access with acute care patients who are unstable and who require haemodynamic monitoring or large fluid infusions. These percutaneously inserted catheters have a rate of infection similar to PICCs (Maki et al, 2006) and are used for short-term critical access. Non-tunnelled CVCs are preferred over PICCs when treatment is required for 14 days or less. Antimicrobial non-tunnelled catheters are often used for these critical patients when the catheter is expected to stay in place for more than 5 days to reduce risk of infection (Hockenhull et al, 2008; Pittiruti et al, 2009; Lai et al, 2013; Chopra et al, 2015a; Lorente et al, 2016) (*Table 6*).

Tunnelled central venous catheters

Tunnelled CVCs are inserted into internal jugular or subclavian veins with a subcutaneous tunnel commonly to the mid-chest region, but also other areas customised to the patient. Tunnelled catheters are indicated for use with intravenous treatment of 31 days or longer, or more episodic treatment over several months. Typically, these CVADs are reserved for patients not considered candidates for a PICC due to vein size or thrombosis risk. Tunnelled internal jugular catheters and small bore catheters are preferred for patients with any level of CKD requiring intravenous treatment for more than 15 days. PICC and tunnelled catheters are appropriate at all time intervals for infusion of irritating or chemotherapeutic medications. Tunnelled catheters are recommended over multi-lumen PICCs when multiple or frequent infusions are required due to their lower incidence of complications (Tran et al, 2010; Chopra et al, 2015a) (*Table 7*).

Subcutaneously implanted ports

With subcutaneously implanted ports, a catheter is inserted into either the internal jugular or subclavian vein and attached to a port reservoir. The port is implanted into a pocket created in a subcutaneous area on the chest (or arm as in arm ports), connected to the catheter, tested for flow and secured with sutures or glue (Simonova et al, 2012; Chopra et al, 2015a). Ports are appropriate for patients with expected treatment longer than 6 months. The MAGIC panelists rated ports as having neutral appropriateness for duration of treatment equal to 3-6 months. Ports may also be considered appropriate for difficult venous access if use for 31 days or more is expected (Chopra et al, 2015a)(*Table 8*).

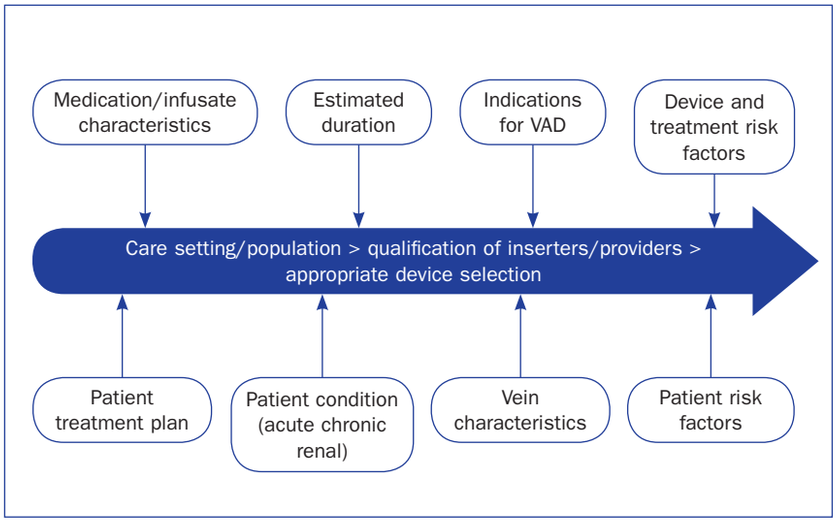

Figure 4. Selection criteria for vascular access devices (PICC Excellence, Inc. ©2016)

Table 9. Selection, care and maintenance appropriate practices

- Evaluate a PICC or CVC order prior to insertion to determine optimal device choice
- Exchange PICC to change device features (number of lumen) or to correctly position catheter
- Verify tip position via chest radiography, fluoroscopy or electrocardiography guidance (after training and technical proficiency is confirmed)
- Provide more than 3 months of uninterrupted systemic anticoagulation for treatment of PICC-related deep vein thrombosis (DVT) in the absence of contraindications. Do not remove a functional catheter unless no longer needed or worsening symptoms persist after more than 72 hours of anticoagulation.
- PICCs of the smallest-sized catheter and appropriate vein size on the contralateral arm may be inserted with patients after DVT with more than 3 months of anticoagulation
- Provide line-free interval (48–72 hours) to ensure clearance of bacteraemia prior to insertion of central catheter
- Removal of a central venous catheter (PICC, CVC, tunnelled catheter) after notification of physician and when catheter has not been used for any clinical purpose for 48 hours or longer
- Removal of catheter when patient no longer has a clinical indication for use or the original use has been met
- Removal of catheter when used only for blood samples in stable patient when peripheral veins available
- Removal of catheter only by clinician trained for removal of specific device

Discussion

For the first time, the MAGIC document provides appropriateness ratings for specific VADs based on infusate, patient, duration and treatment characteristics. Factors such as proposed duration of medication infusions, effects of the medication on vessels, patient condition (renal, critical, chronic) or complications of infection were all evaluated (*Figure 4*), helping create clinically practical recommendations. However, recommendations for clinical appropriateness are often based on criteria that are difficult to estimate, such as duration of treatment. As emphasised by the patient panelist in the MAGIC initiative, an individualised approach is necessary in many situations.

Application of the appropriateness criteria may also require adaptation to the particular care setting (hospital, skilled nursing, home environment). Factors such as reliability of the VAD are more important in the skilled nursing and home environment where clinical support and expertise may be limited. Peripheral catheters and midlines have variable reliability outside the hospital setting.

The concept of vessel health and preservation is focused not just on gaining better outcomes during a single hospitalisation, but on preserving veins for future patient needs (Moureau et al, 2012; Hallam et al, 2016). Understanding and applying clinical research indicating the treatment, practice or process leading to the best results for the patient is challenging for clinicians. Selection of recommendations and guidelines is often convenience and economically oriented rather than patient focused, leading to a greater risk of complications for the patient.

It is important to remember that limitations exist for the MAGIC guidance. First, not all recommendations translate to all patient populations. For instance, placement of CVCs in critically ill patients requires the availability of experienced and skilled staff to insert devices in manners that are safe from insertion complications such as pneumothorax. This is implicitly assumed in MAGIC, but may not be so in the real world. Second, MAGIC does not address certain technological advances including antimicrobial-coated catheters or advanced devices such as infra-red vein finders that may impact on choice and selection of device. These limitations must be borne in mind when considering MAGIC. Technology ever advances and MAGIC should thus not be viewed as an all-encompassing document, but a living and breathing statement that changes with available evidence and practice. Third, it is unclear how best to implement recommendations from MAGIC. Should these be incorporated into checklists, software-based applications or electronic-medical record systems? Who is responsible for adherence? Are there potential barriers in implementation that have not been considered? These types of challenges require careful thought and the use of implementation science to better understand what works and what does not in the real-world setting.

MAGIC has succeeded in creating a practical list of indications, both appropriate and inappropriate, for VAD use. This document guides physicians, bedside clinicians, and those on vascular access teams to the most appropriate selection of the safest device and practices for the patient. To quote Thomas Vesely, a fellow clinician and designated Doctor of Medicine, who spoke to the authors:

> **'More than 20 nationally-recognised guidelines, recommendations, and standards documents concerning vascular access were created by 10 different organisations. Insular creation of such documents is the wrong approach. It's time that all involved agree on 'the rules' even if that requires compromise and MAGIC is a good step in the right direction.'**

More expert discussion, evaluation and research is needed on issues where panelists failed to reach a decision, were neutral or disagreed for VAD indications. Consistent with the variation in panelist responses, published literature often has contradictions in results from one study to another. There was a paucity of randomised controlled trials for specific VADs necessary to establish definitive conclusions. Furthermore, what works in

one setting may not work in another. Understanding how best to implement MAGIC to improve decision-making in vascular access remains a key goal—one that must be actively targeted by those in this field.

Conclusion

Guidelines, recommendations and standards point to the need for evidence-based indications when selecting a VAD. Relying on available literature, the combined clinical experience of the panelists, patient input, and an established methodology embodied in the RAND/UCLA Method, a consensus was reached through MAGIC to establish a working guide for intravenous device indications and contraindications. Careful evaluation and application of MAGIC conclusions into the programme of each facility administering intravenous treatments provides guidance toward the most appropriate and safe patient applications. In this age of electronic medical records, criteria such as MAGIC may serve as a clinical decision process embedded in the electronic medical records framework to guide clinical decisions in keeping with the theory of vessel health and preservation for patients from birth to death. **BJN**

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KEY POINTS

- The ability to preserve vessel health for future medical needs requires clinical education and training in three areas: device selection, placement and daily device care
- Selection of the most appropriate vascular access device (VAD) is necessary to avoid the potentially serious complications of infection and/or thrombosis.
- Selection of a central VAD (CVAD) should be based on indications for that specific device rather than the inability to gain peripheral access
- All VADs have a risk of infection and other complications for the patient and should be removed as soon as no longer medically necessary

Alexandrou E (2015) One Million Global Catheters PIVC Worldwide Prevalence Study: Pilot and Preliminary Study Results. Presentation at the *Annual Scientific Meeting of the Association for Vascular Access*, 29–29 September, Dallas.

Alexandrou E, Ramjan LM, Spencer T et al (2011) The use of midline catheters in the adult acute care setting—clinical implications and recommendations for practice. *J Assoc Vasc Access* **16**(1): 35-41. 10.2309/java.16-1-5

Anderson NR (2004) Midline catheters: the middle ground of intravenous therapy administration. *J Infus Nurs* **27**(5): 313–21

Au AK, Rotte MJ, Grzybowski RJ, Ku BS, Fields JM (2012) Decrease in central venous catheter placement due to use of ultrasound guidance for peripheral intravenous catheters. *Am J Emerg Med* **30**(9): 1950–4. doi: 10.1016/j.ajem.2012.04.016

Bolton D (2015) Clinically indicated replacement of peripheral cannulas. *Br J Nurs* **24**(19): S4–12. doi: 10.12968/bjon.2015.24.Sup19.S4

Caparas JV, Hu J-P (2014) Safe administration of vancomycin through a novel midline catheter: a randomized, prospective clinical trial. *J Vasc Access* **15**(4): 251–6. doi: 10.5301/jva.5000220

Carr PJ, Rippey JCR (2015) Upper extremity deep vein thrombosis: a complication of an indwelling peripherally inserted central venous catheter. *Clin Case Rep* **3**(3): 170–4. doi: 10.1002/ccr3.187

Chinnock B, Thornton S, Hendey GW (2007) Predictors of success in nurse-performed ultrasound-guided cannulation. *J Emerg Med* **33**(4): 401–5. doi: 10.1016/j.jemermed.2007.02.027

Chopra V, Flanders SA, Saint S (2012a) The problem with peripherally inserted central catheters. *JAMA* **308**(15): 1527–8. doi: 10.1001/jama.2012.12704

Chopra V, Anand S, Krein SL, Chenoweth C, Saint S (2012b) Bloodstream infection, venous thrombosis, and peripherally inserted central catheters: reappraising the evidence. *Am J Med* **125**(8): 733–41. doi: 10.1016/j.amjmed.2012.04.010

Chopra V, Anand S, Hickner A et al (2013a) Risk of venous thromboembolism associated with peripherally inserted central catheters: a systematic review and meta-analysis. *Lancet* **382**(9889): 311–25. doi: 10.1016/S0140-6736(13)60592-9

Chopra V, O'Horo JC, Rogers MAM, Maki DG, Safdar N (2013b) The risk of bloodstream infection associated with peripherally inserted central catheters compared with central venous catheters in adults: a systematic review and meta-analysis. *Infect Control Hosp Epidemiol* **34**(9): 908–18. doi: 10.1086/671737

Chopra V, Ratz D, Kuhn L, Lopus T, Chenoweth C, Krein S (2014) PICC-associated bloodstream infections: prevalence, patterns, and predictors. *Am J Med* **127**(4): 319–28. doi: 10.1016/j.amjmed.2014.01.001

Chopra V, Flanders SA, Saint S et al (2015a) The Michigan Appropriateness Guide for Intravenous Catheters (MAGIC): Results From a Multispecialty Panel Using the RAND/UCLA Appropriateness Method. *Ann Intern Med* **163**(6 Suppl): S1–40. doi: 10.7326/M15-0744

Chopra V, Kuhn L, Ratz D, Flanders SA, Krein SL (2015b) Vascular nursing experience, practice knowledge, and beliefs: Results from the Michigan PICC1 survey. *J Hosp Med*. doi: 10.1002/jhm.2523 [E-pub ahead of print]

Cummings M, Hearse N, McCutcheon H, Deuter K (2011) Improving antibiotic treatment outcomes through the implementation of a midline: piloting a change in practice for cystic fibrosis patients. *J Vasc Nurs* **29**(1): 11–5. doi: 10.1016/j.jvn.2010.11.005

Dawson RB, Moureau NL (2013) Midline catheters: an essential tool in CLABSI reduction. *Infect Contr Today* http://tinyurl.com/gofyhnd (accessed 22 March 2016)

Elia F, Ferrari G, Molino P et al (2012) Standard-length catheters vs long catheters in ultrasound-guided peripheral vein cannulation. *Am J Emerg Med* **30**(5): 712–6. doi: 10.1016/j.ajem.2011.04.019

Evans RS, Sharp JH, Linford LH et al (2010) Risk of symptomatic DVT associated with peripherally inserted central catheters. *Chest* **138**(4): 803–10. doi: 10.1378/chest.10-0154

Evans RS, Sharp JH, Linford LH et al (2013) Reduction of peripherally inserted central catheter-associated DVT. *Chest* **143**(3): 627–33. doi: 10.1378/chest.12-0923

Falkowski A (2006) Improving the PICC insertion process. *Nursing* **36**(2): 26–7

Fitch K, Bernstein SJ, Aguilar MD et al (2001) *The RAND/UCLA appropriateness method user's manual*. http://tinyurl.com/z84dpl4 (accessed 5 April 2016)

Gregg SC, Murthi SB, Sisley AC, Stein DM, Scalea TM (2010) Ultrasound-guided peripheral intravenous access in the intensive care unit. *J Crit Care* **25**(3): 514–9. doi: 10.1016/j.jcrc.2009.09.003

Gorski LA, Hallock D, Kuehn SC, Morris P, Russell JM, Skala LC (2012) Recommendations for frequency of assessment of the short peripheral catheter site. *J Infus Nurs* **35**(5): 290–2. doi: 10.1097/NAN.0b013e318267f636

Gorski L, Hadaway L, Hagle M, McGoldrick M, Orr M, Doellman D (2016) Infusion Therapy Standards of Practice. *J Infus Nurs* **39**(1S):159

Greene MT, Flanders SA, Woller SC, Bernstein SJ, Chopra V (2015) The association between PICC use and venous thromboembolism in upper and lower extremities. *Am J Med* **128**(9): 986–93.e1. doi: 10.1016/j.amjmed.2015.03.028

Griffiths V (2007) Midline catheters: indications, complications and maintenance. *Nurs Stand* **22**(11): 48–57. doi: 10.7748/ns2007.11.22.11.48.c6241

Grove JR, Pevec WC (2000) Venous thrombosis related to peripherally inserted central catheters. *J Vasc Interv Radiol* **11**(7): 837–40

Hadaway L (2012) Short peripheral intravenous catheters and infections. *J Infus Nurs* **35**(4): 230–40. doi: 10.1097/NAN.0b013e31825af099

Hallam C, Weston V, Denton A et al (2016) Development of the UK Vessel Health and Preservation (VHP) framework: a multi-organisational collaborative. *Journal of Infection Prevention* **17**(2): 65–72. doi: 10.1177/1757177415624752

Hammes M, Desai A, Pasupneti S et al (2015) Central venous catheters: incidence and predictive factors of venous thrombosis. *Clin Nephrol* **84**(1): 21–8. doi: 10.5414/CN108347

Hawes ML (2007) A proactive approach to combating venous depletion in the hospital setting. *J Infus Nurs* **30**(1): 33–44

Helm RE, Klausner JD, Klemperer JD, Flint LM, Huang E (2015) Accepted but unacceptable: peripheral IV catheter failure. *J Infus Nurs* **38**(3): 189–203. doi: 10.1097/NAN.0000000000000100

Hockenhull JC, Dwan K, Boland A et al (2008) The clinical effectiveness and

cost-effectiveness of central venous catheters treated with anti-infective agents in preventing bloodstream infections: a systematic review and economic evaluation. *Health Technol Assess* **12**(12): iii – iv, xi – xii, 1–154
iData Research (2014) *U.S. Market for Vascular Access Devices and Accessories*. iData Research, Inc,Vancouver. http://tinyurl.com/hmlp7mb (accessed 11 April 2016)
Kaplan D, Casper TC, Elliott CG et al (2015) VTE incidence and risk factors in patients with severe sepsis and septic shock. *Chest* **148**(5): 1224–30. doi: 10.1378/chest.15-0287
Lai NM, Chaiyakunapruk N, Lai NA, O'Riordan E, Pau WSC, Saint S (2013) Catheter impregnation, coating or bonding for reducing central venous catheter-related infections in adults. *Cochrane Database Syst Rev* 6: CD007878. doi: 10.1002/14651858.CD007878.pub2
Liu YT, Alsaawi A, Bjornsson HM (2014) Ultrasound-guided peripheral venous access: a systematic review of randomized-controlled trials. *Eur J Emerg Med* **21**(1): 18–23. doi: 10.1097/MEJ.0b013e328363bebc
Lorente L, Lecuona M, Jiménez A et al (2016) Chlorhexidine-silver sulfadiazine- or rifampicin-miconazole-impregnated venous catheters decrease the risk of catheter-related bloodstream infection similarly. *Am J Infect Control* **44**(1): 50–3. doi: 10.1016/j.ajic.2015.08.014
Loveday HP, Wilson JA, Pratt RJ et al (2014) epic3: national evidence-based guidelines for preventing healthcare-associated infections in NHS hospitals in England. *J Hosp Infect* **86** Suppl 1: S1–70. doi: 10.1016/S0195-6701(13)60012-2
Maki DG, Kluger DM, Crnich CJ (2006) The risk of bloodstream infection in adults with different intravascular devices: a systematic review of 200 published prospective studies. *Mayo Clin Proc* **81**(9): 1159–71. doi: 10.4065/81.9.1159
Marnejon T, Angelo D, Abu Abdou A, Gemmel D (2012) Risk factors for upper extremity venous thrombosis associated with peripherally inserted central venous catheters. *J Vasc Access* **13**(2): 231–8. doi: 10.5301/jva.5000039
Marschall J, Mermel LA, Fakih M et al (2014) Strategies to prevent central line-associated bloodstream infections in acute care hospitals: 2014 update. *Infect Control Hosp Epidemiol* **35**(7): 753–71. doi: 10.1086/676533
McCay AS, Elliott EC, Walden M (2014) PICC Placement in the Neonate. *N Engl J Med* 370(11): e17. doi: 10.1056/NEJMvcm1101914
Moureau NL, Trick N, Nifong T et al (2012) Vessel health and preservation (Part 1): a new evidence-based approach to vascular access selection and management. *J Vasc Access* **13**(3): 351–6. doi: 10.5301/jva.5000042
Moureau N, Poole S, Murdock MA, Gray SM, Semba CP (2002) Central venous catheters in home infusion care: outcomes analysis in 50,470 patients. *J Vasc Interv Radiol* **13**(10): 1009–16
Moureau N, Sigl G, Hill M (2015) How to establish an effective midline program: a case study of 2 hospitals. *Journal of the Association for Vascular Access* **20**(3): 179–88. doi: 10.1016/j.java.2015.05.001
Napalkov P, Felici DM, Chu LK, Jacobs JR, Begelman SM (2013) Incidence of catheter-related complications in patients with central venous or hemodialysis catheters: a health care claims database analysis. *BMC Cardiovascular Disorders* **13**: 86. doi: 10.1186/1471-2261-13-86
Nifong TP, McDevitt TJ (2011) The effect of catheter to vein ratio on blood flow rates in a simulated model of peripherally inserted central venous catheters. *Chest* **140**(1): 48–53. doi: 10.1378/chest.10-2637
O'Grady NP, Alexander M, Burns LA et al (2011) Guidelines for the prevention of intravascular catheter-related infections. *Am J Infect Control* **39**(4 Suppl 1): S1–34. doi: 10.1016/j.ajic.2011.01.003
Periard D, Monney P, Waeber G et al (2008) Randomized controlled trial of peripherally inserted central catheters vs. peripheral catheters for middle duration in-hospital intravenous therapy. *J Thromb Haemost* **6**(8): 1281–8. doi: 10.1111/j.1538-7836.2008.03053.x
Pittiruti M, Hamilton H, Biffi R, MacFie J, Pertkiewicz M for ESPEN (2009) ESPEN Guidelines on Parenteral Nutrition: central venous catheters (access, care, diagnosis and therapy of complications). *Clin Nutr* **28**(4): 365–77. doi: 10.1016/j.clnu.2009.03.015
Rickard CM, Webster J, Wallis MC et al (2012) Routine versus clinically indicated replacement of peripheral intravenous catheters: a randomised controlled equivalence trial. *Lancet* **380**(9847): 1066–74. doi: 10.1016/S0140-6736(12)61082-4
Robinson MK, Mogensen KM, Grudinskas GF, Kohler S, Jacobs DO (2005) Improved care and reduced costs for patients requiring peripherally inserted central catheters: the role of bedside ultrasound and a dedicated team. *J Parenter Enteral Nutr* **29**(5): 374–9
Rutkoff GS (2014) The influence of an antimicrobial peripherally inserted central catheter on central line-associated bloodstream infections in a hospital environment. *Journal of the Association for Vascular Access* **19**(3):172-9. doi: 10.1016/j.java.2014.06.002
Saber W, Moua T, Williams EC et al (2011) Risk factors for catheter-related thrombosis (CRT) in cancer patients: a patient-level data (IPD) meta-analysis of clinical trials and prospective studies. *J Thromb Haemost* **9**(2): 312–9. doi: 10.1111/j.1538-7836.2010.04126.x
Schoenfeld E, Boniface K, Shokoohi H (2011) ED technicians can successfully place ultrasound-guided intravenous catheters in patients with poor vascular access. *Am J Emerg Med* **29**(5): 496–501. doi: 10.1016/j.ajem.2009.11.021
Sharp R, Cummings M, Fielder A, Mikocka-Walus A, Grech C, Esterman A (2015) The catheter to vein ratio and rates of symptomatic venous thromboembolism in patients with a peripherally inserted central catheter (PICC): a prospective cohort study. *Int J Nurs Stud* **52**(3): 677–85. doi: 10.1016/j.ijnurstu.2014.12.002
Shokoohi H, Boniface K, McCarthy M et al (2013) Ultrasound-guided peripheral intravenous access program is associated with a marked reduction in central venous catheter use in noncritically ill emergency department patients. *Ann Emerg Med* **61**(2): 198–203. doi: 10.1016/j.annemergmed.2012.09.016
Simcock L (2008) No going back: advantages of ultrasound-guided upper arm PICC placement. *Journal of the Association for Vascular Access* **13**(4): 191–7. doi: 10.2309/java.13-4-6
Simonova G, Rickard CM, Dunster KR, Smyth DJ, McMillan D, Fraser JF (2012) Cyanoacrylate tissue adhesives—effective securement technique for intravascular catheters: in vitro testing of safety and feasibility. *Anaesth Intensive Care* **40**(3): 460–6
Spencer FA, Emery C, Lessard D, Goldberg RJ, Worcester Venous Thromboembolism Study (2007) Upper extremity deep vein thrombosis: a community-based perspective. *Am J Med* **120**(8): 678–84. doi: 10.1016/j.amjmed.2006.06.046
Stolz LA, Stolz U, Howe C, Farrell IJ, Adhikari S (2015) Ultrasound-guided peripheral venous access: a meta-analysis and systematic review. *J Vasc Access* **16**(4): 321–6. doi: 10.5301/jva.5000346
Tran H, Arellano M, Chamsuddin A et al (2010) Deep venous thromboses in patients with hematological malignancies after peripherally inserted central venous catheters. *Leuk Lymphoma* **51**(8): 1473–7. doi: 10.3109/10428194.2010.481065
Tuffaha HW, Rickard CM, Webster J et al (2014) Cost-effectiveness analysis of clinically indicated versus routine replacement of peripheral intravenous catheters. *Appl Health Econ Health Policy* **12**(1): 51–8. doi: 10.1007/s40258-013-0077-2
Wallis MC, McGrail M, Webster J et al (2014) Risk factors for peripheral intravenous catheter failure: a multivariate analysis of data from a randomized controlled trial. *Infect Control Hosp Epidemiol* **35**(1): 63–8. doi: 10.1086/674398
Warrington WG, Aragon Penoyer D, Kamps TA, Van Hoeck EH (2012) Outcomes of using a modified seldinger technique for long term intravenous therapy in hospitalized patients with difficult venous access. *Journal of the Association for Vascular Access* **17**(1): 24–30. doi: 10.2309/java.17-1-3
Woller SC, Stevens SM, Evans RS (2015) The Michigan Appropriateness Guide for Intravenous Catheters (MAGIC) initiative: A summary and review of peripherally inserted central catheter and venous catheter appropriate use. *J Hosp Med*. doi: 10.1002/jhm.2525