Annals of Internal Medicine SUPPLEMENT

The Michigan Appropriateness Guide for Intravenous Catheters (MAGIC): Results From a Multispecialty Panel Using the RAND/UCLA Appropriateness Method

Vineet Chopra, MD, MSc; Scott A. Flanders, MD; Sanjay Saint, MD, MPH; Scott C. Woller, MD; Naomi P. O'Grady, MD; Nasia Safdar, MD, PhD; Scott O. Trerotola, MD; Rajiv Saran, MD, PhD; Nancy Moureau, BSN, RN; Stephen Wiseman, PharmD; Mauro Pittiruti, MD; Elie A. Akl, MD, MPH, PhD; Agnes Y. Lee, MD, MSc; Anthony Courey, MD; Lakshmi Swaminathan, MD; Jack LeDonne, MD; Carol Becker, MHSA; Sarah L. Krein, PhD, RN; and Steven J. Bernstein, MD, MPH

Use of peripherally inserted central catheters (PICCs) has grown substantially in recent years. Increasing use has led to the realization that PICCs are associated with important complications, including thrombosis and infection. Moreover, some PICCs may not be placed for clinically valid reasons. Defining appropriate indications for insertion, maintenance, and care of PICCs is thus important for patient safety.

An international panel was convened that applied the RAND/UCLA Appropriateness Method to develop criteria for use of PICCs. After systematic reviews of the literature, scenarios related to PICC use, care, and maintenance were developed according to patient population (for example, general hospitalized, critically ill, cancer, kidney disease), indication for insertion (infusion of peripherally compatible infusates vs. vesicants), and duration of use (≤5 days, 6 to 14 days, 15 to 30 days, or ≥31 days). Within each scenario, appropriateness of PICC use was compared with that of other venous access devices.

After review of 665 scenarios, 253 (38%) were rated as appropriate, 124 (19%) as neutral/uncertain, and 288 (43%) as inappropriate. For peripherally compatible infusions, PICC use was rated as inappropriate when the proposed duration of use was 5 or fewer days. Midline catheters and ultrasonography-guided peripheral intravenous catheters were preferred to PICCs for use between 6 and 14 days. In critically ill patients, nontunneled central venous catheters were preferred over PICCs when 14 or fewer days of use were likely. In patients with cancer, PICCs were rated as appropriate for irritant or vesicant infusion, regardless of duration.

The panel of experts used a validated method to develop appropriate indications for PICC use across patient populations. These criteria can be used to improve care, inform quality improvement efforts, and advance the safety of medical patients.

Ann Intern Med. 2015;163:S1-S39. doi:10.7326/M15-0744 **www.annals.org**
For author affiliations, see end of text.

Reliable venous access is a cornerstone of safe and effective care of hospitalized patients. Spurred by technological advances, several venous access devices (VADs) for use during and beyond hospitalization are available to meet this need. In recent years, peripherally inserted central catheters (PICCs) have become popular for venous access in hospital settings (1, 2). Compared with traditional central venous catheters (CVCs), PICCs offer several advantages, including safer insertion in the arm, cost-effective and convenient placement via vascular access nursing teams, and self-care compatibility that facilitates use beyond hospitalization (3–5). It is therefore not surprising that use of PICCs has grown considerably worldwide (6–8).

Despite these advantages, PICCs are central venous catheters that may lead to important complications (9). For instance, problems such as luminal occlusion, malpositioning, and dislodgement occur frequently with these devices (10–12). Similarly, superficial thrombophlebitis or infection at the site of PICC insertion may occur despite uneventful and optimal placement (13, 14). In addition, PICCs are associated with morbid complications, including venous thromboembolism and central line–associated bloodstream infection (15–17). Ensuring appropriate use of PICCs is thus vital to preventing these costly and potentially fatal adverse events.

A growing number of studies suggest substantial variation and potentially inappropriate use of PICCs in hospitalized patients. For example, in a study from a large academic medical center, many PICCs were not actively used or were inserted in patients who also had peripheral intravenous catheters (18). In a decade-long study conducted in a tertiary hospital, changes in patterns of PICC use, including shorter dwell times and ambiguous indications for insertion, were reported (19). Additional cause for concern comes from a recent study, which found that 1 in 5 inpatient providers did not know that their patients had CVCs, with lack of awareness being greatest for PICCs (20). Surveys of inpatient providers have also demonstrated knowledge gaps related to appropriate indications and care practices for PICCs (21, 22). Collectively, these data have not only led to reviews of PICC use in hospitals (23) but also to calls by the Choosing Wisely initiative to improve PICC practices across the United States (24, 25).

The concepts of inappropriate overuse and underuse of medical devices are by no means unique to PICCs. Rather, such issues accompany the diffusion of many novel health technologies. In many such instances, a key barrier to achieving appropriate use is

See also:

Web-Only
Supplement
CME quiz
MOC activity

the fact that evidence at a level of detail needed to apply to the range of patients seen in everyday practice is not available. Nevertheless, clinicians must make choices regarding such innovations on a daily basis, potentially fueling inconsistent practice. In the absence of high-quality evidence, an approach that combines available data with the experience and insight of clinical experts is valuable as it would provide guidance where none is otherwise available.

Given this background, we organized and conducted a multidisciplinary meeting of national and international experts to develop appropriateness criteria for use, care, and management of PICCs and related VADs in hospitalized patients. Our objectives were to 1) develop a list of appropriate indications for use of PICCs in relation to other VADs, 2) define the appropriateness of practices associated with the insertion and care of PICCs, 3) determine appropriate practices for treatment and prevention of PICC complications, and 4) rate the appropriateness of peripheral intravenous catheter use in situations that prompt PICC placement.

METHODS

Overview of the RAND/UCLA Appropriateness Method

We used the RAND Corporation/University of California Los Angeles (RAND/UCLA) Appropriateness Method to create criteria for appropriate use of PICCs and related VADs (10). Introduced in the 1980s, the RAND/UCLA method was developed to enable measurement of overuse of medical and surgical procedures. According to this methodology, a procedure is considered appropriate when the "expected health benefits (e.g., increased life expectancy, relief of pain, reduction of anxiety or pain) exceed the expected negative consequences (e.g., mortality, morbidity, anxiety, pain) by a sufficiently wide margin such that the procedure is worth doing, exclusive of cost." The approach has thus been applied to an array of procedures, including coronary angiography (26), surgical procedures (27, 28), cataract removal (29), and transplant organ allocation (30). Recently, the method was also used to develop criteria for appropriate use of urinary catheters in hospitalized patients (31).

The RAND/UCLA method was particularly valuable for developing PICC appropriateness criteria for several reasons. First, the approach allowed the synthesis of the best available evidence with practice-based, domain-specific insights from experts. This unique combination ensured both clinical relevance and evidentiary support for the developed recommendations. Second, unlike other group-rating methods, the focus of the RAND/UCLA approach is not to ensure consensus, but minimize artifactual disagreement that may arise from misunderstanding of scenarios being rated. This nuance is highly relevant in the case of PICCs, because available evidence is derived from heterogeneous study designs (for example, retrospective, case–control studies and randomized trials), populations (for example, critically ill, cancer), and clinical specialties (nursing, radiology, medical or surgical disciplines) and is thus prone to misinterpretation. Because the RAND/UCLA method pairs clear instructions and precise clinical definitions with a systematic, reliable, and reproducible rating system (27), the recommendations generated will have high internal validity. Finally, should clinical scenarios lack sufficient detail to make an informed judgment regarding appropriateness, the RAND/UCLA method encourages clarification by panelists so as to make ratings more relevant and precise. In this fashion, generalizability and external validity of the developed appropriateness indications are also ensured.

Proper conduct of the RAND/UCLA Appropriateness Method requires the sequential performance of several steps, including information synthesis, panelist selection, creation of scenarios, rating process, and analysis of results.

Information Synthesis

The first step of the RAND/UCLA Appropriateness Method is to systematically review and synthesize the available literature. With the assistance of 2 research librarians, we searched for English-language articles (between 12 November 2012 and 1 July 2013) by using the following databases: MEDLINE via Ovid (1950 to present), EMBASE (1946 to present), BIOSIS (1926 to present), and the Cochrane Central Register of Controlled Trials via Ovid (1960 to present). The search strategy incorporated Boolean logic, controlled vocabularies (for example, Medical Subject Heading terms) and free-text words. Because the panel was focused on determining the appropriateness of PICC use in hospitalized adults, articles that included only pediatric patients or devices not comparable with PICCs (for example, arterial or hemodialysis catheters) were excluded.

We also included relevant guidelines, such as the Infusion Nursing Society Standards of Practice (32), Centers for Disease Control and Prevention/Healthcare Infection Control Practices Advisory Committee central line–associated bloodstream infection prevention guidelines (33), American Society of Anesthesiology Task Force on Central Venous Access (34), American College of Chest Physicians Antithrombotic Therapy and Prevention of Thrombosis Guidelines (35), and International Clinical Practice Guidelines for the Treatment and Prophylaxis of Thrombosis Associated With Central Venous Catheters in Patients With Cancer (36).

All retrieved articles were independently scanned for eligibility by 2 of the authors. Disagreements on eligibility were resolved by consensus, and a final list of eligible studies and tables summarizing the evidence were created. The search strategy is provided in Appendix Table 1 (available at www.annals.org), and Table 1 (on page S25) summarizes the included articles.

Participant and Panelist Selection

Viewpoints related to PICC use are known to vary across specialties; thus, what may be appropriate in one field may not be appropriate in another. To foster discussions about these issues, specialists representing vascular access nursing, hospital-based medicine, inter-

nal medicine, infectious disease, critical care, nephrology, hematology/oncology, pharmacy, surgery, and interventional radiology were considered necessary to ensure representativeness of the panel. Leading national and international experts from each of these professions who are eminent scholars or researchers, represent relevant medical societies, or have substantial clinical experience in the field were invited to participate.

To ensure that deliberations took into account patient-centered viewpoints, we also invited a patient to participate on our panel. We recognized that the ideal patient had to be able to speak about experiences with PICCs and related VADs. We recruited such a patient from our university practice in Ann Arbor, Michigan. Owing to the scientific nature of the material, however, the patient panelist did not rate scenarios and instead contributed to panelist discussions. Through this process, 15 multispecialty panelists were recruited to develop the Michigan Appropriateness Guide for Intravenous Catheters (MAGIC) (**Appendix Table 2**, available at www.annals.org).

Creation of Scenarios

On the basis of articles found through the systematic literature searches, we created clinical scenarios to rate the appropriateness of insertion, maintenance, and care of PICCs. To accurately reflect clinical decision making, devices, including peripheral intravenous catheters, ultrasonography-guided peripheral intravenous catheters, midline catheters, nontunneled CVCs, tunneled CVCs, and ports, were compared with PICCs (**Figure 1**). Scenarios were crafted so as to allow judgment of real-world use of PICCs; thus, areas of consensus, controversy, and ambiguity were purposefully included. To further ensure validity, we asked each expert to provide a list of concerns related to PICC use that were most relevant to their practice (**Appendix Table 3**, available at www.annals.org). If not already represented, these issues were also incorporated into scenarios of appropriateness.

We developed a conceptual framework to ensure that scientific content, clinical indications, relevant VADs, and contextual factors were adequately represented when drafting scenarios (**Figure 2**). Thus, indications for PICC insertion were systematically categorized into 1) duration of venous access (≤5 days, 6 to 14 days, 15 to 30 days, ≥31 days); 2) type of infusate (for example, irritants or vesicants, including parenteral nutrition and chemotherapy); and 3) use for specific reasons, such as frequent obtaining of blood samples, poor or difficult venous access, and continuation of intravenous therapies in the outpatient setting. For each of these instances, clinical scenarios incorporating 1) patient-specific factors (for example, critical illness, cancer diagnosis, stage of chronic kidney disease [CKD]), 2) device-specific factors (number of lumens, gauge, type of PICC, alternative VADs), and 3) provider-specific factors (the operator inserting the PICC, technique for PICC insertion) were created. In addition, scenarios regarding appropriate practices for care, management, and treatment of PICC complications were written. Finally, because lack of peripheral access often prompts PICC use for specific clinical needs (for example, need for contrast-based studies or blood transfusion), scenarios related to use of peripheral intravenous catheter in such settings were created.

We pilot-tested all scenarios with 2 hospital-medicine physicians and further edited them for content and clarity on the basis of their feedback. In this manner, 665 scenarios and 391 unique indications for PICCs and related VADs were developed.

Rating Process

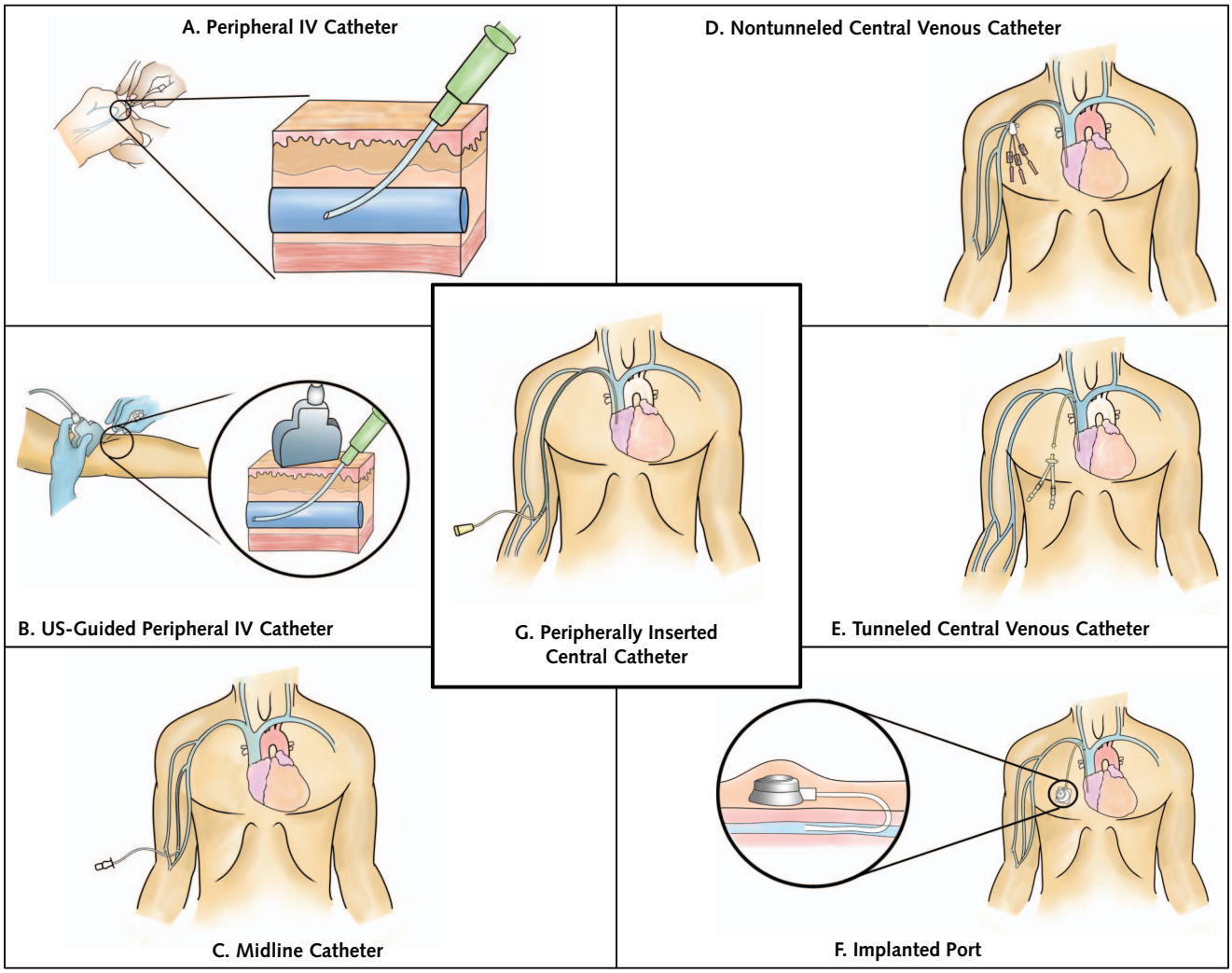
Rating of scenarios and indications were conducted over 2 rounds. In round 1, each panelist received the literature review, definitions of all terms used, a rating document, and instructions for rating. Panelists were asked to dedicate at least 4 hours to complete the rating document. In accordance with the RAND/UCLA method, panelists were instructed not to consider cost when making judgments; rather, they were asked to use the available scientific evidence and best clinical judgment in rating appropriateness (**Supplement**, available at www.annals.org). To ensure that appropriateness was rated exclusive of confounding circumstances (such as specialist availability), panelists were also instructed to assume availability of all resources related to the scenarios.

For each indication, panel members rated appropriateness by considering the benefit–harm ratio on a scale of 1 to 9, where 1 indicated that harms outweigh benefit and 9 signified that benefits outweigh harm; **Appendix Table 4** (available at www.annals.org) provides examples of this process. A middle rating of 5 signified that harms or benefits were equal, or that the rater could not make an informed judgment on the indication. For a series of indications where 2 devices were appropriate, we asked panelists to rate preference for use of one device compared with the other, regardless of cost. Median ratings on opposite ends of the scale (for example, 1 to 3 or 7 to 9) were used to indicate preference of one device over another; a rating in the range of 4 to 6 suggested no preference.

Each panelist rated every scenario twice in a 2-round, modified Delphi process. In the first round, ratings were made individually and no interaction between panelists occurred. In the second round, panel members traveled to Ann Arbor, Michigan, for an in-person meeting where individualized documents showing their ratings along with the distribution of all first-round ratings of the panel were provided.

Over 2 days, a RAND/UCLA methodology expert and a scientific content expert moderated a panel discussion of all indications and scenarios. The sessions were structured to encourage debate and discussion specifically about ratings where disagreement (opposite ratings) or neutrality/uncertainty (ratings of 4 to 6) occurred in round 1. For instance, it often became apparent in the second round that panelists had disagreed not on the indication, but on the patient or circumstances being considered because of inherent assumptions, specialty-specific views, or ambiguity in

Figure 1. Vascular access devices reviewed to formulate appropriateness ratings.



IV = intravenous; US = ultrasonography. **A.** Peripheral IV catheter. These devices are typically 3 to 6 cm, enter and terminate in the peripheral veins (*cross-section*), and are often placed in the upper extremity in veins of the hand. **B.** US-guided peripheral IV catheter. Ultrasonography may be used to facilitate placement of peripheral intravenous catheters in arm veins that are difficult to palpate or visualize. "Long" peripheral IV catheters (typically ≥8 cm) that are specifically designed to reach deeper veins are also available for insertion under US guidance. **C.** Midline catheter. These devices are 7.5 to 25 cm in length and are typically inserted in veins above the antecubital fossa. The catheter tip resides in the basilic or cephalic vein, terminating just short of the subclavian vein. These devices cannot accommodate irritant or vesicant infusions. **D.** Nontunneled central venous catheter. Also referred to as "acute" or "short-term" central venous catheters, these are often inserted for durations of 7 to 14 d. They are typically 15 to 25 cm and are placed via direct puncture and cannulation of the internal jugular, subclavian, or femoral veins. **E.** Tunneled central venous catheter. These differ from nontunneled catheters in that the insertion site on the skin and site of ultimate venipuncture are physically separated, often by several centimeters, reducing the risk for bacterial entry into the bloodstream and facilitating optimal location of the catheter for care of the exit site. Tunneled devices may be cuffed or noncuffed; the former devices have a polyethylene or silicone flange that anchors the catheter within the subcutaneous tissue and limits entry of bacteria along the extraluminal surface of the device. **F.** Implanted port. Ports are implanted in the subcutaneous tissue of the chest and feature a reservoir for injection or aspiration (*inset*) and a catheter that communicates from the reservoir to a deep vein of the chest, thus providing central venous access. Ports are cosmetically more desirable than other types of central venous catheter and can remain in place for months or years. **G.** Peripherally inserted central catheter. These long vascular access devices (>45 cm) are inserted into peripheral veins of the upper arm in adults and advanced so that the tip of the catheter resides in the lower portion of the superior vena cava or upper portion of the right atrium. They are similar to central venous catheters in that they provide access to the central circulation, but they do so without the insertion risks associated with direct puncture of deep veins in the neck, chest, or groin.

the scenario itself. When this occurred, the scenario was rewritten with input from the entire panel such that clarifying language or necessary specification was included.

For example, ratings for PICC insertion in patients with CKD were found to be widely disparate in round 1. During round 2, our panel nephrologist clarified that placement of PICCs in patients with stage 3b or greater CKD was specifically contraindicated. Therefore, for indications that included CKD, 2 sets of scenarios were created (stage 3a or lower vs. stage 3b or higher), using Xs and Os on the rating form to distinguish these ratings. Panelists then rerated each of the scenarios, improving validity and agreement of their responses.

Data Processing and Analysis

First-round ratings were submitted either electronically via an online survey system or through paper forms. Data obtained from paper ratings were manually entered into a study database (Qualtrics Research Suite Package, Qualtrics USA) and checked in duplicate for transcription errors. Descriptive statistics (mean, median, mode) were calculated for all variables. A summary result document was created that listed the frequency of responses, median responses, and each individual panelist's response for every scenario. In accordance with the RAND/UCLA method, all indications were classified into 3 levels of appropriateness:

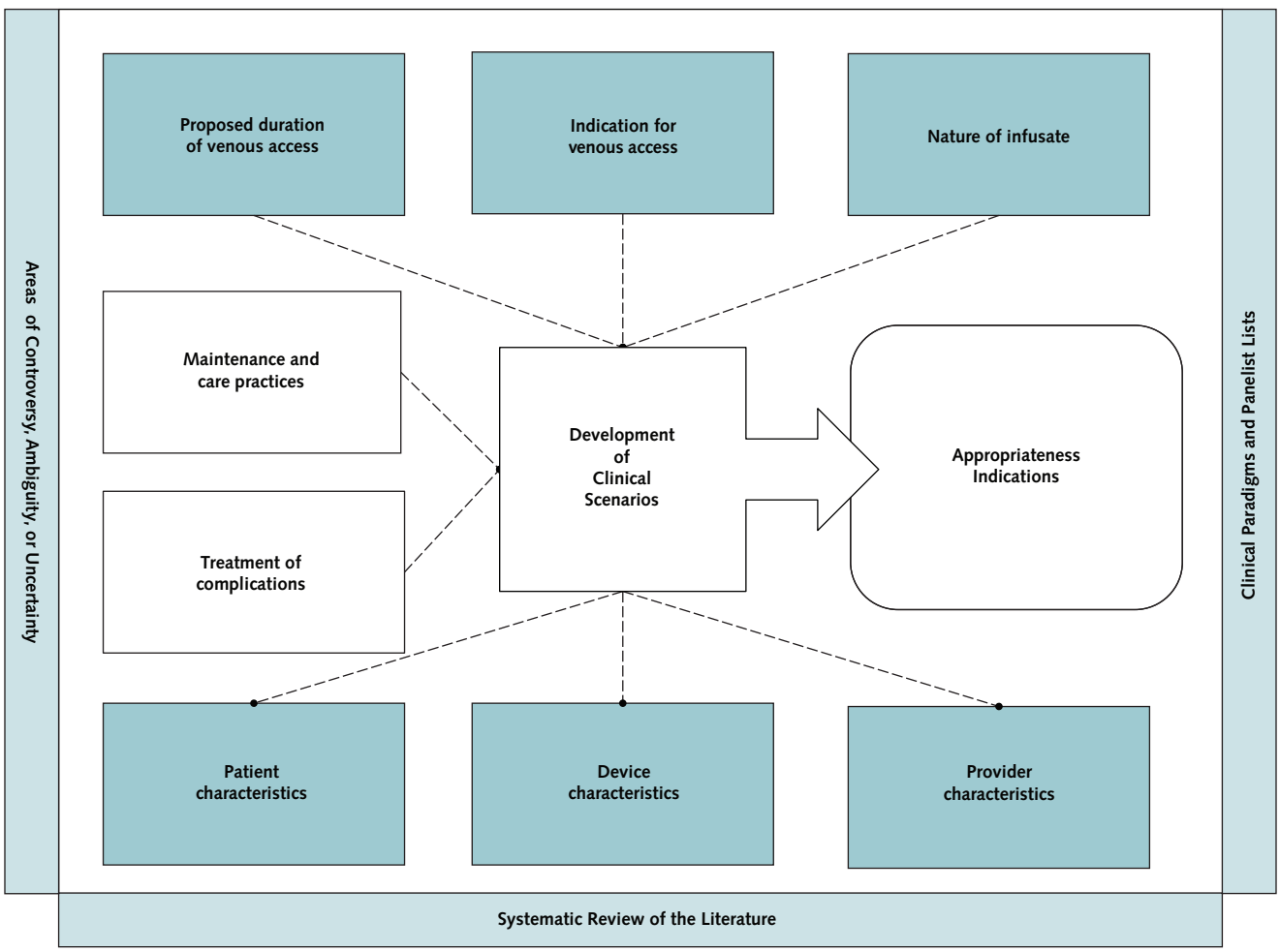
1. Appropriate: panel median score of 7 to 9, without disagreement;
2. Uncertain/neutral: panel median score of 4 to 6, or with disagreement regardless of median; and
3. Inappropriate: panel median score of 1 to 3, without disagreement.

Disagreement was said to have occurred when at least 5 of the 15 panel members rated an indication as appropriate (median score, 7 to 9) and at least 5 panelists rated the same indication as inappropriate (median score, 1 to 3). Only indications without disagreement were classified as inappropriate or appropriate.

Definitions

To ensure consistency, standardized definitions of devices (for example, PICC, midline), populations (active cancer, "special" populations), indications (for example, frequent obtaining of blood samples, hemodynamic monitoring), and infusates (irritant, vesicant) were provided to panelists. A complete glossary of terms and definitions used is provided in the ratings document in the **Supplement** (available at www.annals.org).

Figure 2. Conceptual framework used for the development of scenarios and indications of appropriateness.



To develop a conceptual framework, systematic reviews of the literature were conducted to determine the evidence base. With input from panelists, areas of controversy and ambiguity were identified and contextualized within clinical paradigms and lists of common problems associated with peripherally inserted central catheters. By methodologically pairing selection of venous access device with indication, duration, and nature of venous access and specific patient, device, and provider variables (*center boxes*), scenarios for panelists were created. These scenarios formed the basis for the appropriateness indications.

Role of the Funding Source

This project was supported by a Young Researcher Award from the Society of Hospital Medicine to Dr. Chopra. Funds were used to support panelist lodging, meals, transportation, and venue. Blue Cross Blue Shield of Michigan provided salary support for 3 of the authors through a grant to the University of Michigan. Neither funder had a role in the design, conduct, or analysis of the project or the decision to submit the manuscript for publication.

RESULTS

Within the 665 scenarios reviewed, panel members rated 391 unique indications for PICCs and related VADs. During the first round, the panel rated 237 scenarios as appropriate (36%), 267 as inappropriate (40%), and 161 as neutral/uncertain (24%). After the second round of in-person interactions, 253 scenarios were rated as appropriate (38%), 288 as inappropriate (43%), and 124 as neutral/uncertain (19%). Thus, during the second round of discussions, better distinction of neutral/uncertain indications as being appropriate or inappropriate indications occurred. A substantial proportion of this convergence in ratings reflected resolution of disagreement (30 of 37 scenarios) from round 1 to round 2.

1. Appropriateness of PICC Insertion in Specific Populations

A. Appropriateness of PICC Insertion in Hospitalized Medical Patients

In hospitalized medical patients, panelists rated insertion of PICCs for infusion of peripherally compatible infusates as inappropriate if the expected duration of use was 5 or fewer days. In such scenarios, use of peripheral intravenous catheters or ultrasonography-guided peripheral intravenous catheters was rated as appropriate.

If the proposed duration of infusion was 6 to 14 days, panelists rated PICC use as appropriate but indicated a preference for midline catheters and ultrasonography-guided peripheral intravenous catheters over PICCs for this period. This rating reflected evidence from observational studies that suggested both efficacy and lower risk for complications associated with these devices compared with PICCs for this interval (37–41).

When the proposed duration of infusion was 15 or more days, PICCs were preferred to midline catheters, given the possibility of failure of the latter beyond this period (42, 43). However, panelists recognized that midline catheters may be used for up to 4 weeks and are approved for such duration of use (32).

Use of tunneled catheters and implanted ports were rated appropriate only if the proposed duration of infusion was 31 or more days. Panelists noted that these more invasive devices should be reserved for instances when use of PICCs is not feasible (for example, no suitable vein or site of insertion for PICC is identified), is relatively contraindicated (for example, recent history of thrombosis), or when episodic infusions over several months are necessary (Figure 3).

For infusion of irritants or vesicants, such as parenteral nutrition or chemotherapy, PICC use was rated as appropriate at any proposed duration of use. Because peripheral intravenous catheters, ultrasonography-guided peripheral intravenous catheters, and midline catheters would not provide central venous access, these VADs were rated as inappropriate for this indication for all durations of use.

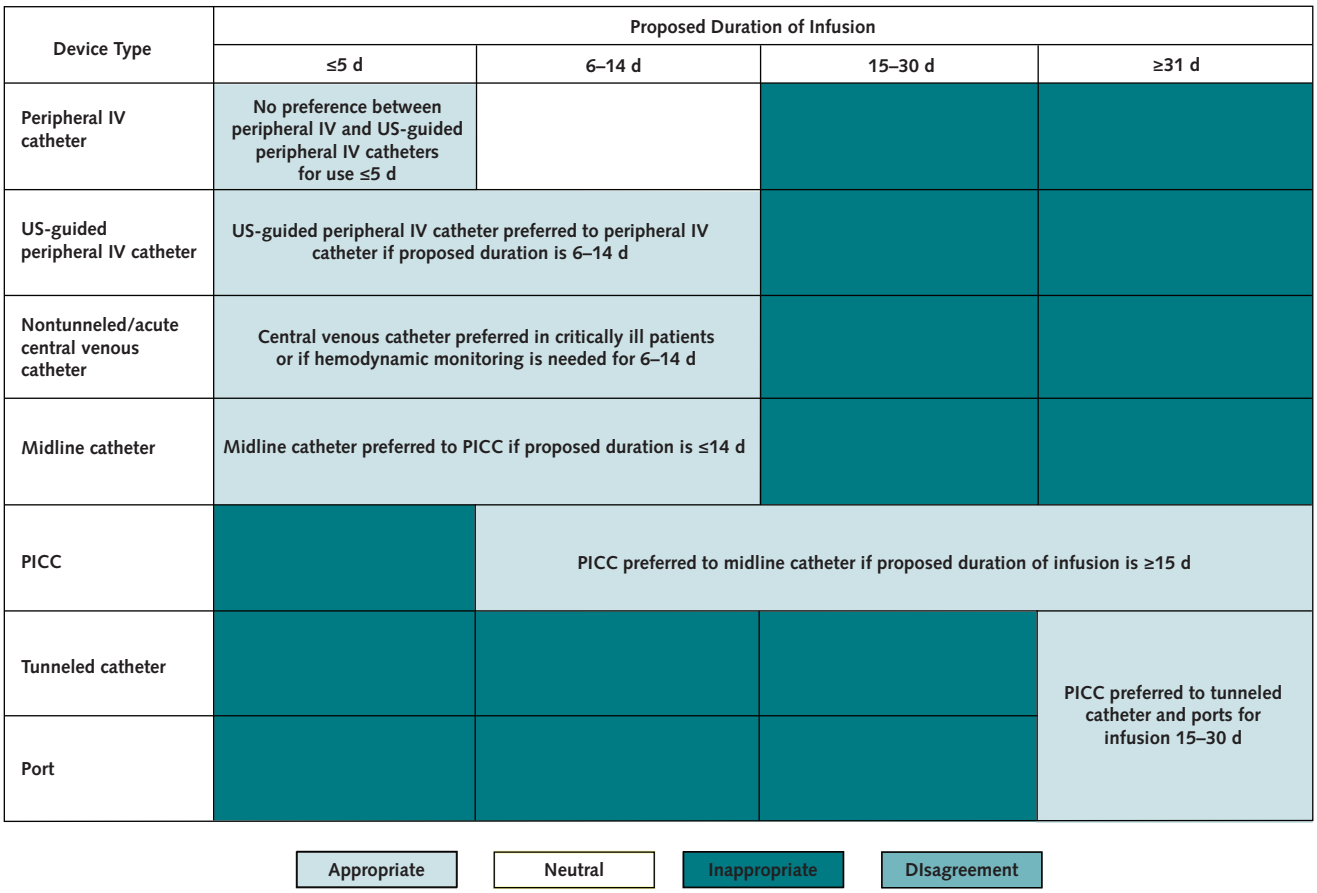
If skilled operators are available, panelists rated use of nontunneled CVCs as appropriate when the expected duration of use was 14 or fewer days. Panelists also rated use of tunneled, cuffed catheters and implanted ports as appropriate for infusion of irritants or vesicants, but only when the proposed duration of therapy was 15 or more days or 31 or more days, respectively (Figure 4).

Panelists disagreed on the appropriateness of PICC placement when the indication was frequent obtaining of blood samples (≥3 phlebotomies per day) or difficult or poor peripheral venous access for proposed durations of 5 or fewer days. Our patient panel member actively participated in this discussion, suggesting that such decisions should be individualized between the patient and provider after discussing risks and benefits related to PICC use and alternative options. Insertion of PICCs was rated as appropriate when the proposed duration of use for frequent phlebotomy or difficult venous access was 6 or more days. In patients with difficult venous access, ultrasonography-guided peripheral intravenous catheters and midline catheters were preferred over PICCs when the expected duration of use was 14 or fewer days. Panelists rated use of CVCs for both difficult venous access and frequent phlebotomy as appropriate, provided the proposed duration of use was 14 or fewer days. Placement of tunneled catheters for patients with difficult venous access was rated as appropriate only if the proposed duration of use was 31 or more days. Ports were rated as inappropriate for frequent obtaining of blood samples at all durations and appropriate for difficult venous access if use for 31 or more days was expected (Figures 5 and 6).

B. Appropriateness of PICCs in Patients With CKD, Cancer, or Critical Illness

Panelists rated the appropriateness of PICC placement in patients with CKD according to disease stage as defined by the Kidney Disease: Improving Global Outcomes CKD Work Group (44). Among patients with stage 1 to 3a CKD (estimated glomerular filtration rate ≥45 mL/min), rating of indications for PICC use followed those of general medical patients. However, the panel noted that managing such patients on the basis of CKD stage alone might be imperfect because myriad factors, including age, magnitude of albuminuria, race, and blood pressure, influence progression of renal disease (45–49). The panel therefore recommended consultation with a nephrologist before PICC insertion if

Figure 3. Venous access device recommendations for infusion of peripherally compatible infusate.



IV = intravenous; PICC = peripherally inserted central catheter; US = ultrasonography.

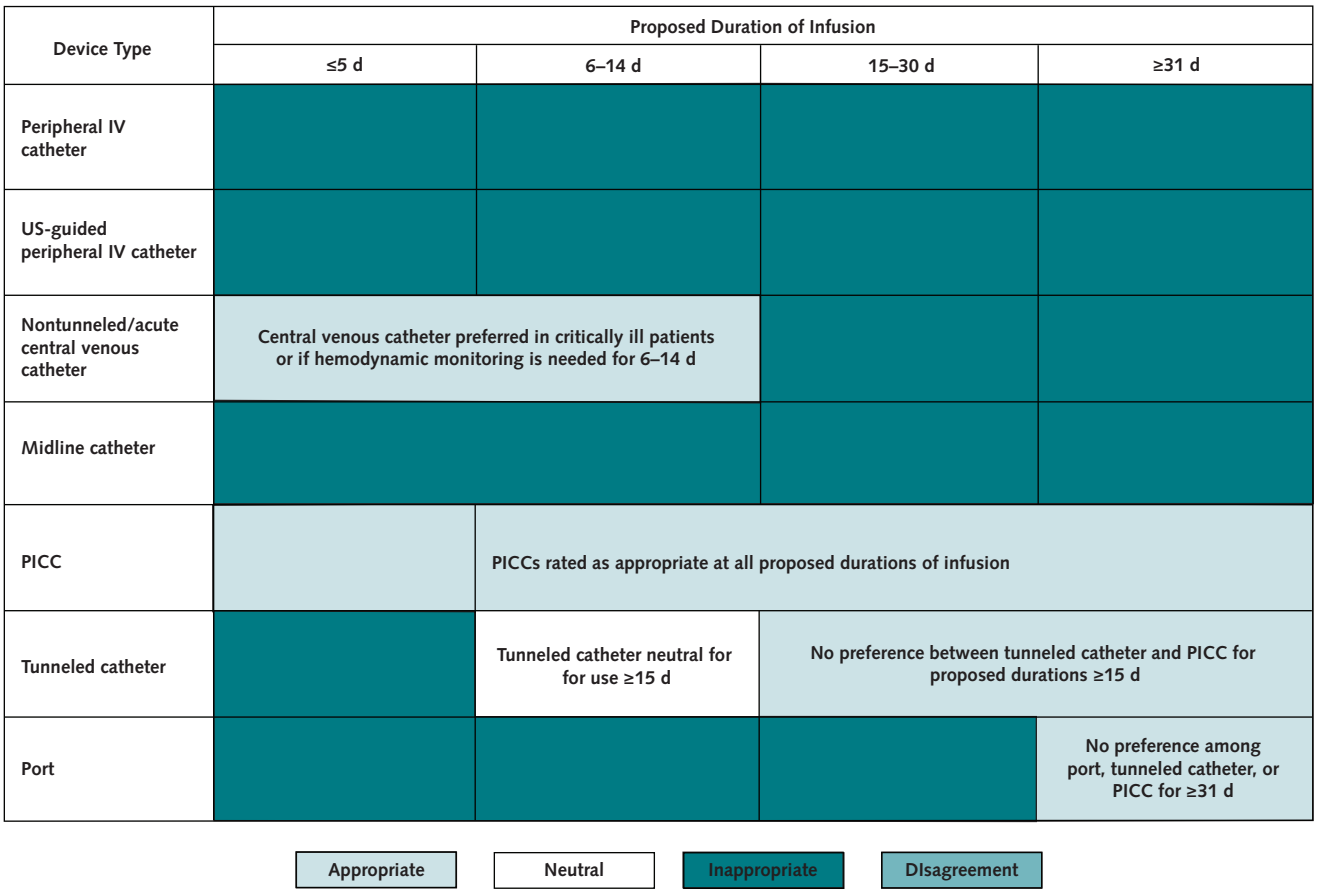
ambiguity regarding the severity of underlying kidney disease exists. However, for patients with stage 3b CKD or greater (estimated glomerular filtration rate <45 mL/min), panelists acknowledged the imperative to preserve peripheral and central veins for possible hemodialysis or creation of arteriovenous fistulae and grafts (49). Thus, regardless of indication, insertion of devices (PICCs, midline catheters) into arm veins was rated as inappropriate in such patients. When venous access for 5 or fewer days was necessary, panelists recommend placement of peripheral IVs in the dorsum of the hand (avoiding the forearm veins) for infusion of peripherally compatible infusates. If venous access for longer durations or infusion of a non–peripherally compatible drug is needed, use of tunneled small-bore central catheters (for example, 4-French single-lumen or 5-French double-lumen catheters inserted in the jugular vein and tunneled toward the chest) was rated as appropriate (50). For patients receiving any form of renal replacement therapy, panelists also recommended consultation with a nephrologist to discuss the possibility of drug administration during or toward the end of the dialysis procedure.

These recommendations notwithstanding, panelists acknowledged that recommendations for patients with stage 3b CKD or greater would need to be individualized, taking into account such factors as the urgency of the situation; rationale for venous preservation; likelihood of eventual renal replacement therapy; and availability of resources, such as tunneled small-bore central catheters.

Given the risks for and consequences of infectious (51, 52) and thrombotic (53–55) complications, as well as the unique indication of chemotherapy, ratings for PICC placement in patients with cancer differed from those for general medical patients. Recognizing the heterogeneity of thrombosis risk in patients with cancer, the panel discussion focused largely on patients with solid tumors. Panelists debated on whether ratings for chemotherapy should be structured by cycles of treatment versus time; given the desire for generalizability, the panel agreed on time as a more practical scale. Therefore, for infusion of nonirritant or nonvesicant chemotherapy, PICCs were rated as appropriate only if the proposed duration of such treatment was 3 or fewer months.

When peripherally administrable chemotherapy for less than 3 months was necessary, panelists disagreed on PICC appropriateness, given the availability of high-

Figure 4. Venous access device recommendations for infusion of non–peripherally compatible infusates.



IV = intravenous; PICC = peripherally inserted central catheter; US = ultrasonography.

quality evidence regarding risk for thrombosis with these devices in patients with cancer (16). However, members of the panel cited conflicting evidence regarding nonthrombotic complications associated with PICC use (15, 56–58). Of note, a study published since the panel meeting (coauthored by one of our panelists) reported a low rate of PICC complications when proper care was ensured (59). Nevertheless, given the divergent data, panelists rated interval placement of peripheral intravenous catheters with each chemotherapy treatment as the most appropriate strategy.

Like PICCs, tunneled, cuffed catheters were rated as appropriate when at least 3 months of treatment were proposed or when PICCs were not feasible (for example, peripheral veins were not available). Ports were rated as appropriate if the duration of treatment was projected to be 6 or more months, but neutral for durations of 3 to 6 months. Panelists noted that earlier use of ports may be appropriate but may be challenging owing to coagulation abnormalities or availability of interventional radiology.

For infusion of irritant or vesicant chemotherapy, panelists rated PICC or tunneled, cuffed catheter use as appropriate at all time intervals; ports were rated as neutral at 3 to 6 months and appropriate at 6 or more months. Panelists recommended tunneled, cuffed catheters over multilumen PICCs in settings where multiple or frequent infusions are required, citing lower risk for complications (60). However, panelists preferred PICCs to tunneled, cuffed catheters when managing patients with coagulopathy and those with severe or prolonged thrombocytopenia (61). When the indication for PICC placement was frequent phlebotomy or difficult peripheral venous access in a hospitalized patient with cancer, panelists raised the threshold for PICC use compared with general medical patients. Thus, PICCs were considered appropriate only if the proposed duration of use was 15 or more days; midline catheters were rated as appropriate for 14 or fewer days of use.

Appropriateness of indications for PICC insertion in critically ill patients also differed from those for general medical patients, given the likely availability of intensivists who could insert CVCs and concerns about hemodynamic stability, infection, and thrombosis. Panelists consequently rated PICC use as inappropriate for infusion of peripherally compatible infusates unless the proposed duration of treatment was 15 or more days. For the same indication, peripheral intravenous catheters and midline catheters were rated as appropriate for proposed durations of 5 or fewer days and 6 to 14

days, respectively. Although limited data supporting the recommendation for midline catheter use in critical care patients were available at the time of the meeting, a recent study reported favorable outcomes and cost savings with this device (62). Central venous catheters were rated as appropriate when the proposed duration of treatment was 6 to 14 days in hemodynamically stable patients; use of CVCs for proposed durations beyond 15 days was rated as uncertain, with panelists expressing concerns about infection and thrombosis.

In hemodynamically unstable patients or scenarios where invasive hemodynamic monitoring or central access was necessary, insertion of CVCs and PICCs was rated as appropriate for durations of 14 or fewer days and 15 or more days, respectively. Panelists preferred CVCs to PICCs in patients who were hemodynamically unstable or were actively receiving vasopressors. In this setting, urgent requests for PICC placement were rated as inappropriate. Given the risk for insertion complications, panelists preferred use of PICCs to CVCs in critically ill patients with coagulopathies (such as disseminated intravascular coagulation or sepsis), especially if use for more than 15 days was proposed.

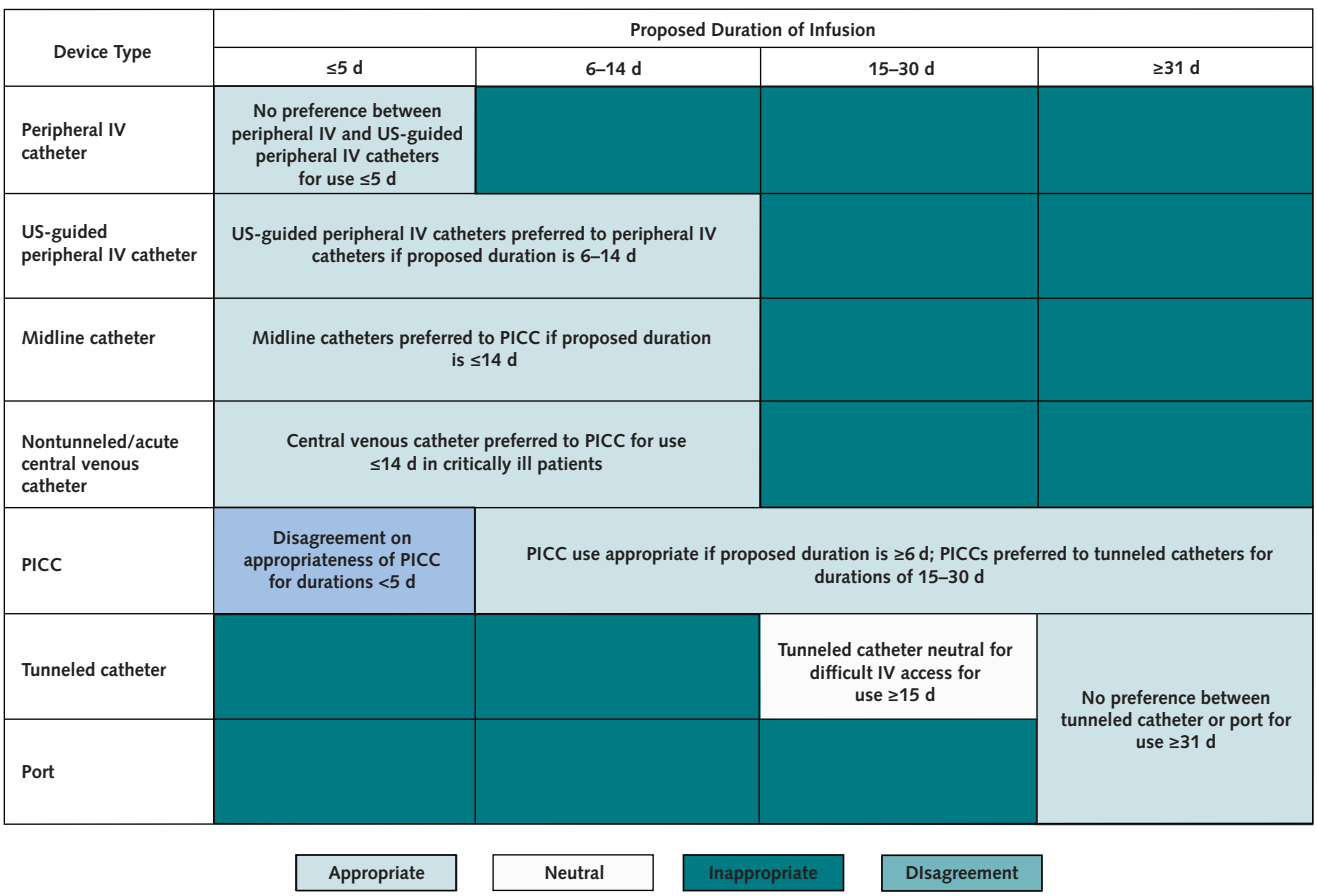
C. Appropriateness of PICC Insertion in Special Populations

Panelists rated the appropriateness of PICCs in populations that need lifelong intravenous access (for example, sickle cell anemia, short-gut syndrome, or cystic fibrosis) and populations residing in skilled nursing facilities.

For populations that may require lifelong access, ratings were structured on the basis of how often patients may be hospitalized within 1 year. For patients who are infrequently hospitalized (≤5 hospitalizations per year), PICC insertion was rated as inappropriate when the expected duration of use was 5 or fewer days. Insertion of a PICC was rated as uncertain when the expected duration of use was between 6 and 14 days. The panel preferred midline catheters to PICCs for this duration, assuming that peripherally compatible infusates were proposed (63). However, PICCs were rated as appropriate when the duration of use was expected to last 15 or more days.

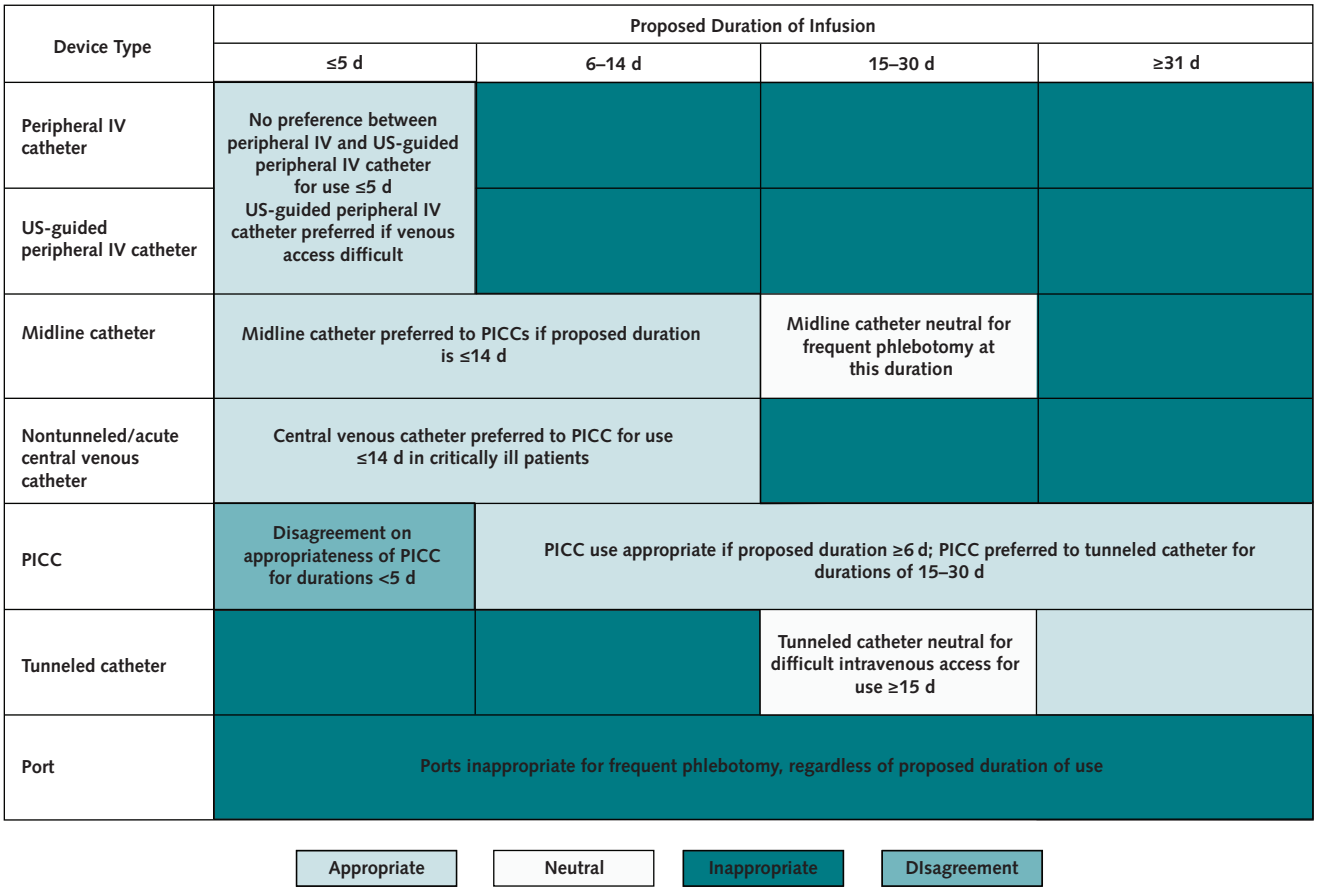
More permanent devices, such as tunneled, cuffed catheters or ports, were not considered appropriate for patients with infrequent hospitalizations, but our patient panelist (reflecting on her experiences) com-

Figure 5. Venous access device recommendations for patients with difficult venous access.



IV = intravenous; PICC = peripherally inserted central catheter; US = ultrasonography.

Figure 6. Venous access device recommendations for patients who require frequent phlebotomy.



IV = intravenous; PICC = peripherally inserted central catheter; US = ultrasonography.

mented that an individualized approach would be necessary in such situations. In contrast, when patients in this category are frequently hospitalized (≥6 hospitalizations per year), panelists rated use of tunneled, cuffed catheters as appropriate when the expected duration of venous access was 15 or more days. Ports were rated as appropriate when the proposed duration of use in frequently hospitalized patients was expected to be 31 or more days. Panelists preferred placement of tunneled, cuffed catheters to PICCs when use for 15 or more days was expected, citing the need to preserve veins to meet future, likely recurrent needs.

For patients residing in skilled nursing facilities, PICCs were rated as appropriate for infusion of nonirritant, nonvesicant treatments or frequent phlebotomy if the proposed duration of use was expected to be more than 15 days. Appropriateness of PICC was rated as uncertain for durations of 6 to 14 days, where panelists rated midline catheters as appropriate. For venous access of 5 or fewer days, peripheral intravenous catheters were rated as being the most appropriate VAD. Given the variable resources in such facilities and challenges in obtaining venous access, the appropriateness of midline catheters was rated neutral for this period. For infusion of irritants or vesicants in this setting, panelists rated PICCs as appropriate regardless of duration of use.

A summary of these ratings is provided in Table 2.

2. Appropriateness of PICC Practices

A. Appropriateness of PICC Insertion Practices

Before PICC insertion for specialty-specific indications, panelists rated consultations with specialists as appropriate (for example, infectious diseases before placement of a PICC for intravenous antibiotic therapy, or hematology–oncology before PICC insertion for chemotherapy). For patients who require prolonged antibiotic infusions (for example, infections, such as osteomyelitis), panelists rated PICC placement within 2 to 3 days of hospital admission as appropriate in the absence of bacteremia. In the presence of bacteremia, PICC placement was rated as uncertain owing to ambiguities regarding pathogen, intensity of bacteremia, and clearance of infection, among other factors. Consultation with infectious diseases specialists was suggested in this setting.

Preferential placement of PICCs by interventional radiology professionals was rated as appropriate when 1) a suitable target vein for insertion cannot be identi-

fied on bedside ultrasonography, 2) the guidewire or catheter fails to advance during bedside placement, or 3) the patient requests sedation that cannot be safely delivered at the bedside. In addition, placement by an interventional radiologist was rated as appropriate for patients with bilateral mastectomy, altered chest anatomy, or superior vena cava filters. For patients with permanent pacemakers or defibrillators, preferential placement by an interventional radiologist rather than a vascular nursing professional was rated as appropriate if the contralateral arm was not amenable to insertion. These ratings were largely driven by expert opinion.

Panelists rated the appropriateness of specific PICC insertion practices on the basis of availability of the contralateral arm for placement. In accordance with Infusion Nursing Society Standards of Practice (32), avoiding insertion over a bruised or corded venous segment, near or over an open wound or burn, and into veins below the elbow was rated as appropriate. Owing to heightened risk for thrombosis, panelists rated avoiding PICC placement in a hemiparetic or immobile arm as appropriate when the opposite limb was available (64). Avoiding PICC insertion in the dominant arm as a strategy to prevent complications was rated as inappropriate, given the lack of convincing data to support this practice. However, our vascular nursing and patient panelists recommended that technical aspects and patient preferences be considered when selecting arm of insertion.

Prior to PICC use, radiographic verification of PICC tip position was rated as appropriate after blind bedside PICC placement or admission to a hospital with an existing PICC. Conversely, panelists rated routine radiographic verification of PICC tip position as inappropriate when PICCs were placed with electrocardiographic guidance, provided that proficiency with this technology had been demonstrated and adequate tracings (such as P-wave deflections) were observed.

To limit the risk for thrombosis, the U.S. Food and Drug Administration and specialty societies recommend that CVCs terminate in the lower one third of the superior vena cava or cavoatrial junction; "higher" (such as the upper one third of the superior vena cava) or "lower" positions (such as the right atrium) were not recommended (32, 65, 66). Acknowledging these concerns, panelists rated adjustment of the PICC when the tip was in the upper or middle one third of the superior vena cava or right ventricle as appropriate.

However, panelists deviated from existing recommendations in rating the right atrium as an appropriate position for the PICC tip and one that does not warrant adjustment. This rating was made after extensive discussions of clinical practice and review of contemporary evidence, which did not suggest that termination of PICCs or CVCs in the right atrium was associated with adverse outcomes in adults (66–71). Panelists recognized that supporting data were observational, and a well-conducted randomized, controlled trial would be helpful in supporting this recommendation.

Table 2. Guide for PICC Use

Appropriate indications for PICC use
Delivery of peripherally compatible infusates when the proposed duration of such use is ≥6 d*
Delivery of non–peripherally compatible infusates (e.g., irritants or vesicants), regardless of proposed duration of use
Delivery of cyclical or episodic chemotherapy that can be administered through a peripheral vein in patients with active cancer, provided that the proposed duration of such treatment is ≥3 mo†
Invasive hemodynamic monitoring or requirement to obtain central venous access in a critically ill patient, provided the proposed duration of such use is ≥15 d‡
Frequent phlebotomy (every 8 h) in a hospitalized patient, provided that the proposed duration of such use is ≥6 d
Intermittent infusions or infrequent phlebotomy in patients with poor/difficult peripheral venous access, provided that the proposed duration of such use is ≥6 d§
For infusions or palliative treatment during end-of-life care‖
Delivery of peripherally compatible infusates for patients residing in skilled nursing facilities or transitioning from hospital to home, provided that the proposed duration of such use is ≥15 d¶
Inappropriate indications for PICC use
Placement for any indication other than infusion of non–peripherally compatible infusates (e.g., irritants or vesicants) when the proposed duration of use is ≤5 d
Placement in a patient with active cancer for cyclical chemotherapy that can be administered through a peripheral vein, when the proposed duration of such treatment is ≤3 mo and peripheral veins are available
Placement in a patient with stage 3b or greater chronic kidney disease (estimated glomerular filtration rate ≤44 mL/min) or in patients currently receiving renal replacement therapy via any modality
Insertion for nonfrequent phlebotomy if the proposed duration of such use is ≤5 d
Patient or family request in a patient who is not actively dying or in hospice, for comfort in obtaining daily blood samples for laboratory analysis
Medical or nursing provider request in the absence of other appropriate criteria for PICC use

PICC = peripherally inserted central catheter.
* Use of ultrasonography-guided peripheral intravenous catheters or midlines is preferred over use of PICCs for infusion of peripherally compatible infusates up to 14 d. In patients with poor peripheral venous access, use of ultrasonography-guided peripheral intravenous catheters and midlines is also preferred over use of PICCs.
† In patients with cancer, the risk for thrombosis associated with PICCs may outweigh benefits. Patients who are scheduled to receive multiple cycles of peripherally compatible chemotherapy for durations <3 mo should do so via peripheral intravenous catheters with each infusion.
‡ Use of nontunneled central venous catheters is preferred over use of PICCs for central venous access or invasive hemodynamic monitoring <14 d and in patients with documented hemodynamic instability where urgent venous access is necessary.
§ Use of ultrasonography-guided peripheral intravenous catheters or midlines is preferred over use of PICCs for patients with poor/difficult peripheral venous access.
‖ Placement of a PICC in a terminally ill patient is appropriate if it facilitates comfort goals of care. PICCs may be left in place in such patients to attain similar goals.
¶ Use of PICCs for home-based infusions or in skilled nursing facilities (where resources are limited) is inappropriate for short-term durations (<14 d). In such settings, use of peripheral intravenous catheters or midlines was rated as appropriate.

The possibility of atrial tachyarrhythmia during or after PICC insertion in this position was also debated (72). As with any CVC, placement of the PICC tip in the right atrium in the setting of an atrial arrhythmia was not recommended. However, in the absence of contraindications, repositioning the PICC tip simply because it resides in the right atrium was rated as inappropriate.

B. Appropriateness of PICC Selection, Care, and Maintenance Practices

Without a documented rationale for a multilumen PICC (for example, multiple incompatible fluids), panelists rated default use of single-lumen devices as an appropriate and potentially important way to reduce PICC complications (73–75). Insertion of multilumen PICCs to separate obtaining blood samples from giving infusions or to ensure a "backup" lumen was available was also rated as inappropriate. To clarify device needs, collaboration with pharmacists or vascular access operators before ordering a PICC was rated as appropriate.

Regarding dressings, panelists rated placement of sterile gauze between the PICC entry site and adhesive dressing for the first 1 to 2 days of insertion as appropriate; thereafter use of clear, transparent dressings that permit site examination and weekly or more frequent changes of wet, loose, or soiled dressings was rated appropriate. Use of cyanoacrylate products ("super glue") to prevent oozing or discharge from the exit site or to secure catheters was rated as neutral by panelists, who noted lack of substantial evidence or experience to support this recommendation (76). In accordance with available guidelines (33), routine use of chlorhexidine dressings without documented adherence to basic infection-prevention efforts or in the absence of high rates of central line–associated bloodstream infection was rated as inappropriate.

Panelists rated use of normal saline rather than heparin to maintain catheter patency and prevent lumen occlusion as appropriate, as reflected in recent recommendations (77, 78). Regardless of how far out the PICC was dislodged, panelists rated advancement of migrated PICCs as inappropriate; in this setting, guidewire exchange of the PICC was rated as appropriate, provided that there are no signs of local or systemic infection. Guidewire exchange was also rated as appropriate when changes to existing PICC characteristics (such as number of lumen or power-injection compatibility) were desired. Should a PICC no longer be functional, exchange over a guidewire was rated as appropriate, provided that an indication warranting continued PICC use was present. Ratings regarding guidewire exchanges were driven largely by expert recommendation.

C. Appropriateness of Management of PICC Complications

In patients with a centrally positioned, otherwise functional PICC that is complicated by image-confirmed PICC-related deep venous thrombosis (DVT), panelists rated PICC removal as appropriate only when 1) the PICC is clinically no longer necessary; 2) the PICC is only being used for phlebotomy, but peripheral veins are available; 3) symptoms of venous occlusion (arm pain, swelling) persist despite therapeutic anticoagulation for 72 or more hours; and 4) bacteremia with objective evidence of line-related infection exists. Panelists rated removal of a functional PICC in the presence of DVT as inappropriate when 1) irritants or vesicant infusions remain necessary; 2) the patient has poor peripheral venous access and requires frequent phlebotomy (and may thus require another PICC); and 3) the patient has minimal improvement in symptoms of venous occlusion, but therapeutic anticoagulation has been provided for 72 or fewer hours. Panelists were neutral regarding PICC removal when 1) a patient could not receive systemic anticoagulation, but the PICC remained clinically necessary and 2) a line-related infection was suspected, but not confirmed. In general, these ratings mirrored existing evidence-based recommendations (35, 53, 79).

When treating PICC-related DVT, panelists rated provision of at least 3 months of anticoagulation at a treatment dose as appropriate. Shorter durations of anticoagulation or removal of the PICC as definitive therapy (in the absence of contraindications to anticoagulation) was rated as inappropriate. When treating with warfarin, panelists recommended targeting anticoagulation to an international normalized ratio of 2 to 3; lower or higher international normalized ratio targets were rated as inappropriate. Use of low-molecular-weight heparin over warfarin was preferred in patients with cancer. Owing to insufficient evidence, preferential use of target-specific oral anticoagulants over traditional agents among patients with cancer was rated as inappropriate. Panelists rated urgent referral to interventional radiology for catheter-directed treatment of PICC-related DVT as appropriate when symptoms of venous occlusion were associated with phlegmasia cerulea dolens (swollen, enlarged, painful, and purplish discoloration of the affected limb).

Panelists rated the appropriateness of placement of a new PICC in patients who experienced PICC-related DVT within the past 30 days. In this scenario, panelists strongly urged against placement of a PICC, given the high risk for recurrent thrombosis. Placement of a PICC was specifically rated as inappropriate if the indication for insertion was 1) frequent phlebotomy when peripheral access was available, or 2) patient request for comfort in non–end-of-life settings. Insertion of a PICC was also considered inappropriate if the patient were to require surgery lasting 1 hour or longer, owing to heightened risk for DVT in this situation (67).

In the setting of PICC-related DVT, appropriateness of PICC insertion for parenteral antibiotics for 10 or more days was rated as uncertain; panelists recommended a midline catheter in this scenario. If a PICC was absolutely necessary in a patient with recent PICC-related DVT, panelists rated use of the smallest catheter gauge and least number of lumens as appropriate (74, 75, 80). Placement in a vein in the contralateral arm following at least 3 months of anticoagulation for the PICC-related DVT was also rated as appropriate in this setting.

Panelists rated the appropriateness of practices related to management of PICC-related bloodstream infections. Regardless of clinical context and in accordance with recommendations (33, 81), panelists rated use of PICCs as a strategy to reduce bloodstream infection as inappropriate. In the setting of bacteremia or

fever, PICC removal in the absence of confirmatory evidence of line-related infection was rated as uncertain. Panelists stated that these approaches would be dictated by such factors as pathogen, intensity of bacteremia, and clinical stability, among others, and consultation with infectious disease would be appropriate.

In patients with confirmed PICC-related bloodstream infection, continued treatment using the affected PICC, guidewire exchange, or placement of a new device in the contralateral arm without documented clearance of infection was rated as inappropriate. After a line-free interval (typically 48 to 72 hours) and negative blood cultures, panelists rated placement of a PICC or other acute CVC as appropriate only if an indication warranting central catheter use was present. Panelists preferred use of peripheral IVs in such patients wherever possible.

D. Appropriateness of PICC Removal

In contradistinction to indwelling urinary catheters (82), panelists rated PICC removal without physician notification as inappropriate. After physician notification, panelists rated PICC removal as appropriate when 1) the PICC has not been used for any clinical purpose for 48 hours or longer; 2) the patient no longer has a clinical indication for a PICC, or the original indication for use has been met (for example, an antibiotic course has been completed); or 3) the PICC is only used for routine obtaining of blood samples in a hemodynamically stable patient and peripheral veins are available. Panelists rated routine removal of a PICC in a hemodynamically stable patient with poor venous access or hemodynamically unstable patients as uncertain. Removal of a PICC by clinicians who have received training to remove CVCs, but not PICCs, was rated as inappropriate (32).

A summary of these ratings is provided in Table 3.

Table 3. Guide for PICC Insertion, Care, and Maintenance Practices

Appropriate PICC practices

- Before ordering a PICC, consult relevant specialists (e.g., infectious diseases, oncology), operators (vascular access professional), and/or hospital pharmacists to determine optimal device choice and characteristics*
- After non-EKG or non–fluoroscopically guided PICC insertion, verify PICC tip position via chest radiography
- Only adjust PICCs that terminate in the upper or middle one third of the superior vena cava or right ventricle
- In the absence of indications for a multilumen PICC, use a single-lumen PICC of the smallest gauge
- Use normal saline rather than heparin to flush PICCs after infusion or phlebotomy
- Exchange PICCs to change device features (e.g., number of lumens) or treat dislodgement over a guidewire
- Provide ≥3 mo of uninterrupted systemic anticoagulation for treatment of PICC-related DVT in the absence of contraindications to such therapy†
- Use the smallest sized catheter and vein on the contralateral arm after ≥3 mo of therapeutic anticoagulation when placing a PICC in a patient with history of PICC-related DVT‡
- Provide a "line-free" interval to ensure clearance of bacteremia when managing PICC-related bloodstream infections

Inappropriate PICC practices

- Urgent requests for PICC placement in a hemodynamically unstable patient in the wards or ICU
- Preferential placement of a PICC on the basis of arm dominance
- Chest radiography verification of the PICC tip after placement via verified EKG guidance or fluoroscopy§
- Adjustment of PICC tips that reside in the lower one third of the superior vena cava, cavoatrial junction, or right atrium
- Advancement of a partially dislodged PICC in the setting of external migration of the catheter of any length
- Removal of PICCs that are clinically necessary, centrally positioned, and otherwise functional in the setting of PICC-related DVT
- Routine removal or replacement of PICCs that are clinically necessary without objective evidence of catheter-associated bloodstream infection in febrile patients
- Removal of a PICC by a health care team member not trained to remove this device

DVT = deep venous thrombosis; EKG = electrocardiography; ICU = intensive care unit; PICC = peripherally inserted central catheter.
* Consultations with nephrologists for patients with stage 1 to 3a chronic kidney disease was rated as neutral owing to challenges related to determining stage of kidney disease in hospitalized patients. In such patients, consultation is recommended especially if hospitalized with acute kidney injury or fluctuating renal function.
† In patients with cancer, use of low-molecular-weight heparin over warfarin for systemic anticoagulation was rated as preferred. Extending the duration of anticoagulation beyond such periods if the PICC remained in place was rated as appropriate.
‡ If the contralateral arm is not available, selection of a vein not involved with the original PICC-DVT in the ipsilateral arm was rated as appropriate.
§ When forgoing chest radiographs for PICC tip position, technical proficiency in the placement of PICCs via EKG guidance is assumed. Additionally, verification of tip-positioning via EKG (adequate P-wave deflection/mapping) is assumed. If concerns regarding positioning exist, obtaining a chest radiograph is appropriate.

3. Appropriateness of Peripheral Intravenous Catheter Use in Specific Scenarios

Because PICC use is often driven by difficult peripheral venous access, we asked panelists to rate appropriateness of peripheral intravenous catheter use in various clinical scenarios that often prompt PICC use. In the absence of other indications for central venous access, panelists rated use of ultrasonography-guided peripheral intravenous catheters as appropriate before insertion of a PICC in general medical, critically ill, and cancer populations with difficult venous access (39, 68). However, use of ultrasonography-guided peripheral intravenous catheters in patients with stage 3b or greater CKD was rated as inappropriate. If a suitable arm vein could not be found, panelists rated placement of a peripheral intravenous catheter catheter in the external jugular vein of the neck as appropriate only if the proposed duration of use was 96 hours or less or in an emergency situation. Panelists rated placement of a peripheral intravenous catheter in the lower extremity as appropriate only in emergencies.

Citing the results of a Cochrane systematic review (83) and a randomized trial (84), panelists rated replacement of peripheral intravenous catheters as appropriate when prompted by clinical signs and symptoms rather than prespecified durations. Panelists noted that such practice might extend availability of peripheral venous access (83), reduce cost (85), and limit use of PICCs, but recognized that these data were limited to 1 randomized trial and low event rates in the literature. When PICC placement was requested for blood transfusions, panelists rated 16-, 18-, and 20-

Table 4. Guide for Peripheral Intravenous Catheter Practices

Appropriate peripheral intravenous catheter practices
Insert a peripheral intravenous catheter in the external jugular vein if the proposed duration of use is ≤4 d or an emergent/life-threatening situation exists
Place a peripheral intravenous catheter in the foot only in the setting of an emergent, life-threatening situation
Use ultrasonographic guidance to place short or long peripheral intravenous catheters in patients with difficult venous access who require treatment for ≤5 d*
Remove peripheral intravenous catheters in the setting of redness, swelling, or phlebitis over the vein of insertion
In hospitalized patients who are likely to require ≥15 d of intravenous antibiotics, transition from a peripheral intravenous catheter to a PICC or midline catheter as soon as possible†
Use a 16-, 18-, or 20-gauge peripheral intravenous catheters in an upper-extremity vein rather than a PICC when venous access is needed for blood transfusion or performance of a contrast-based radiographic study
Inappropriate peripheral intravenous catheter practices
Removal of peripheral intravenous catheters on the basis of a routine schedule or in the absence of redness, swelling, or other signs of inflammation is inappropriate; site rotation should be driven by clinically warranted change‡
Removal of a functioning peripheral intravenous catheter that has been inserted in the field (e.g., ambulance or nonhospital site) in the absence of redness, tenderness, or swelling over the insertion site is inappropriate
Placement of peripheral intravenous catheters on the same side as prior breast surgery, axillary node dissection, or arteriovenous fistulae (regardless of whether the fistula is functional or not) is inappropriate
In the absence of a clinical indication warranting insertion, routine placement of a peripheral intravenous catheter at the time of admission to the hospital is inappropriate
In the absence of a clinical indication warranting continued use, routine replacement of a peripheral intravenous catheter is inappropriate

PICC = peripherally inserted central catheter.
* Use of ultrasonography-guided peripheral intravenous catheters is inappropriate in patients with advanced (stage 3b or greater) chronic kidney disease. In such patients, consultation with a nephrologist and use of a small-bore tunneled central catheter are appropriate.
† Delaying transition from a peripheral intravenous catheter to a PICC before discharge may deplete available venous access sites and is not appropriate when intravenous antibiotic treatment beyond 15 d is clinically necessary.
‡ Routine changes of peripheral intravenous catheters may result in loss of potentially available peripheral veins for infusion or therapy, inadvertently leading to greater use of PICCs in hospitalized patients.

gauge peripheral intravenous catheters as appropriate and preferable to PICC use. For administering intravenous contrast through radiographic injectors, panelists rated use of 16- to 20-gauge peripheral intravenous catheters as appropriate and preferred over PICCs; use of 22-gauge devices or larger was rated as inappropriate.

A summary of these ratings is provided in Table 4.

Discussion

Our 15-member multidisciplinary panel successfully applied the RAND/UCLA Appropriateness Method to generate novel criteria for use, care, and management of PICCs in hospitalized patients. In addition, panelists rated the comparative utility of other VADs in relation to PICCs, providing new insights for decision making in venous access. The implication of this work is substantial, because it provides a potential means to quantify appropriateness, qualify existing use, and improve care of PICCs and related devices in hospitalized patients. Given an international team of experts that represented multiple subspecialties and the inclusion of a patient to formulate panelist ratings, these criteria are well-positioned to broadly improve the quality and safety of venous access in hospitalized adults.

As with many health care innovations, PICCs were introduced to solve an important clinical problem in a defined population (86). However, over time, the use of PICCs has evolved to span diverse indications and patient populations. In hospital settings, accumulating evidence suggests that placement of PICCs may occur for potentially inappropriate reasons (18, 87). Notwithstanding such benefits as convenience, comfort, and economic efficiency (4, 88), PICC insertion may introduce unnecessary risk and potential for preventable harm (15, 16, 73). Despite this fact, no framework to inform use of these devices has been developed to date.

These observations were the motivation underlying this project, which sought to incorporate existing evidence with the knowledge of clinicians and content experts to define criteria for appropriate PICC use. Unlike existing recommendations, our appropriateness criteria represent a departure from the status quo in several ways.

First, they offer clinical granularity for clinicians. For example, existing guidelines recommend "use of midline catheters or PICCs instead of a short peripheral intravenous catheter when the duration of IV [intervenous] therapy will likely exceed six days" (33). Our criteria build on this advice by adding such details as what patient-specific considerations should be incorporated in this decision, which other devices may be appropriate, and when PICC use for shorter durations might be reasonable.

Second, whereas existing recommendations target proceduralists or specialties that most often insert devices, our criteria are the first to provide direction to clinicians, such as internists or hospitalists, who order PICCs. Thus, these criteria fill a critical gap, bringing recommendations to those that drive the decision to place such devices.

Finally, by tackling some of the most controversial topics of venous access—including when to adjust the PICC position, appropriate indications for removal, and indications for reinsertion of PICCs after complications—our criteria advance the science of vascular access in important and innovative ways.

Some aspects of panelist deliberations and ratings merit further discussion. First, patterns of recommendations for PICC appropriateness often hinged on 2 variables: the nature of the infusate and duration of venous access. Thus, non–peripherally compatible infusions or scenarios where venous access was necessary for 6 days or longer often led panelists to rate PICC use as appropriate; conversely, shorter duration of use with peripherally compatible infusions led to a recommendation for use of a peripheral intravenous catheter, ultrasonography-guided catheter, or midline catheter.

Unlike existing standards, however, variation in risk for complications according to patient population influenced this pattern. This is well-illustrated in ratings for critically ill patients and those with cancer, where a theme of limiting PICCs to durations of use of 15 days or longer is evident.

Second, throughout deliberations, panelists noted that it is often challenging for clinicians to estimate an expected duration of venous access. Relatedly, a "maximal" window within which PICCs may be safely used is not known and depends on myriad factors, including adequacy of care and differential risk for complications. Finally, panelists acknowledged that separation of indications for PICC placement into individual categories and defining VADs by finite duration was artificial, because venous access is rarely driven by a single clinical purpose or limited by duration.

On balance, panelists rationalized that clinicians often do not reflect carefully enough on the nature of venous access or weigh its inherent risks and benefits. Panel members added that in many hospitals, the decision to place a PICC is often dichotomous, with consideration of other devices lacking. Thus, an unforeseen advantage of these criteria is the introduction of a physician-directed "time-out" in vascular access decision making. During this pause, reflection on the appropriate device, patient risk factors, and discussions with specialists could conceivably improve outcomes in hospital settings.

Our approach has several limitations. First, we excluded neonatal and pediatric studies when formulating these recommendations, because considerable differences in PICC use exist between these patients and adults. However, because these populations often receive PICCs, future panels should choose to focus on these subsets.

Second, although our panel was multidisciplinary, we did not include bedside nurses, who often request PICCs in hospitalized settings. However, vascular nurses and hospitalists are attuned to considerations regarding PICC use from this group of providers and were well-represented on our panel.

Third, the applicability of these recommendations will vary on the basis of provider scope of practice, education, and training. As echoed in other standards (89), provider availability, competence, and technical expertise should guide insertion and selection of appropriate VADs.

Finally, our panel was focused on appropriateness of PICCs in relation to other devices. We acknowledge that certain devices may be used for longer durations (for example, midline catheters for up to 28 days) or indications of different durations (for example, intravenous antibiotics for 6 weeks). These limitations were necessary to ensure comparability among various devices and generalizability of these recommendations.

Despite these limitations, our appropriateness criteria represent a major multidisciplinary effort toward improving decision making related to PICCs and related VADs. Avoiding PICC use for inappropriate indications, considering alternative devices, ensuring appropriate consultations, and outlining instances where PICC removal is appropriate are but a few examples of how these recommendations may be implemented to improve practice. In addition, by including a patient whose opinion influenced panel deliberations, we took into account the implications of provider decisions from "the other side of the needle." Finally, the criteria we propose span not just indications for PICC insertion but also best practices for use, care, and maintenance. Thus, we hope that our recommendations will provide clarity for management of complex situations not only before, but also during and after, PICC placement.

Although optimal strategies to implement our criteria remain to be defined, an expansive range of options is possible. For example, routine benchmarking and feedback of metrics, such as PICC dwell time, indications for insertion, and practices related to management of complications, may serve to inform hospital-specific "PICC dashboards" and quality-improvement efforts. Alternatively, more sophisticated paradigms, such as decision aids and computerized physician order-entry taking into account proposed duration of use, indication, and patient characteristics, are also plausible.

Because many of our recommendations are algorithmic, Web sites or smartphone applications to determine the appropriateness of PICCs before insertion seem to be feasible. We are beginning to explore these options through 2 strategic partners. First, through the ongoing Blue Cross Blue Shield/Blue Care Network–funded Hospital Medicine Safety collaborative quality improvement project, we will use our appropriateness criteria to evaluate and improve PICC utilization in 47 Michigan hospitals (90). Because the Hospital Medicine Safety project is composed of diverse hospitals and is built on a robust data platform, we will also seek to understand contextual barriers, facilitators, and unintended consequences related to use of our criteria.

Second, through work recently funded by the Veterans Affairs National Center for Patient Safety and the No Preventable Harms Campaign, we will test ways in which to operationalize our criteria within the highly integrated Veterans Affairs health system. Given the advanced electronic medical record systems in this setting, our experiences will shed new light on implementation strategies that could inform our work within and beyond this setting. Such research may take several forms. For instance, quasi-experimental designs, such as pre–post or interrupted time series that examine the influence of specific appropriateness recommendations (for example, avoid use of PICCs for peripherally compatible infusions lasting 5 days or less) within and between hospitals, could be tested in participating Michigan and Veterans Affairs sites. Alternatively, a "bundle" of best practices related to PICCs, including appropriateness criteria for insertion, care, and management, may be deployed, leveraging a stepwedge or cluster randomized approach to account for secular trends.

More robust research designs, such as randomized clinical trials, that utilize our criteria are also feasible.

For example, randomly assigning patients who require less than 2 weeks of peripherally compatible infusions to receive a midline catheter or PICC is not only feasible but also relevant, because many PICCs are placed to deliver antibiotics for such intervals after hospital discharge. Such a study may be powered to ascertain the noninferiority of midline catheters, rates of therapy completion, or complications with either device. Therefore, several research designs that span one or more hospitals, and one or more of our recommendations, may be used as interventions to target clinical outcomes, overall utilization, adverse events, and costs.

In conclusion, we used the RAND/UCLA Appropriateness Method to define best practices for PICC insertion, care, and management. Although a key first step, these criteria offer but a blueprint of best practices. To make MAGIC truly happen, diffusion, uptake, and refinement from the providers and stakeholders engaged in vascular access is necessary. Through use of a systematic rating process, a multidisciplinary international panel, and patient representation, we hope to achieve this goal. Our patients deserve nothing less.

From University of Michigan Medical School, Patient Safety Enhancement Program of the Veterans Affairs Ann Arbor Healthcare System, and the Institute for Healthcare Policy and Innovation, University of Michigan Ann Arbor, and Oakwood Hospital, Dearborn, Michigan; Intermountain Medical Center, Murray, and the University of Utah School of Medicine, Salt Lake City, Utah; Clinical Center, National Institutes of Health, Bethesda, and Greater Baltimore Medical Center, Baltimore, Maryland; William S. Middleton Memorial Veterans Affairs Hospital and Division of Infectious Diseases, University of Wisconsin Medical School, Madison, Wisconsin; Perelman School of Medicine, University of Pennsylvania, Philadelphia, Pennsylvania; PICC Excellence, Hartwell, Georgia; Catholic University, Rome, Italy; American University of Beirut, Lebanon; and University of British Columbia, Vancouver, British Columbia, Canada.

Portions of this work were presented at the 2015 Annual Society of Hospital Medicine Meeting, Washington, DC, and the 2015 Society for Healthcare Epidemiology of America Meeting, Orlando, Florida.

Acknowledgment: The authors thank Tanya Boldenow, MD, and Aaron Berg, MD, for reviewing early drafts of the appropriateness document; Andy Hickner, MSI, and Marisa Conte, MSI, for assistance with literature searches; and Georgiann Ziegler, their patient panelist, whose views greatly influenced panel discussions.

Disclosures: Dr. Chopra reports grants from the Society of Hospital Medicine and Agency for Healthcare Research and Quality during the conduct of the study. Dr. Flanders reports grants from Blue Cross Blue Shield of Michigan during the conduct of the study and consultancy for the Institute for Healthcare Improvement and the Society of Hospital Medicine; employment by the University of Michigan; one expert review per year as expert testimony; grants or grants pending from the CDC Foundation, Blue Cross Blue Shield of Michigan, Michigan Hospital Association, and Agency for Healthcare Research and Quality; honoraria for various talks at hospitals as a visiting professor; and royalties from Wiley Publishing outside the submitted work. Dr. Saint reports serving on the medical advisory board of Doximity (a social networking site for physicians) and receiving an honorarium for being a member of this medical advisory board, and serving on the scientific advisory board of Jvion (a health care technology company) outside the submitted work. Dr. Woller reports a grant paid by Bristol Myers-Squibb to Intermountain Healthcare, with no financial support to Dr. Woller, outside the submitted work. Dr. Trerotola reports personal fees from University of Michigan during the conduct of the study and grants from Vascular Pathways; personal fees from Bard Peripheral Vascular, B. Braun, Orbimed, Teleflex, Cook, W.L. Gore, and Lutonix outside the submitted work. Dr. Moureau reports PICC Appropriateness Panel reimbursement during the conduct of the study and serving as chief executive officer of PICC Excellence, Inc.; vascular access specialist and team member at Greenville Hospital System, Greenville, South Carolina; and associate adjunct professor and member of Alliance for Vascular Access Device Training and Research (AVATAR), Griffith University, Brisbane, Australia, outside the submitted work. Dr. LeDonne reports personal fees from Teleflex, Ethicon, Bard International, SonoSite, and 3M outside the submitted work. Ms. Becker reports grants from the Society of Hospital Medicine and Blue Cross Blue Shield of Michigan during the conduct of the study. Dr. Bernstein reports grants from Department of Veterans Affairs National Center for Patient Safety and Blue Cross Blue Shield of Michigan during the conduct of the study; in addition, he is a member of the Blue Care Network Clinical Quality Committee, which reviews issues related to quality of care, and although peripherally inserted central venous catheters have not been considered in the past, their use may be reviewed in the future. Dr. Bernstein is also director of quality for the University of Michigan Medical Group; if the appropriateness of peripherally inserted central venous catheter criteria developed as part of this process are widely adopted, they could be applied to the University of Michigan by outside agencies. Authors not named here have disclosed no conflicts of interest. Disclosures can also be viewed at www.acponline.org/authors/icmje/ConflictOfInterestForms.do?msNum=M15-0744.

Grant Support: By a Young Researcher Award from the Society of Hospital Medicine and a career development award (1-K08-HS022835-01) from the Agency for Healthcare Research and Quality to Dr. Chopra and by Blue Cross Blue Shield and Blue Care Network of Michigan, which provided salary support for Drs. Flanders and Bernstein and Ms. Becker through the Michigan Hospital Medicine Safety Consortium.

Requests for Single Reprints: Vineet Chopra, MD, MSc, Institute for Healthcare Policy and Innovation, University of Michigan, North Campus Research Complex, 2800 Plymouth Road, Building 16, Room 432W, Ann Arbor, MI 48109; e-mail vineetc@umich.edu.

Current Author Addresses: Dr. Chopra: Institute for Healthcare Policy and Innovation, University of Michigan, North Campus Research Complex, 2800 Plymouth Road, Building 16, Room 432W, Ann Arbor, MI 48109.

Dr. Flanders: Taubman Medical Center, University of Michigan, 1500 East Medical Center Drive, SPC 5376, Ann Arbor, MI 48109.

Dr. Saint: Institute for Healthcare Policy and Innovation, University of Michigan, North Campus Research Complex, 2800 Plymouth Road, Building 16, Room 432W, Ann Arbor, MI 48109.

Dr. Woller: Intermountain Medical Center, PO Box 57700, 5169 South Cottonwood Street, Suite 307, Murray, UT 84107.

Dr. O'Grady: Critical Care Medicine Department, Clinical Center, National Institutes of Health, 10 Center Drive, Building 10, Room 2C145, Bethesda, MD 20892.

Dr. Safdar: University of Wisconsin Medical School, MFCB 5221, 1685 Highland Avenue, Madison WI 53705.

Dr. Trerotola: Department of Radiology, University of Pennsylvania Medical Center, 1 Silverstein, 3400 Spruce Street, Philadelphia, PA 19104.

Dr. Saran: Division of Nephrology, Department of Internal Medicine, University of Michigan Medical School, 1415 Washington Heights, SPH I, Suite 3645, Ann Arbor, MI 48109-2029.

Ms. Moureau: PICC Excellence, Inc., 1905 Whippoorwill Trail, Hartwell, GA 30643.

Dr. Wiseman: Veterans Affairs Ann Arbor Healthcare System, VISN 11, 2215 Fuller Road, Department of Pharmacy (119), Ann Arbor, MI 48105.

Dr. Pittiruti: Catholic University, Via Malcesine 65, 00135 Rome, Italy.

Dr. Akl: American University of Beirut Medical Center, PO Box 11-0236 Riad-El-Solh 1107 2020, Beirut, Lebanon.

Dr. Lee: Division of Hematology, University of British Columbia, 2775 Laurel Street, 10th Floor, Vancouver, British Columbia V5Z 1M9, Canada.

Dr. Courey: Taubman Medical Center, University of Michigan, 1500 East Medical Center Drive, SPC 3918, Ann Arbor, MI 48109-3918.

Dr. Swaminathan: Division of Hospital Medicine, Oakwood Hospital, 18101 Oakwood Boulevard, Dearborn, MI 48124.

Dr. LeDonne: Department of Surgery, Greater Baltimore Medical Center, 10210 Breconshire Road, Ellicott City, MD 21041.

Ms. Becker: Institute for Healthcare Policy and Innovation, University of Michigan, North Campus Research Complex, 2800 Plymouth Road, Building 16, Room 476C, Ann Arbor, MI 48109.

Dr. Krein: Department of Veterans Affairs, 2800 Plymouth Road, Building 16, Room 33W, Ann Arbor, MI 48109-2800.

Dr. Bernstein: Institute for Healthcare Policy and Innovation, University of Michigan, North Campus Research Complex, 2800 Plymouth Road, Building 16, Room 446E, Ann Arbor, MI 48109.

Author Contributions: Conception and design: E.A. Akl, C. Becker, S.J. Bernstein, V. Chopra, S.A. Flanders, S.L. Krein, J. LeDonne, S. Saint, L. Swaminathan, S. Wiseman, S. Woller

Analysis and interpretation of the data: C. Becker, S.J. Bernstein, V. Chopra, J. LeDonne, A.Y. Lee, M. Pittiruti, S. Trerotola

Drafting of the article: S.J. Bernstein, V. Chopra, A.J. Courey, N. O'Grady, S. Trerotola.

Critical revision for important intellectual content: E.A. Akl, C. Becker, S.J. Bernstein, V. Chopra, A.J. Courey, S.A. Flanders, S.L. Krein, J. LeDonne, A.Y. Lee, N.L. Moureau, N. O'Grady, M. Pittiruti, N. Safdar, S. Saint, R. Saran, L. Swaminathan, S. Trerotola, S. Wiseman, S. Woller.

Final approval of the article: E.A. Akl, C. Becker, S.J. Bernstein, V. Chopra, A.J. Courey, S.A. Flanders, S.L. Krein, J. LeDonne, A.Y. Lee, N.L. Moureau, N. O'Grady, M. Pittiruti, N. Safdar, S. Saint, R. Saran, L. Swaminathan, S. Trerotola, S. Wiseman, S. Woller.

Provision of study materials or patients: V. Chopra, S.A. Flanders, A.Y. Lee.

Statistical expertise: S.J. Bernstein, V. Chopra.

Obtaining of funding: V. Chopra, A.J. Courey, S.A. Flanders, S. Saint.

Administrative, technical, or logistic support: C. Becker, S.J. Bernstein, V. Chopra, S.A. Flanders, R. Saran.

Collection and assembly of data: E.A. Akl, C. Becker, V. Chopra, S.A. Flanders, N.L. Moureau, N. O'Grady, L. Swaminathan, S. Trerotola, S. Wiseman, S. Woller.

References

1. **Al Raiy B, Fakih MG, Bryan-Nomides N, Hopfner D, Riegel E, Nenninger T, et al.** Peripherally inserted central venous catheters in the acute care setting: a safe alternative to high-risk short-term central venous catheters. Am J Infect Control. 2010;38:149-53. [PMID: 19836854] doi:10.1016/j.ajic.2009.06.008

2. **Gunst M, Matsushima K, Vanek S, Gunst R, Shafi S, Frankel H.** Peripherally inserted central catheters may lower the incidence of catheter-related blood stream infections in patients in surgical intensive care units. Surg Infect (Larchmt). 2011;12:279-82. [PMID: 20629557] doi:10.1089/sur.2008.058

3. **Meyer BM.** Developing an alternative workflow model for peripherally inserted central catheter placement. J Infus Nurs. 2012;35:34-42. [PMID: 22222290] doi:10.1097/NAN.0b013e31823bc8fd

4. **Walker G, Todd A.** Nurse-led PICC insertion: is it cost effective? Br J Nurs. 2013;22:S9-15. [PMID: 24350393]

5. **Burns T, Lamberth B.** Facility wide benefits of radiology vascular access teams. Radiol Manage. 2010;32:28-32. [PMID: 22279726]

6. **Johansson E, Hammarskjöld F, Lundberg D, Arnlind MH.** Advantages and disadvantages of peripherally inserted central venous catheters (PICC) compared to other central venous lines: a systematic review of the literature. Acta Oncol. 2013;52:886-92. [PMID: 23472835] doi:10.3109/0284186X.2013.773072

7. **Lobo BL, Vaidean G, Broyles J, Reaves AB, Shorr RI.** Risk of venous thromboembolism in hospitalized patients with peripherally inserted central catheters. J Hosp Med. 2009;4:417-22. [PMID: 19753569] doi:10.1002/jhm.442

8. **Konstantinou EA, Stafylarakis E, Kapritsou M, Mitsos AP, Fotis TG, Kiekkas P, et al.** Greece reports prototype intervention with first peripherally inserted central catheter: case report and literature review. J Vasc Nurs. 2012;30:88-93. [PMID: 22901447] doi:10.1016/j.jvn.2012.03.001

9. **Chopra V, Flanders SA, Saint S.** The problem with peripherally inserted central catheters. JAMA. 2012;308:1527-8. [PMID: 23073947] doi:10.1001/jama.2012.12704

10. **Fitch K, Bernstein SJ, Aguilar MD, Burnand B, LaCalle JR, Lázaro P, et al.** The RAND/UCLA Appropriateness Method User's Manual. Santa Monica, CA: RAND; 2001.

11. **Song L, Li H.** Malposition of peripherally inserted central catheter: experience from 3,012 patients with cancer. Exp Ther Med. 2013;6:891-893. [PMID: 24137284]

12. **Pikwer A, Åkeson J, Lindgren S.** Complications associated with peripheral or central routes for central venous cannulation. Anaesthesia. 2012;67:65-71. [PMID: 21972789] doi:10.1111/j.1365-2044.2011.06911.x

13. **Li J, Fan YY, Xin MZ, Yan J, Hu W, Huang WH, et al.** A randomised, controlled trial comparing the long-term effects of peripherally inserted central catheter placement in chemotherapy patients using B-mode ultrasound with modified Seldinger technique versus

blind puncture. Eur J Oncol Nurs. 2014;18:94-103. [PMID: 24018351] doi:10.1016/j.ejon.2013.08.003
14. **Leung TK, Lee CM, Tai CJ, Liang YL, Lin CC.** A retrospective study on the long-term placement of peripherally inserted central catheters and the importance of nursing care and education. Cancer Nurs. 2011;34:E25-30. [PMID: 20885304] doi:10.1097/NCC.0b013e3181f1ad6f
15. **Chopra V, O'Horo JC, Rogers MA, Maki DG, Safdar N.** 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. 2013;34:908-18. [PMID: 23917904] doi:10.1086/671737
16. **Chopra V, Anand S, Hickner A, Buist M, Rogers MA, Saint S, et al.** Risk of venous thromboembolism associated with peripherally inserted central catheters: a systematic review and meta-analysis. Lancet. 2013;382:311-25. [PMID: 23697825] doi:10.1016/S0140-6736(13)60592-9
17. **Chopra V, Anand S, Krein SL, Chenoweth C, Saint S.** Bloodstream infection, venous thrombosis, and peripherally inserted central catheters: reappraising the evidence. Am J Med. 2012;125:733-41. [PMID: 22840660] doi:10.1016/j.amjmed.2012.04.010
18. **Tejedor SC, Tong D, Stein J, Payne C, Dressler D, Xue W, et al.** Temporary central venous catheter utilization patterns in a large tertiary care center: tracking the "idle central venous catheter." Infect Control Hosp Epidemiol. 2012;33:50-7. [PMID: 22173522] doi:10.1086/663645
19. **Gibson C, Connolly BL, Moineddin R, Mahant S, Filipescu D, Amaral JG.** Peripherally inserted central catheters: use at a tertiary care pediatric center. J Vasc Interv Radiol. 2013;24:1323-31. [PMID: 23876551] doi:10.1016/j.jvir.2013.04.010
20. **Chopra V, Govindan S, Kuhn L, Ratz D, Sweis RF, Melin N, et al.** Do clinicians know which of their patients have central venous catheters?: a multicenter observational study. Ann Intern Med. 2014;161:562-7. [PMID: 25329204] doi:10.7326/M14-0703
21. **Chopra V, Kuhn L, Flanders SA, Saint S, Krein SL.** Hospitalist experiences, practice, opinions, and knowledge regarding peripherally inserted central catheters: results of a national survey. J Hosp Med. 2013;8:635-8. [PMID: 24142565] doi:10.1002/jhm.2095
22. **Chopra V, Kuhn L, Coffey CE Jr, Salameh M, Barron J, Krein S, et al.** Hospitalist experiences, practice, opinions, and knowledge regarding peripherally inserted central catheters: a Michigan survey. J Hosp Med. 2013;8:309-14. [PMID: 23526586] doi:10.1002/jhm.2031
23. **Wojnar DG, Beaman ML.** Peripherally inserted central catheter: compliance with evidence-based indications for insertion in an inpatient setting. J Infus Nurs. 2013;36:291-6. [PMID: 23823005] doi:10.1097/NAN.0b013e318297c1a8
24. **American Society of Nephrology**. Choosing wisely. Don't place peripherally inserted central catheters (PICC) in stage III-V CKD patients without consulting nephrology. 4 April 2012. Accessed at www.choosingwisely.org/clinician-lists/american-society-nephrology-peripherally-inserted-central-catheters-in-stage-iii-iv-ckd-patients on 12 May 2015.
25. **Society of General Internal Medicine**. Choosing wisely. Don't place, or leave in place, peripherally inserted central catheters for patient or provider convenience. 12 September 2013. Accessed at www.choosingwisely.org/clinician-lists/society-general-internal-medicine-peripherally-inserted-central-catheters-for-patient-provider-convenience on 12 May 2015.
26. **Bernstein SJ, Brorsson B, Aberg T, Emanuelsson H, Brook RH, Werkö L.** Appropriateness of referral of coronary angiography patients in Sweden. SECOR/SBU Project Group. Heart. 1999;81:470-7. [PMID: 10212163]
27. **Lawson EH, Gibbons MM, Ko CY, Shekelle PG.** The appropriateness method has acceptable reliability and validity for assessing overuse and underuse of surgical procedures. J Clin Epidemiol. 2012;65:1133-43. [PMID: 23017632] doi:10.1016/j.jclinepi.2012.07.002
28. **Connolly SM, Baker DR, Coldiron BM, Fazio MJ, Storrs PA, Vidimos AT, et al; American Academy of Dermatology.** AAD/ACMS/ASDSA/ASMS 2012 appropriate use criteria for Mohs micrographic surgery: a report of the American Academy of Dermatology, American College of Mohs Surgery, American Society for Dermatologic Surgery Association, and the American Society for Mohs Surgery. Dermatol Surg. 2012;38:1582-603. [PMID: 22958088] doi:10.1111/j.1524-4725.2012.02574.x
29. **Llorente C, Blasco JA, Quintana JM, Bilbao A, Alberdi T, Lacalle JR, et al; IRYSS-Cataract Group.** Interhospital variation in appropriateness of cataract surgery. J Eval Clin Pract. 2011;17:188-95. [PMID: 20846279] doi:10.1111/j.1365-2753.2010.01421.x
30. **Santori G, Fontana I, Valente R, Ghirelli R, Valente U.** Application of the RAND/UCLA Appropriateness Method to evaluate an information system for kidney/pancreas transplantation in adult recipients. Transplant Proc. 2008;40:2021-3. [PMID: 18675119] doi:10.1016/j.transproceed.2008.05.018
31. **Meddings J, Saint S, Fowler KE, Gaies E, Hickner A, Krein SL, et al.** The Ann Arbor criteria for appropriate urinary catheter use in hospitalized medical patients: results obtained by using the RAND/UCLA Appropriateness Method. Ann Intern Med. 2015;162:S1-34. [PMID: 25938928] doi:10.7326/M14-1304
32. **Infusion Nurses Society.** Infusion nursing standards of practice. J Infus Nurs. 2011;34(Suppl 1):S1-109.
33. **O'Grady NP, Alexander M, Burns LA, Dellinger EP, Garland J, Heard SO, et al; Healthcare Infection Control Practices Advisory Committee (HICPAC) (Appendix 1).** Summary of recommendations: Guidelines for the Prevention of Intravascular Catheter-related Infections. Clin Infect Dis. 2011;52:1087-99. [PMID: 21467014] doi:10.1093/cid/cir138
34. **Rupp SM, Apfelbaum JL, Blitt C, Caplan RA, Connis RT, Domino KB, et al; American Society of Anesthesiologists Task Force on Central Venous Access.** Practice guidelines for central venous access: a report by the American Society of Anesthesiologists Task Force on Central Venous Access. Anesthesiology. 2012;116:539-73. [PMID: 22307320] doi:10.1097/ALN.0b013e31823c9569
35. **Guyatt GH, Akl EA, Crowther M, Gutterman DD, Schuünemann HJ; American College of Chest Physicians Antithrombotic Therapy and Prevention of Thrombosis Panel.** Executive summary: Antithrombotic Therapy and Prevention of Thrombosis, 9th ed: American College of Chest Physicians Evidence-Based Clinical Practice Guidelines. Chest. 2012;141:7S-47S. [PMID: 22315257] doi:10.1378/chest.1412S3
36. **Debourdeau P, Farge D, Beckers M, Baglin C, Bauersachs RM, Brenner B, et al.** International clinical practice guidelines for the treatment and prophylaxis of thrombosis associated with central venous catheters in patients with cancer. J Thromb Haemost. 2013;11:71-80. [PMID: 23217208] doi:10.1111/jth.12071
37. **Meyer P, Cronier P, Rousseau H, Vicaut E, Choukroun G, Chergui K, et al.** Difficult peripheral venous access: clinical evaluation of a catheter inserted with the Seldinger method under ultrasound guidance. J Crit Care. 2014;29:823-7. [PMID: 24927983] doi:10.1016/j.jcrc.2014.04.022
38. **Caparas JV, Hu JP.** Safe administration of vancomycin through a novel midline catheter: a randomized, prospective clinical trial. J Vasc Access. 2014;15:251-6. [PMID: 24811603] doi:10.5301/jva.5000220
39. **Liu YT, Alsaawi A, Bjornsson HM.** Ultrasound-guided peripheral venous access: a systematic review of randomized-controlled trials. Eur J Emerg Med. 2014;21:18-23. [PMID: 23880981] doi:10.1097/MEJ.0b013e328363bebc
40. **Mermel LA, Parenteau S, Tow SM.** The risk of midline catheterization in hospitalized patients. A prospective study. Ann Intern Med. 1995;123:841-4. [PMID: 7486466]
41. **Elia F, Ferrari G, Molino P, Converso M, De Filippi G, Milan A, et al.** Standard-length catheters vs long catheters in ultrasound-guided peripheral vein cannulation. Am J Emerg Med. 2012;30:712-6. [PMID: 21703801] doi:10.1016/j.ajem.2011.04.019
42. **Anderson NR.** Midline catheters: the middle ground of intravenous therapy administration. J Infus Nurs. 2004;27:313-21. [PMID: 15385895]

43. **Anderson NR.** When to use a midline catheter. Nursing. 2005;35: 28. [PMID: 15818264]
44. **National Kidney Foundation/Kidney Disease Outcomes Quality Initiative.** KDOQI 2012 clinical practice guidelines for chronic kidney disease. Kidney Int. 2013;(Suppl 3):1-150.
45. **Coresh J, Turin TC, Matsushita K, Sang Y, Ballew SH, Appel LJ, et al; CKD Prognosis Consortium.** Decline in estimated glomerular filtration rate and subsequent risk of end-stage renal disease and mortality. JAMA. 2014;311:2518-31. [PMID: 24892770]
46. **Kellum JA, Lameire N; KDIGO AKI Guideline Work Group.** Diagnosis, evaluation, and management of acute kidney injury: a KDIGO summary (part 1). Crit Care. 2013;17:204. [PMID: 23394211] doi:10 .1186/cc11454
47. **Inker LA, Astor BC, Fox CH, Isakova T, Lash JP, Peralta CA, et al.** KDOQI US commentary on the 2012 KDIGO clinical practice guideline for the evaluation and management of CKD. Am J Kidney Dis. 2014;63:713-35. [PMID: 24647050] doi:10.1053/j.ajkd.2014.01.416
48. **National Kidney Foundation.** K/DOQI clinical practice guidelines for chronic kidney disease: evaluation, classification, and stratification. Am J Kidney Dis. 2002;39:S1-266. [PMID: 11904577]
49. **El Ters M, Schears GJ, Taler SJ, Williams AW, Albright RC, Jenson BM, et al.** Association between prior peripherally inserted central catheters and lack of functioning arteriovenous fistulas: a case-control study in hemodialysis patients. Am J Kidney Dis. 2012;60: 601-8. [PMID: 22704142] doi:10.1053/j.ajkd.2012.05.007
50. **Sasadeusz KJ, Trerotola SO, Shah H, Namyslowski J, Johnson MS, Moresco KP, et al.** Tunneled jugular small-bore central catheters as an alternative to peripherally inserted central catheters for intermediate-term venous access in patients with hemodialysis and chronic renal insufficiency. Radiology. 1999;213:303-6. [PMID: 10540677]
51. **Walshe LJ, Malak SF, Eagan J, Sepkowitz KA.** Complication rates among cancer patients with peripherally inserted central catheters. J Clin Oncol. 2002;20:3276-81. [PMID: 12149302]
52. **Mollee P, Jones M, Stackelroth J, van Kuilenburg R, Joubert W, Faoagali J, et al.** Catheter-associated bloodstream infection incidence and risk factors in adults with cancer: a prospective cohort study. J Hosp Infect. 2011;78:26-30. [PMID: 21459476] doi:10.1016 /j.jhin.2011.01.018
53. **Zwicker JI, Connolly G, Carrier M, Kamphuisen PW, Lee AY.** Catheter-associated deep vein thrombosis of the upper extremity in cancer patients: guidance from the SSC of the ISTH. J Thromb Haemost. 2014;12:796-800. [PMID: 24548519] doi:10.1111/jth.12527
54. **Saber W, Moua T, Williams EC, Verso M, Agnelli G, Couban S, et al.** 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. 2011;9:312-9. [PMID: 21040443] doi:10.1111/j.1538-7836.2010.04126.x
55. **Lee AY, Levine MN, Butler G, Webb C, Costantini L, Gu C, et al.** Incidence, risk factors, and outcomes of catheter-related thrombosis in adult patients with cancer. J Clin Oncol. 2006;24:1404-8. [PMID: 16549834]
56. **Del Principe MI, Buccisano F, Maurillo L, Venditti D, Cefalo M, Sarlo C, et al.** Infections increase the risk of central venous catheter-related thrombosis in adult acute myeloid leukemia. Thromb Res. 2013;132:511-4. [PMID: 24090605] doi:10.1016/j.thromres.2013.08 .007
57. **Ahn DH, Illum HB, Wang DH, Sharma A, Dowell JE.** Upper extremity venous thrombosis in patients with cancer with peripherally inserted central venous catheters: a retrospective analysis of risk factors. J Oncol Pract. 2013;9:e8-12. [PMID: 23633980] doi:10.1200 /JOP.2012.000595
58. **Bellesi S, Chiusolo P, De Pascale G, Pittiruti M, Scoppettuolo G, Metafuni E, et al.** Peripherally inserted central catheters (PICCs) in the management of oncohematological patients submitted to autologous stem cell transplantation. Support Care Cancer. 2013;21: 531-5. [PMID: 22864473] doi:10.1007/s00520-012-1554-0
59. **Cotogni P, Pittiruti M, Barbero C, Monge T, Palmo A, Boggio Bertinet D.** Catheter-related complications in cancer patients on home parenteral nutrition: a prospective study of over 51,000 catheter days. JPEN J Parenter Enteral Nutr. 2013;37:375-83. [PMID: 23002096] doi:10.1177/0148607112460552
60. **Tran H, Arellano M, Chamsuddin A, Flowers C, Heffner LT, Langston A, et al.** Deep venous thromboses in patients with hematological malignancies after peripherally inserted central venous catheters. Leuk Lymphoma. 2010;51:1473-7. [PMID: 20443681] doi: 10.3109/10428194.2010.481065
61. **Potet J, Thome A, Curis E, Arnaud FX, Weber-Donat G, Valbousquet L, et al.** Peripherally inserted central catheter placement in cancer patients with profound thrombocytopaenia: a prospective analysis. Eur Radiol. 2013;23:2042-8. [PMID: 23440314] doi:10.1007 /s00330-013-2778-1
62. **Deutsch GB, Sathyanarayana SA, Singh N, Nicastro J.** Ultrasound-guided placement of midline catheters in the surgical intensive care unit: a cost-effective proposal for timely central line removal. J Surg Res. 2014;191:1-5. [PMID: 24565504] doi:10.1016/j.jss .2013.03.047
63. **Sharp R, Esterman A, McCutcheon H, Hearse N, Cummings M.** The safety and efficacy of midlines compared to peripherally inserted central catheters for adult cystic fibrosis patients: a retrospective, observational study. Int J Nurs Stud. 2014;51:694-702. [PMID: 24103730] doi:10.1016/j.ijnurstu.2013.09.002
64. **Wilson TJ, Brown DL, Meurer WJ, Stetler WR Jr, Wilkinson DA, Fletcher JJ.** Risk factors associated with peripherally inserted central venous catheter-related large vein thrombosis in neurological intensive care patients. Intensive Care Med. 2012;38:272-8. [PMID: 22113818] doi:10.1007/s00134-011-2418-7
65. **Food and Drug Administration Task Force.** Precautions necessary with central venous catheters. FDA Drug Bull. 1989;July:15-6.
66. **Vesely TM.** Central venous catheter tip position: a continuing controversy. J Vasc Interv Radiol. 2003;14:527-34. [PMID: 12761305]
67. **Debourdeau P, Kassab Chahmi D, Le Gal G, Kriegel I, Desruennes E, Douard MC, et al; Working group of the SOR.** 2008 SOR guidelines for the prevention and treatment of thrombosis associated with central venous catheters in patients with cancer: report from the working group. Ann Oncol. 2009;20:1459-71. [PMID: 19525362] doi:10.1093/annonc/mdp052
68. **Dariushnia SR, Wallace MJ, Siddiqi NH, Towbin RB, Wojak JC, Kundu S, et al; Society of Interventional Radiology Standards of Practice Committee.** Quality improvement guidelines for central venous access. J Vasc Interv Radiol. 2010;21:976-81. [PMID: 20610180] doi:10.1016/j.jvir.2010.03.006
69. BCSH guidelines on the insertion and management of central venous lines. Br J Haematol. 1997;98:1041-7. [PMID: 9326209]
70. **Fletcher SJ, Bodenham AR.** Safe placement of central venous catheters: where should the tip of the catheter lie? [Editorial]. Br J Anaesth. 2000;85:188-91. [PMID: 10992821]
71. **Pittiruti M, Lamperti M.** Late cardiac tamponade in adults secondary to tip position in the right atrium: an urban legend? A systematic review of the literature. J Cardiothorac Vasc Anesth. 2015; 29:491-5. [PMID: 25304887] doi:10.1053/j.jvca.2014.05.020
72. **Elsharkawy H, Lewis BS, Steiger E, Farag E.** Post placement positional atrial fibrillation and peripherally inserted central catheters. Minerva Anestesiol. 2009;75:471-4. [PMID: 19377410]
73. **Evans RS, Sharp JH, Linford LH, Lloyd JF, Tripp JS, Jones JP, et al.** Risk of symptomatic DVT associated with peripherally inserted central catheters. Chest. 2010;138:803-10. [PMID: 20923799] doi:10 .1378/chest.10-0154
74. **Evans RS, Sharp JH, Linford LH, Lloyd JF, Woller SC, Stevens SM, et al.** Reduction of peripherally inserted central catheter-associated DVT. Chest. 2013;143:627-33. [PMID: 22878346]
75. **O'Brien J, Paquet F, Lindsay R, Valenti D.** Insertion of PICCs with minimum number of lumens reduces complications and costs. J Am Coll Radiol. 2013;10:864-8. [PMID: 24075218] doi:10.1016/j.jacr.2013 .06.003
76. **Simonova G, Rickard CM, Dunster KR, Smyth DJ, McMillan D, Fraser JF.** Cyanoacrylate tissue adhesives—effective securement technique for intravascular catheters: in vitro testing of safety and feasibility. Anaesth Intensive Care. 2012;40:460-6. [PMID: 22577911]

77. **Dal Molin A, Allara E, Montani D, Milani S, Frassati C, Cossu S, et al.** Flushing the central venous catheter: is heparin necessary? J Vasc Access. 2014;15:241-8. [PMID: 24811598] doi:10.5301/jva.5000225
78. **López-Briz E, Ruiz Garcia V, Cabello JB, Bort-Marti S, Carbonell Sanchis R, Burls A.** Heparin versus 0.9% sodium chloride intermittent flushing for prevention of occlusion in central venous catheters in adults. Cochrane Database Syst Rev. 2014;10:CD008462. [PMID: 25300172] doi:10.1002/14651858.CD008462.pub2
79. **Lee A.** VTE in patients with cancer—diagnosis, prevention, and treatment. Thromb Res. 2008;123 Suppl 1:S50-4. [PMID: 18824256] doi:10.1016/j.thromres.2008.08.017
80. **Pingleton SK, Carlton E, Wilkinson S, Beasley J, King T, Wittkopp C, et al.** Reduction of venous thromboembolism (VTE) in hospitalized patients: aligning continuing education with interprofessional team-based quality improvement in an academic medical center. Acad Med. 2013;88:1454-9. [PMID: 23969376] doi:10.1097/ACM.0b013e3182a4aa51
81. **Safdar N, Maki DG.** Risk of catheter-related bloodstream infection with peripherally inserted central venous catheters used in hospitalized patients. Chest. 2005;128:489-95. [PMID: 16100130]
82. **Meddings J, Rogers MA, Krein SL, Fakih MG, Olmsted RN, Saint S.** Reducing unnecessary urinary catheter use and other strategies to prevent catheter-associated urinary tract infection: an integrative review. BMJ Qual Saf. 2014;23:277-89. [PMID: 24077850] doi:10.1136/bmjqs-2012-001774
83. **Webster J, Osborne S, Rickard CM, New K.** Clinically-indicated replacement versus routine replacement of peripheral venous catheters. Cochrane Database Syst Rev. 2013;4:CD007798. [PMID: 23633346] doi:10.1002/14651858.CD007798.pub3
84. **Rickard CM, Webster J, Wallis MC, Marsh N, McGrail MR, French V, et al.** Routine versus clinically indicated replacement of peripheral intravenous catheters: a randomised controlled equivalence trial. Lancet. 2012;380:1066-74. [PMID: 22998716] doi:10.1016/S0140-6736(12)61082-4
85. **Tuffaha HW, Rickard CM, Webster J, Marsh N, Gordon L, Wallis M, et al.** Cost-effectiveness analysis of clinically indicated versus routine replacement of peripheral intravenous catheters. Appl Health Econ Health Policy. 2014;12:51-8. [PMID: 24408785] doi:10.1007/s40258-013-0077-2
86. **Hoshal VL Jr.** Total intravenous nutrition with peripherally inserted silicone elastomer central venous catheters. Arch Surg. 1975;110:644-6. [PMID: 805577]
87. **Zingg W, Sandoz L, Inan C, Cartier V, Clergue F, Pittet D, et al.** Hospital-wide survey of the use of central venous catheters. J Hosp Infect. 2011;77:304-8. [PMID: 21288595] doi:10.1016/j.jhin.2010.11.011
88. **Hornsby S, Matter K, Beets B, Casey S, Kokotis K.** Cost losses associated with the "PICC, stick, and run team" concept. J Infus Nurs. 2005;28:45-53. [PMID: 15684904]
89. **Moureau N, Lamperti M, Kelly LJ, Dawson R, Elbarbary M, van Boxtel AJ, et al.** Evidence-based consensus on the insertion of central venous access devices: definition of minimal requirements for training. Br J Anaesth. 2013;110:347-56. [PMID: 23361124] doi:10.1093/bja/aes499
90. **Michigan Hospital Medicine Safety Consortium.** Venous thromboembolism (VTE) prophylaxis and peripherally inserted central catheter (PICC) project. 2013. Accessed at www.mi-hms.org/ongoing-projects.php on 12 May 2015.
91. **Abdullah BJ, Mohammad N, Sangkar JV, Abd Aziz YF, Gan GG, Goh KY, et al.** Incidence of upper limb venous thrombosis associated with peripherally inserted central catheters (PICC). Br J Radiol. 2005;78:596-600. [PMID: 15961840]
92. **Akers AS, Chelluri L.** Peripherally inserted central catheter use in the hospitalized patient: is there a role for the hospitalist? J Hosp Med. 2009;4:E1-4. [PMID: 19670373] doi:10.1002/jhm.446
93. **Akl EA, Vasireddi SR, Gunukula S, Yosuico VE, Barba M, Sperati F, et al.** Anticoagulation for patients with cancer and central venous catheters. Cochrane Database Syst Rev. 2011:CD006468. [PMID: 21491394] doi:10.1002/14651858.CD006468.pub4
94. **Alexandrou E, Spencer TR, Frost SA, Mifflin N, Davidson PM, Hillman KM.** Central venous catheter placement by advanced practice nurses demonstrates low procedural complication and infection rates—a report from 13 years of service. Crit Care Med. 2014;42:536-43. [PMID: 24145843] doi:10.1097/CCM.0b013e3182a667f0
95. **Alhimyary A, Fernandez C, Picard M, Tierno K, Pignatone N, Chan HS, et al.** Safety and efficacy of total parenteral nutrition delivered via a peripherally inserted central venous catheter. Nutr Clin Pract. 1996;11:199-203. [PMID: 9016135]
96. **Alkindi S, Matwani S, Al-Maawali A, Al-Maskari B, Pathare A.** Complications of PORT-A-CATH in patients with sickle cell disease. J Infect Public Health. 2012;5:57-62. [PMID: 22341844] doi:10.1016/j.jiph.2011.10.004
97. **Allan ND, Giare-Patel K, Olson ME.** An in vivo rabbit model for the evaluation of antimicrobial peripherally inserted central catheter to reduce microbial migration and colonization as compared to an uncoated PICC. J Biomed Biotechnol. 2012;2012:921617. [PMID: 22969275] doi:10.1155/2012/921617
98. **Allen AW, Megargell JL, Brown DB, Lynch FC, Singh H, Singh Y, et al.** Venous thrombosis associated with the placement of peripherally inserted central catheters. J Vasc Interv Radiol. 2000;11:1309-14. [PMID: 11099241]
99. **Al-Tawfiq JA, Abed MS, Memish ZA.** Peripherally inserted central catheter bloodstream infection surveillance rates in an acute care setting in Saudi Arabia. Ann Saudi Med. 2012;32:169-73. [PMID: 22366831]
100. **Amerasekera SS, Jones CM, Patel R, Cleasby MJ.** Imaging of the complications of peripherally inserted central venous catheters. Clin Radiol. 2009;64:832-40. [PMID: 19589422] doi:10.1016/j.crad.2009.02.021
101. **Armstrong SD, Thomas W, Neaman KC, Ford RD, Paulson J.** The impact of antibiotic impregnated PICC lines on the incidence of bacteremia in a regional burn center. Burns. 2013;39:632-5. [PMID: 23010088] doi:10.1016/j.burns.2012.08.017
102. **Association for Vascular Access.** Position statement: the use of Seldinger or modified seldinger technique, in combination with real-time imaging modalities for peripherally inserted central catheter and midline placements by clinicians. 2011. Accessed at www.avainfo.org/website/download.asp?id=280292 on 12 May 2015.
103. **Aw A, Carrier M, Koczerginski J, McDiarmid S, Tay J.** Incidence and predictive factors of symptomatic thrombosis related to peripherally inserted central catheters in chemotherapy patients. Thromb Res. 2012;130:323-6. [PMID: 22444157] doi:10.1016/j.thromres.2012.02.048
104. **Bai YG, Hou HR.** Application of ultrasound-guided peripherally inserted central catheter insertion in elderly patients. Chinese Journal of Clinical Nutrition. 2010;18:16-8.
105. **Bai XH, Zang S, Yu L.** A comparison of two intravenous infusion devices in lung carcinoma patients receiving combined radiotherapy and chemotherapy. J Cancer Res Ther. 2013;9:664-7. [PMID: 24518714] doi:10.4103/0973-1482.126475
106. **Barr DA, Semple L, Seaton RA.** Self-administration of outpatient parenteral antibiotic therapy and risk of catheter-related adverse events: a retrospective cohort study. Eur J Clin Microbiol Infect Dis. 2012;31:2611-9. [PMID: 22526869]
107. **Bates SM, Jaeschke R, Stevens SM, Goodacre S, Wells PS, Stevenson MD, et al; American College of Chest Physicians.** Diagnosis of DVT: Antithrombotic Therapy and Prevention of Thrombosis, 9th ed: American College of Chest Physicians Evidence-Based Clinical Practice Guidelines. Chest. 2012;141:e351S-418S. [PMID: 22315267] doi:10.1378/chest.11-2299
108. **Baumgarten K, Hale Y, Messonnier M, McCabe M, Albright M, Bergeron E.** Bridging the gap: a collaborative to reduce peripherally inserted central catheter infections in the home care environment. Ochsner J. 2013;13:352-8. [PMID: 24052764]
109. **Baxi S, Stoneman E, Sharma A, Knoester J, Zalewski C, Chenoweth C.** Evaluation of peripherally inserted central catheter (PICC) adjustment and risk of bloodstream infections (BSI) and thrombus formation [Abstract]. Presented at Joint 48th Interscience Conference on Antimicrobial Agents and Chemotherapy and 46th Annual

Meeting of the Infectious Diseases Society of America, Washington, DC, 25–28 October 2008. Abstract K-3408. Accessed at https://idsa.confex.com/idsa/2008/webprogram/Paper26467.html on 27 July 2015.
110. **Baxi SM, Shuman EK, Scipione CA, Chen B, Sharma A, Rasanathan JJ, et al.** Impact of postplacement adjustment of peripherally inserted central catheters on the risk of bloodstream infection and venous thrombus formation. Infect Control Hosp Epidemiol. 2013; 34:785-92. [PMID: 23838218] doi:10.1086/671266
111. **Bonciarelli G, Batacchi S, Biffi R, Buononato M, Damascelli B, Ghibaudo F, et al; Gruppo Aperto di Studio Accessi Venosi Centrali a Lungo Termine (Study Group on Long-Term Central Venous Access).** GAVeCeLT* consensus statement on the correct use of totally implantable venous access devices for diagnostic radiology procedures. J Vasc Access. 2011;12:292-305. [PMID: 21534233] doi:10.5301/JVA.2011.7736
112. **Bonizzoli M, Batacchi S, Cianchi G, Zagli G, Lapi F, Tucci V, et al.** Peripherally inserted central venous catheters and central venous catheters related thrombosis in post-critical patients. Intensive Care Med. 2011;37:284-9. [PMID: 20857280] doi:10.1007/s00134-010-2043-x
113. **Bottino J, McCredie KB, Groschel DH, Lawson M.** Long-term intravenous therapy with peripherally inserted silicone elastomer central venous catheters in patients with malignant diseases. Cancer. 1979;43:1937-43. [PMID: 109182]
114. **Burg T, Myles T.** Complications associated with peripherally inserted central catheters in antepartum patients. Am J Obstet Gynecol. 2005;193:S81.
115. **Butler PJ, Sood S, Mojibian H, Tal MG.** Previous PICC placement may be associated with catheter-related infections in hemodialysis patients. Cardiovasc Intervent Radiol. 2011;34:120-3. [PMID: 20857109] doi:10.1007/s00270-010-9974-z
116. **Cape AV, Mogensen KM, Robinson MK, Carusi DA.** Peripherally inserted central catheter (PICC) complications during pregnancy. JPEN J Parenter Enteral Nutr. 2014;38:595-601. [PMID: 23715775] doi:10.1177/0148607113489994
117. **Catalano O, de Lutio di Castelguidone E, Sandomenico C, Petrillo M, Aprea P, Granata V, et al.** Central venous device-related thrombosis as imaged with MDCT in oncologic patients: prevalence and findings. Acta Radiol. 2011;52:148-54. [PMID: 21498342] doi:10.1258/ar.2010.100294
118. **Chakravarthy SB, Rettmann J, Markewitz BA, Elliott G, Sarfati M, Nohavec R.** Peripherally inserted central catheter (PICC) associated upper extremity deep venous thrombosis (UEDVT) in critical care setting. Chest. 2005;128:193S-4S.
119. **Chemaly RF, de Parres JB, Rehm SJ, Adal KA, Lisgaris MV, Katz-Scott DS, et al.** Venous thrombosis associated with peripherally inserted central catheters: a retrospective analysis of the Cleveland Clinic experience. Clin Infect Dis. 2002;34:1179-83. [PMID: 11941543]
120. **Cheong K, Perry D, Karapetis C, Koczwara B.** High rate of complications associated with peripherally inserted central venous catheters in patients with solid tumours. Intern Med J. 2004;34:234-8. [PMID: 15151668]
121. **Chittick P, Azhar S, Movva K, Keller P, Boura JA, Band J.** Early onset versus late onset peripherally inserted central venous catheter infections: an analysis of risk factors and microbiology. Infect Control Hosp Epidemiol. 2013;34:980-3. [PMID: 23917915] doi:10.1086/671726
122. **Chopra V, Ratz D, Kuhn L, Lopus T, Chenoweth C, Krein S.** PICC-associated bloodstream infections: prevalence, patterns, and predictors. Am J Med. 2014;127:319-28. [PMID: 24440542] doi:10.1016/j.amjmed.2014.01.001
123. **Cortelezzia A, Fracchiolla NS, Maisonneuve P, Moia M, Luchesini C, Ranzi ML, et al.** Central venous catheter-related complications in patients with hematological malignancies: a retrospective analysis of risk factors and prophylactic measures. Leuk Lymphoma. 2003;44:1495-501. [PMID: 14565650]
124. **Couban S, Goodyear M, Burnell M, Dolan S, Wasi P, Barnes D, et al.** Randomized placebo-controlled study of low-dose warfarin for the prevention of central venous catheter-associated thrombosis in patients with cancer. J Clin Oncol. 2005;23:4063-9. [PMID: 15767639]
125. **Crnich CJ, Maki DG.** The promise of novel technology for the prevention of intravascular device-related bloodstream infection. II. Long-term devices. Clin Infect Dis. 2002;34:1362-8. [PMID: 11981732]
126. **Curigliano G, Balduzzi A, Cardillo A, Ghisini R, Peruzzotti G, Orlando L, et al.** Low-dose aspirin for the prevention of venous thromboembolism in breast cancer patients treated with infusional chemotherapy after insertion of central vein catheter. Support Care Cancer. 2007;15:1213-7. [PMID: 17578607]
127. **Daneman N, Downing M, Zagorski BM.** How long should peripherally inserted central catheterization be delayed in the context of recently documented bloodstream infection? J Vasc Interv Radiol. 2012;23:123-5. [PMID: 22221476] doi:10.1016/j.jvir.2011.09.024
128. **Dawson RB, Moureau NL.** Midline catheters: an essential tool in CLABSI reduction. Infection Control Today. 2013:42-6.
129. **DeLemos C, Abi-Nader J, Akins PT.** Use of peripherally inserted central catheters as an alternative to central catheters in neurocritical care units. Crit Care Nurse. 2011;31:70-5. [PMID: 21459866] doi:10.4037/ccn2011911
130. **Diaz K, Kelly SG, Smith B, Malani PN, Younger JG.** A prospective study of central venous catheters placed in a tertiary care emergency department: indications for use, infectious complications, and natural history. Am J Infect Control. 2012;40:65-7. [PMID: 21741118] doi:10.1016/j.ajic.2011.03.018
131. **Di Nisio M, Van Sluis GL, Bossuyt PM, Büller HR, Porreca E, Rutjes AW.** Accuracy of diagnostic tests for clinically suspected upper extremity deep vein thrombosis: a systematic review. J Thromb Haemost. 2010;8:684-92. [PMID: 20141579] doi:10.1111/j.1538-7836.2010.03771.x
132. **Duerksen DR, Papineau N, Siemens J, Yaffe C.** Peripherally inserted central catheters for parenteral nutrition: a comparison with centrally inserted catheters. JPEN J Parenter Enteral Nutr. 1999;23:85-9. [PMID: 10081998]
133. **Durrani O.** Incidence of PICC line associated thrombosis in patients already on prophylaxis for thromboembolism. Crit Care Med. 2009;37:A365.
134. **Fagnani D, Franchi R, Porta C, Pugliese P, Borgonovo K, Bertolini A, et al; POLONORD Group.** Thrombosis-related complications and mortality in cancer patients with central venous devices: an observational study on the effect of antithrombotic prophylaxis. Ann Oncol. 2007;18:551-5. [PMID: 17158773]
135. **Fearonce G, Faraklas I, Saffle JR, Cochran A.** Peripherally inserted central venous catheters and central venous catheters in burn patients: a comparative review. J Burn Care Res. 2010;31:31-5. [PMID: 20061834] doi:10.1097/BCR.0b013e3181cb8eaa
136. **Fletcher JJ, Stetler W, Wilson TJ.** The clinical significance of peripherally inserted central venous catheter-related deep vein thrombosis. Neurocrit Care. 2011;15:454-60. [PMID: 21541826] doi:10.1007/s12028-011-9554-3
137. **Freixas N, Bella F, Limón E, Pujol M, Almirante B, Gudiol F.** Impact of a multimodal intervention to reduce bloodstream infections related to vascular catheters in non-ICU wards: a multicentre study. Clin Microbiol Infect. 2013;19:838-44. [PMID: 23130638] doi:10.1111/1469-0691.12049
138. **Frizzelli R, Tortelli O, Di Comite V, Ghirardi R, Pinzi C, Scarduelli C.** Deep venous thrombosis of the neck and pulmonary embolism in patients with a central venous catheter admitted to cardiac rehabilitation after cardiac surgery: a prospective study of 815 patients. Intern Emerg Med. 2008;3:325-30. [PMID: 18357502] doi:10.1007/s11739-008-0142-2
139. **Furuya EY, Dick A, Perencevich EN, Pogorzelska M, Goldmann D, Stone PW.** Central line bundle implementation in US intensive care units and impact on bloodstream infections. PLoS One. 2011;6:e15452. [PMID: 21267440] doi:10.1371/journal.pone.0015452
140. **Gong P, Huang XE, Chen CY, Liu JH, Meng AF, Feng JF.** Comparison of complications of peripherally inserted central catheters

with ultrasound guidance or conventional methods in cancer patients. Asian Pac J Cancer Prev. 2012;13:1873-5. [PMID: 22901139]
141. **Göransson KE, Johansson E.** Prehospital peripheral venous catheters: a prospective study of patient complications. J Vasc Access. 2012;13:16-21. [PMID: 21725949] doi:10.5301/JVA.2011.8418
142. **Grant JD, Lee EW, Kee ST.** Defining the incidence and characteristics of PICC-induced upper extremity deep vein thrombosis in 6,513 UCLA patients. J Investig Med. 2008;56:131-2.
143. **Grant JD, Stevens SM, Woller SC, Lee EW, Kee ST, Liu DM, et al.** Diagnosis and management of upper extremity deep-vein thrombosis in adults. Thromb Haemost. 2012;108:1097-108. [PMID: 23093319] doi:10.1160/TH12-05-0352
144. **Gregg SC, Murthi SB, Sisley AC, Stein DM, Scalea TM.** Ultrasound-guided peripheral intravenous access in the intensive care unit. J Crit Care. 2010;25:514-9. [PMID: 19836193] doi:10.1016/j.jcrc.2009.09.003
145. **Griffiths V.** Midline catheters: indications, complications and maintenance. Nurs Stand. 2007;22:48-57. [PMID: 18075023]
146. **Grove JR, Pevec WC.** Venous thrombosis related to peripherally inserted central catheters. J Vasc Interv Radiol. 2000;11:837-40. [PMID: 10928518]
147. **Hadaway L.** Hub disinfection and its impact on catheter-related infections. Journal of Vascular Access Devices. 2001;(Summer):33-6.
148. **Hadaway L.** Needleless connectors: improving practice, reducing risks. Journal of the Association for Vascular Access. 2011;16:20-33.
149. **Hadaway L.** Needleless connectors for IV catheters. Am J Nurs. 2012;112:32-44.[PMID:23075549]doi:10.1097/01.NAJ.0000422253.72836.c1
150. **Hadaway L.** Short peripheral intravenous catheters and infections. J Infus Nurs. 2012;35:230-40. [PMID: 22759827] doi:10.1097/NAN.0b013e31825af099
151. **Harnage SA.** Acheiving zero catheter related blood stream infection: 15 months success in a community based medical center. Journal of the Association for Vascular Access. 2007;12:218-25.
152. **Harnage S.** Seven years of zero central-line-associated bloodstream infections. Br J Nurs. 2012;21:S6-12. [PMID: 23469515]
153. **Hughes ME.** PICC-related thrombosis: pathophysiology, incidence, morbidity, and the effect of ultrasound-guided placement technique on occurrence in cancer patients. Journal of the Association for Vascular Access. 2011;16:8-18.
154. **Hughes ME.** Reducing PICC migrations and improving patient outcomes. Br J Nurs. 2014;23:S12-8.
155. **Itkin M, Mondshein JI, Stavropoulos SW, Shlansky-Goldberg RD, Soulen MC, Trerotola SO.** Peripherally inserted central catheter thrombosis–reverse tapered versus nontapered catheters: a randomized controlled study. J Vasc Interv Radiol. 2014;25:85-91. [PMID: 24268631] doi:10.1016/j.jvir.2013.10.009
156. **Jin J, Chen C, Zhao R, Li A, Shentu Y, Jiang N.** Repositioning techniques of malpositioned peripherally inserted central catheters. J Clin Nurs. 2013;22:1791-804. [PMID: 23240918] doi:10.1111/jocn.12004
157. **Joffe HV, Goldhaber SZ.** Upper-extremity deep vein thrombosis. Circulation. 2002;106:1874-80. [PMID: 12356644]
158. **Johansson E, Hammarskjöld F, Lundberg D, Heibert Arnlind M.** A survey of the current use of peripherally inserted central venous catheter (PICC) in Swedish oncology departments [Letter]. Acta Oncol. 2013;52:1241-2. [PMID: 23786177] doi:10.3109/0284186X.2013.806820
159. **Johnston AJ, Streater CT, Noorani R, Crofts JL, Del Mundo AB, Parker RA.** The effect of peripherally inserted central catheter (PICC) valve technology on catheter occlusion rates–the 'ELeCTRiC' study. J Vasc Access. 2012;13:421-5. [PMID: 22505280] doi:10.5301/jva.5000071
160. **Jones MA, Lee DY, Segall JA, Landry GJ, Liem TK, Mitchell EL, et al.** Characterizing resolution of catheter-associated upper extremity deep venous thrombosis. J Vasc Surg. 2010;51:108-13. [PMID: 19879094] doi:10.1016/j.jvs.2009.07.124
161. **Kallen AJ, Patel PR, O'Grady NP.** Preventing catheter-related bloodstream infections outside the intensive care unit: expanding prevention to new settings. Clin Infect Dis. 2010;51:335-41. [PMID: 20572762] doi:10.1086/653942
162. **Kelly L.** A practical guide to safe PICC placement. Br J Nurs. 2013;22:S13-9. [PMID: 23752499]
163. **King MM, Rasnake MS, Rodriguez RG, Riley NJ, Stamm JA.** Peripherally inserted central venous catheter-associated thrombosis: retrospective analysis of clinical risk factors in adult patients. South Med J. 2006;99:1073-7. [PMID: 17100027]
164. **Lamperti M, Bodenham AR, Pittiruti M, Blaivas M, Augoustides JG, Elbarbary M, et al.** International evidence-based recommendations on ultrasound-guided vascular access. Intensive Care Med. 2012;38:1105-17. [PMID: 22614241] doi:10.1007/s00134-012-2597-x
165. **Latham HE, Rawson ST, Dwyer TT, Patel CC, Wick JA, Simpson SQ.** Peripherally inserted central catheters are equivalent to centrally inserted catheters in intensive care unit patients for central venous pressure monitoring. J Clin Monit Comput. 2012;26:85-90. [PMID: 22290064] doi:10.1007/s10877-012-9337-1
166. **Lelkes V, Kumar A, Shukla PA, Contractor S, Rutan T.** Analysis of the Sherlock II tip location system for inserting peripherally inserted central venous catheters. Clin Imaging. 2013;37:917-21. [PMID: 23867159] doi:10.1016/j.clinimag.2013.04.009
167. **Leroyer C, Lashéras A, Marie V, Le Bras Y, Carteret T, Dupon M, et al.** Prospective follow-up of complications related to peripherally inserted central catheters. Med Mal Infect. 2013;43:350-5. [PMID: 23876203] doi:10.1016/j.medmal.2013.06.013
168. **Leung TK, Chang CP, Lee CM, Shen LK.** Retrospective study of the total insertion period of peripherally inserted central catheter: discussion of anti-thrombogenic surface and other biomaterial requirements. Biomed Mater Eng. 2006;16:183-8. [PMID: 16518017]
169. **Loupus D, Scheutrumpf S, Vazquez L.** A retrospective review of peripherally inserted central catheters and upper extremity deep venous thrombosis in persons with cervical spinal cord injuries. Journal of the Association for Vascular Access. 2008;13:82-7.
170. **Maki DG, Kluger DM, Crnich CJ.** The risk of bloodstream infection in adults with different intravascular devices: a systematic review of 200 published prospective studies. Mayo Clin Proc. 2006;81:1159-71. [PMID: 16970212]
171. **Malinoski D, Ewing T, Bhakta A, Schutz R, Imayanagita B, Casas T, et al.** Which central venous catheters have the highest rate of catheter-associated deep venous thrombosis: a prospective analysis of 2,128 catheter days in the surgical intensive care unit. J Trauma Acute Care Surg. 2013;74:454-60. [PMID: 23354238] doi:10.1097/TA.0b013e31827a0b2f
172. **Marnejon T, Angelo D, Abdou AA, Gemmel D.** Risk factors for upper extremity venous thrombosis associated with peripherally inserted central venous catheters. Journal of the Association for Vascular Access. 2012;13:231-8.
173. **Marschall J, Mermel LA, Fakih M, Hadaway L, Kallen A, O'Grady NP, et al.** Strategies to prevent central line-associated bloodstream infections in acute care hospitals: 2014 update. Infect Control Hosp Epidemiol. 2014;35 Suppl 2:S89-107. [PMID: 25376071]
174. **Mermis JD, Strom JC, Greenwood JP, Low DM, He J, Stites SW, et al.** Quality improvement initiative to reduce deep vein thrombosis associated with peripherally inserted central catheters in adults with cystic fibrosis. Ann Am Thorac Soc. 2014;11:1404-10. [PMID: 25295962] doi:10.1513/AnnalsATS.201404-175OC
175. **Merrell SW, Peatross BG, Grossman MD, Sullivan JJ, Harker WG.** Peripherally inserted central venous catheters. Low-risk alternatives for ongoing venous access. West J Med. 1994;160:25-30. [PMID: 8128698]
176. **Meyer BM.** Managing peripherally inserted central catheter thrombosis risk: a guide for clinical best practice. Journal of the Association for Vascular Access. 2011;16:144-7.
177. **Milstone AM, Sengupta A.** Do prolonged peripherally inserted central venous catheter dwell times increase the risk of bloodstream infection? Infect Control Hosp Epidemiol. 2010;31:1184-7. [PMID: 20887217] doi:10.1086/656589
178. **Minkovich L, Djaiani G, McCluskey SA, Mitsakakis N, Gilbert RW, Beattie WS.** Frequent malpositions of peripherally inserted cen-

tral venous catheters in patients undergoing head and neck surgery. Can J Anaesth. 2011;58:709-13. [PMID: 21547595] doi:10.1007/s12630-011-9512-8
179. **Miyagaki H, Nakajima K, Hara J, Yamasaki M, Kurokawa Y, Miyata H, et al.** Performance comparison of peripherally inserted central venous catheters in gastrointestinal surgery: a randomized controlled trial. Clin Nutr. 2012;31:48-52. [PMID: 21945145] doi:10.1016/j.clnu.2011.09.002
180. **Morden P, Sokhandon F, Miller L, Savin M, Kirsch M, Farah M, et al.** The role of saline flush injection rate in displacement of CT-injectable peripherally inserted central catheter tip during power injection of contrast material. AJR Am J Roentgenol. 2014;202:W13-8. [PMID: 24370160] doi:10.2214/AJR.13.10625
181. **Moureau N, Poole S, Murdock MA, Gray SM, Semba CP.** Central venous catheters in home infusion care: outcomes analysis in 50,470 patients. J Vasc Interv Radiol. 2002;13:1009-16. [PMID: 12397122]
182. **Mukherjee S.** Catheter related upper extremity thrombosis in oncological practice–a study on incidence and risk factors [Abstract]. Br J Cancer. 2001;85:66.
183. **Nash EF, Helm EJ, Stephenson A, Tullis E.** Incidence of deep vein thrombosis associated with peripherally inserted central catheters in adults with cystic fibrosis. J Vasc Interv Radiol. 2009;20:347-51. [PMID: 19157904] doi:10.1016/j.jvir.2008.11.018
184. **Nifong TP, McDevitt TJ.** The effect of catheter to vein ratio on blood flow rates in a simulated model of peripherally inserted central venous catheters. Chest. 2011;140:48-53. [PMID: 21349931] doi:10.1378/chest.10-2637
185. **Nunoo RH, Asgeirsson T, Slay H, Zhang S, Luchtefeld M.** The impact of PICC lines on venous thromboembolism (VTE) rates in patients who undergo bowel major bowel resection [Abstract]. J Am Coll Surg. 2011;213:S23.
186. **O'Grady NP, Chertow DS.** Managing bloodstream infections in patients who have short-term central venous catheters. Cleve Clin J Med. 2011;78:10-7. [PMID: 21199902] doi:10.3949/ccjm.77a.10015
187. **Oliver G, Jones M.** ECG or X-ray as the 'gold standard' for establishing PICC-tip location? Br J Nurs. 2014;23 Suppl 19:S10-6. [PMID: 25345477] doi:10.12968/bjon.2014.23.Sup19.S10
188. **Ong B, Gibbs H, Catchpole I, Hetherington R, Harper J.** Peripherally inserted central catheters and upper extremity deep vein thrombosis. Australas Radiol. 2006;50:451-4. [PMID: 16981942]
189. **Paauw JD, Borders H, Ingalls N, Boomstra S, Lambke S, Fedeson B, et al.** The incidence of PICC line-associated thrombosis with and without the use of prophylactic anticoagulants. JPEN J Parenter Enteral Nutr. 2008;32:443-7. [PMID: 18596317] doi:10.1177/0148607108319801
190. **Pari C, Passoni C, Di Pietro A, Magon G, Piredda A, Biffi R.** From international guidelines to a shared clinical pathway: the IEO PICC team experience. Journal of the Association for Vascular Access. 2011;12:81.
191. **Patel BM, Dauenhauer CJ, Rady MY, Larson JS, Benjamin TR, Johnson DJ, et al.** Impact of peripherally inserted central catheter on catherer-related bloostream infections in the intensive care unit. J Patient Saf. 2007;3:142-8.
192. **Patel GS, Jain K, Kumar R, Strickland AH, Pellegrini L, Slavotinek J, et al.** Comparison of peripherally inserted central venous catheters (PICC) versus subcutaneously implanted port-chamber catheters by complication and cost for patients receiving chemotherapy for non-haematological malignancies. Support Care Cancer. 2014;22:121-8. [PMID: 24005884] doi:10.1007/s00520-013-1941-1
193. **Paz-Fumagalli R, Miller YA, Russell BA, Crain MR, Beres RA, Mewissen MW.** Impact of peripherally inserted central catheters on phlebitic complications of peripheral intravenous therapy in spinal cord injury patients. J Spinal Cord Med. 1997;20:341-4. [PMID: 9261781]
194. **Penney-Timmons E, Sevedge S.** Outcome data for peripherally inserted central catheters used in an acute care setting. J Infus Nurs. 2004;27:431-6. [PMID: 15586107]
195. **Periard D, Monney P, Waeber G, Zurkinden C, Mazzolai L, Hayoz D, et al.** Randomized controlled trial of peripherally inserted central catheters vs. peripheral catheters for middle duration in-hospital intravenous therapy. J Thromb Haemost. 2008;6:1281-8. [PMID: 18541001] doi:10.1111/j.1538-7836.2008.03053.x
196. **Periard D.** Peripherally inserted central catheter in leukemia: insertion site determines clotting risk. Leuk Lymphoma. 2010;51:1391-2. [PMID: 20687797] doi:10.3109/10428194.2010.508824
197. **Petree C, Wright DL, Sanders V, Killion JB.** Reducing blood stream infections during catheter insertion. Radiol Technol. 2012;83:532-40. [PMID: 22763830]
198. **Pittiruti M, Hamilton H, Biffi R, MacFie J, Pertkiewicz M; ESPEN.** ESPEN Guidelines on Parenteral Nutrition: central venous catheters (access, care, diagnosis and therapy of complications). Clin Nutr. 2009;28:365-77. [PMID: 19464090] doi:10.1016/j.clnu.2009.03.015
199. **Pittiruti M, Brutti A, Celentano D, Pomponi M, Biasucci DG, Annetta MG, et al.** Clinical experience with power-injectable PICCs in intensive care patients. Crit Care. 2012;16:R21. [PMID: 22305301] doi:10.1186/cc11181
200. **Pongruangporn M, Ajenjo MC, Russo AJ, McMullen KM, Robinson C, Williams RC, et al.** Patient- and device-specific risk factors for peripherally inserted central venous catheter-related bloodstream infections. Infect Control Hosp Epidemiol. 2013;34:184-9. [PMID: 23295565] doi:10.1086/669083
201. **Qiu XX, Guo Y, Fan HB, Shao J, Zhang XB.** Incidence, risk factors and clinical outcomes of peripherally inserted central catheter spontaneous dislodgment in oncology patients: a prospective cohort study. Int J Nurs Stud. 2014;51:955-63. [PMID: 24246096] doi:10.1016/j.ijnurstu.2013.10.021
202. **Raad II, Luna M, Khalil SA, Costerton JW, Lam C, Bodey GP.** The relationship between the thrombotic and infectious complications of central venous catheters. JAMA. 1994;271:1014-6. [PMID: 8139059]
203. **Richters A, van Vliet M, Peer PG, Verweij PE, Laros-van Gorkom BA, Blijlevens NM, et al.** Incidence of and risk factors for persistent gram-positive bacteraemia and catheter-related thrombosis in haematopoietic stem cell transplantation. Bone Marrow Transplant. 2014;49:264-9. [PMID: 24185587] doi:10.1038/bmt.2013.172
204. **Robinson MK, Mogensen KM, Grudinskas GF, Kohler S, Jacobs DO.** Improved care and reduced costs for patients requiring peripherally inserted central catheters: the role of bedside ultrasound and a dedicated team. JPEN J Parenter Enteral Nutr. 2005;29:374-9. [PMID: 16107601]
205. **Romagnoli E, Simioni L, Bullian P, Masia G, Fai B, Cecconello M, et al.** Upper arm deep venous thrombosis in peripherally inserted central venous catheter (PICC): data in our oncologic patients population. Thromb Res. 2010;125:S170.
206. **Rooden CJ, Tesselaar ME, Osanto S, Rosendaal FR, Huisman MV.** Deep vein thrombosis associated with central venous catheters–a review. J Thromb Haemost. 2005;3:2409-19. [PMID: 15975139]
207. **Ros M, Borras N, Domingo-Demench J, Arteta E, Valverde M.** Risk factors for venous thrombotic events in patients with head and neck cancer treated through a peripherally inserted central venous catheter. Eur J Cancer Suppl. 2005;3:442.
208. **Rosenthal K.** Bridging the I.V. access gap with midline catheters. Nursing. 2008;38 Suppl Med:2-5. [PMID: 18708995] doi:10.1097/01.NURSE.0000334057.91316.45
209. **Rutkoff GS.** 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. 2014;19:172-9.
210. **Sansivero G, Siskin G, Tessier M, MacDowell B.** Securacath subcutaneous securement in peripherally inserted central catheters: results of a prospective 50 patient trial with an internal securement device. J Vasc Access. 2011;12:81.
211. **Santolim TQ, Santos LA, Giovani AM, Dias VC.** The strategic role of the nurse in the selection of IV devices. Br J Nurs. 2012;21:S28-32. [PMID: 23469519]
212. **Schimp VL, Munkarah AR, Morris RT, Deppe G, Malone J Jr.** Upper extremity deep vein thrombosis associated with indwelling

peripheral venous catheters in gynecology oncology patients. Gynecol Oncol. 2003;89:301-5. [PMID: 12713995]
213. **Seeley MA, Santiago M, Shott S.** Prediction tool for thrombi associated with peripherally inserted central catheters. J Infus Nurs. 2007;30:280-6. [PMID: 17895807]
214. **Shea CD, Chang GL, Rahimi R, Mahdavian M.** The incidence of symptomatic, PICC-related venous thrombosis in hospitalized patients with inflammatory bowel disease [Abstract]. Am J Gastroenterol. 2006;101:S460.
215. **Simcock L.** No going back: advantages of ultrasound-guided upper arm PICC placement. Journal of the Association for Vascular Access. 2008;13:191-7.
216. **Skaff ER, Doucette S, McDiarmid S, Huebsch L, Sabloff M.** Vascular access devices in leukemia: a retrospective review amongst patients treated at the Ottawa Hospital with induction chemotherapy for acute leukemia. Leuk Lymphoma. 2012;53:1090-5. [PMID: 22080756] doi:10.3109/10428194.2011.639879
217. **Skiest DJ, Abbott M, Keiser P.** Peripherally inserted central catheters in patients with AIDS are associated with a low infection rate. Clin Infect Dis. 2000;30:949-52. [PMID: 10880311]
218. **Smith JR, Friedell ML, Cheatham ML, Martin SP, Cohen MJ, Horowitz JD.** Peripherally inserted central catheters revisited. Am J Surg. 1998;176:208-11. [PMID: 9737634]
219. **Smith RN, Nolan JP.** Central venous catheters. BMJ. 2013;347:f6570. [PMID: 24217269] doi:10.1136/bmj.f6570
220. **Snelling R, Jones G, Figueredo A, Major P.** Central venous catheters for infusion therapy in gastrointestinal cancer. A comparative study of tunnelled centrally placed catheters and peripherally inserted central catheters. J Intraven Nurs. 2001;24:38-47. [PMID: 11836843]
221. **Sperry BW, Roskos M, Oskoui R.** The effect of laterality on venous thromboembolism formation after peripherally inserted central catheter placement. J Vasc Access. 2012;13:91-5. [PMID: 21948128] doi:10.5301/jva.5000014
222. **Stokowski G, Steele D, Wilson D.** The use of ultrasound to improve practice and reduce complication rates in peripherally inserted central catheter insertions: final report of investigation. J Infus Nurs. 2009;32:145-55. [PMID: 19444022] doi:10.1097/NAN.0b013e3181a1a98f
223. **Strahilevitz J, Lossos IS, Verstandig A, Sasson T, Kori Y, Gillis S.** Vascular access via peripherally inserted central venous catheters (PICCs): experience in 40 patients with acute myeloid leukemia at a single institute. Leuk Lymphoma. 2001;40:365-71. [PMID: 11426559]
224. **Thakarar K, Collins M, Kwong L, Sulis C, Korn C, Bhadelia N.** The role of tissue plasminogen activator use and systemic hypercoagulability in central line-associated bloodstream infections. Am J Infect Control. 2014;42:417-20. [PMID: 24559598] doi:10.1016/j.ajic.2013.11.016
225. **Timsit JF, Farkas JC, Boyer JM, Martin JB, Misset B, Renaud B, et al.** Central vein catheter-related thrombosis in intensive care patients: incidence, risks factors, and relationship with catheter-related sepsis. Chest. 1998;114:207-13. [PMID: 9674471]
226. **Tiwari MM, Hermsen ED, Charlton ME, Anderson JR, Rupp ME.** Inappropriate intravascular device use: a prospective study. J Hosp Infect. 2011;78:128-32. [PMID: 21507524] doi:10.1016/j.jhin.2011.03.004
227. **Touré A, Duchamp A, Peraldi C, Barnoud D, Lauverjat M, Gelas P, et al.** A comparative study of peripherally-inserted and Broviac catheter complications in home parenteral nutrition patients. Clin Nutr. 2015;34:49-52. [PMID: 24439240] doi:10.1016/j.clnu.2013.12.017
228. **Trerotola SO, Thompson S, Chittams J, Vierregger KS.** Analysis of tip malposition and correction in peripherally inserted central catheters placed at bedside by a dedicated nursing team. J Vasc Interv Radiol. 2007;18:513-8. [PMID: 17446542]
229. **Trerotola SO, Stavropoulos SW, Mondschein JI, Patel AA, Fishman N, Fuchs B, et al.** Triple-lumen peripherally inserted central catheter in patients in the critical care unit: prospective evaluation. Radiology. 2010;256:312-20. [PMID: 20574104] doi:10.1148/radiol.10091860
230. **Trick WE, Vernon MO, Welbel SF, Wisniewski MF, Jernigan JA, Weinstein RA.** Unnecessary use of central venous catheters: the need to look outside the intensive care unit. Infect Control Hosp Epidemiol. 2004;25:266-8. [PMID: 15061422]
231. **Turcotte S, Dubé S, Beauchamp G.** Peripherally inserted central venous catheters are not superior to central venous catheters in the acute care of surgical patients on the ward. World J Surg. 2006;30:1605-19. [PMID: 16865322]
232. **Ugas MA, Cho H, Trilling GM, Tahir Z, Raja HF, Ramadan S, et al.** Central and peripheral venous lines-associated blood stream infections in the critically ill surgical patients. Ann Surg Innov Res. 2012;6:8. [PMID: 22947496] doi:10.1186/1750-1164-6-8
233. **Vidal V, Muller C, Jacquier A, Giorgi R, Le Corroller T, Gaubert J, et al.** [Prospective evaluation of PICC line related complications]. J Radiol. 2008;89:495-8. [PMID: 18477956]
234. **Vizcarra C, Cassutt C, Corbitt N, Richardson D, Runde D, Stafford K.** Recommendations for improving safety practices with short peripheral catheters. J Infus Nurs. 2014;37:121-4. [PMID: 24583942] doi:10.1097/NAN.0000000000000028
235. **Wallis MC, McGrail M, Webster J, Marsh N, Gowardman J, Playford EG, et al.** Risk factors for peripheral intravenous catheter failure: a multivariate analysis of data from a randomized controlled trial. Infect Control Hosp Epidemiol. 2014;35:63-8. [PMID: 24334800] doi:10.1086/674398
236. **Wilson TJ, Stetler WR Jr, Fletcher JJ.** Comparison of catheter-related large vein thrombosis in centrally inserted versus peripherally inserted central venous lines in the neurological intensive care unit. Clin Neurol Neurosurg. 2013;115:879-82. [PMID: 22948189] doi:10.1016/j.clineuro.2012.08.025
237. **Worley TA, Revesz E, Clark ET, Podbielkski FJ.** Peripherally inserted central catheters do not increase the risk of upper extremity deep vein thrombosis. Chest. 2007;132:492a.
238. **Worth LJ, Seymour JF, Slavin MA.** Infective and thrombotic complications of central venous catheters in patients with hematological malignancy: prospective evaluation of nontunneled devices. Support Care Cancer. 2009;17:811-8. [PMID: 19096883] doi:10.1007/s00520-008-0561-7
239. **Xing L, Adhikari VP, Liu H, Kong LQ, Liu SC, Li HY, et al.** Diagnosis prevention and treatment for PICC-related upper extremity deep vein thrombosis in breast cancer patients. Asia Pac J Clin Oncol. 2012;8:e12-6. [PMID: 22897494] doi:10.1111/j.1743-7563.2011.01508.x
240. **Yamada R, Morita T, Yashiro E, Otani H, Amano K, Tei Y, et al.** Patient-reported usefulness of peripherally inserted central venous catheters in terminally ill cancer patients. J Pain Symptom Manage. 2010;40:60-6.[PMID:20638981]doi:10.1016/j.jpainsymman.2009.11.327
241. **Yap YS, Karapetis C, Lerose S, Iyer S, Koczwara B.** Reducing the risk of peripherally inserted central catheter line complications in the oncology setting. Eur J Cancer Care (Engl). 2006;15:342-7. [PMID: 16968315]
242. **Yi XL, Chen J, Li J, Feng L, Wang Y, Zhu JA, et al.** Risk factors associated with PICC-related upper extremity venous thrombosis in cancer patients. J Clin Nurs. 2014;23:837-43. [PMID: 23710585] doi:10.1111/jocn.12227
243. **Yue ZY, Li JY, Yu CH, Zhao SZ, Fu Y.** [Complications with peripherally inserted central catheters—observations and nursing experiences at one medical center in Chengdu]. Hu Li Za Zhi. 2010;57:79-85. [PMID: 20535681]
244. **Zhu M, Cui H, Xi H, Ye G, Li D, Wei J.** Prevention and treatment of deep vein thrombosis induced by peripherally inserted enteral catheter. Chinese Journal of Clinical Nutrition. 2008;16:160-3.
245. **Zochios V, Umar I, Simpson N, Jones N.** Peripherally inserted central catheter (PICC)-related thrombosis in critically ill patients. J Vasc Access. 2014;15:329-37. [PMID: 24811591] doi:10.5301/jva.5000239

Table 1. Summary of Studies Included in the Literature Review

Study, Year (Reference)	Participants, *n*	Design	Focus or Overview	Study Sample and Characteristics	Device	Findings and Comments
Abdullah et al, 2005 (91)	26	Prospective cohort study	Determine the incidence of DVT in patients with PICCs as diagnosed with an upper-limb venogram at the time of PICC removal	Patients aged 15–70 y with PICCs at the University of Malaya Medical Centre	PICC	PICCs were associated with a significant rate of DVT by venography; no correlation between size and insertion site of catheter and UEVTE were noted.
Ahn et al, 2013 (57)	237	Retrospective cohort study	Ascertain risk factors associated with PICC-related DVT in cancer patients	Patients with cancer and PICCs at the Dallas VA medical center from 2006 to 2009	PICC	Antiplatelet agents were protective against DVT whereas use of ESAs, hospitalization, and treatment dose anticoagulation were associated with DVT
Akers and Chelluri, 2009 (92)	5	Retrospective cohort study	Analysis of CVC use 18 mo before and after a hospitalist training program to place PICCs	3 hospitalists were trained to place PICCs in patients at 1 university-affiliated community hospital	PICC	After training, use of CVCs doubled, with PICCs representing over 80% of all devices
Akl et al, 2011 (93)	3611	Cochrane systematic review	Evaluate the efficacy and safety of anticoagulation in patients with cancer	Patients with cancer and CVCs from 12 RCTs	CVC	A clear rationale supporting use of anticoagulants to prevent CRT could not be defined
Alexandrou et al, 2014 (94)	3447	Prospective cohort study	Report characteristics and outcomes from a CVC insertion service offered by trained nurses	Adult patients with a CVC, PICC, high-flow dialysis catheter, or midlines in one tertiary care university hospital in Sydney, Australia, between November 1996 and December 2009	CVADs	Trained vascular access nurses using US and best practice can lower complication rates during insertion and may improve patient safety
Alhimyary et al, 1996 (95)	231	Prospective cohort study	Report complications using PICCs for TPN in non-ICU patients compared to placement of CVCs in the subclavian vein	Non-ICU patients who needed TPN received PICCs inserted in the antecubital vein or CVCs at 1 institution from July 1991 to March 1994	CVC, PICC	Complication rates did not differ significantly between the 2 groups; PICCs can be used safely for exclusive TPN administration
Alkindi et al, 2012 (96)	16	Retrospective cohort study	Review outcomes related to implanted port placement in patients with sickle cell disease who required red cell exchange/transfusion	Patients with sickle cell disease who were frequently hospitalized at a single academic medical center	Port	Of 24 devices placed, 17 required removal owing to infection or thrombosis. The median working life of the ports was 688.5 d (range, 39–3925 d). The number of infections was significantly correlated with the number of ports (Pearson $r = 0.66$; $P < 0.01$)
Allan et al, 2012 (97)	10	In vivo comparison study	Rabbit model used to evaluate the performance of antimicrobial (chlorhexidine)-coated PICCs in a clinical setting, compared with uncoated catheters	Healthy, 15-week-old New Zealand white female rabbits	PICC	Chlorhexidine-coated catheters significantly reduced microbial colonization and prevented microbial migration compared with uncoated devices
Allen et al, 2000 (98)	119	Retrospective cohort study	Evaluate the rate of DVT in patients who had venography before and after PICC placement	354 PICCs were placed in 119 patients between April 1992 and August 1998 at a single center; all patients underwent venography before and after PICC placement	PICC	Overall rate of DVT associated with PICCs was 38%; incidence was highest for PICCs placed in the cephalic vein (57%)
Al Raiy et al, 2010 (1)	1260	Prospective cohort study	Compare PICC-related CLABSI rates with those associated with CVCs in hospitalized patients	Patients with CVCs in non-ICUs and patients with PICCs hospital-wide at 1 institution	CVC, PICC	CVCs and PICCs had similar rates of CLABSI; with surveillance and intervention, high-risk CVCs were removed; PICCs may be safer for longer IV access
Al-Tawfiq et al, 2012 (99)	92 PICCs	Prospective cohort study	Describe PICC-related BSI incidence in 1 hospital setting	Hospitalized patients with PICCs at Dhahran Health Care Center, Saudi Arabia, from January to December 2009	PICC	Rates of PICC-related CLABSI varied according to patient factors, such as cancer and critical illness
Amerasekera et al, 2009 (100)	NA	Review	Overview of venous anatomy and complications related to PICC use with radiographic images	NA	PICC	To help diagnose PICC complications, radiologists should have good knowledge of venous anatomy and imaging techniques related to PICC insertion
Anderson, 2004 (42)	6004 midline catheters; 337 PICCs	Review article and retrospective cohort study	Examine midline catheter use as a bridge between peripheral and central catheters over a 6-year period	Patients at Evangelical Community Hospital in Lewisburg, PA	PIVC, midline catheter, PICCIV	Substituting a midline for a short peripheral catheter led to improved outcomes, including reduced rates of venipuncture, decreased length of stay, and improved staff and patient satisfaction
Armstrong et al, 2013 (101)	49	Case-control study	Compare bacteremia rates in patients with antibiotic (minocycline–rifampin) impregnated PICCs vs. those who received conventional PICCs	Patients admitted to a regional burn center who required a PICC as part of clinical care	PICC	Antibiotic-impregnated PICCs substantially decreased the rate of bacteremia in burn patients (0% vs. 50%)
Association for Vascular Access, 2011 (102)	NA	Guideline	Position statement and recommendations for the insertion of CVADs by registered nurses using US guidance	NA	CVC, midline catheter, PICC	US guidance for placement of CVADs by trained nurses is safe and cost-effective and should become part of routine practice
Aw et al, 2012 (103)	340	Retrospective cohort study	Determine the incidence of symptomatic PICC-related DVT in cancer patients	Patients with cancer who had PICCs placed by US guidance for delivery of chemotherapy	PICC	Symptomatic PICC-related DVT is frequent in this population; diabetes and chronic obstructive pulmonary disease are risk factors for PICC-related DVT
Bai and Hou, 2010 (104)	37	Prospective cohort study	Explore feasibility of US-guided PICC insertion in elderly adults using modified Seldinger technique	Elderly adults with PICCs inserted by US guidance in a Chinese medical center	PICC	US-guided insertion of PICCs is safe and effective for elderly adults with nonpalpable veins

Continued on following page

Table 1–Continued

Study, Year (Reference)	Participants, *n*	Design	Focus or Overview	Study Sample and Characteristics	Device	Findings and Comments
Bai et al, 2013 (105)	128	Prospective cohort study	Determine clinical outcomes in patients who received chemotherapy via an indwelling IVs compared to PICCs	Patients with lung cancer in 1 radiation oncology department in Shenyang, China	IV, PICC	Patients undergoing combined radiation therapy and chemotherapy prefer a PIVC over a PICC for intermittent chemotherapy
Barr et al, 2012 (106)	2766	Retrospective cohort study	Examine rates of complications and outcomes in patients receiving outpatient antibiotic therapy by device type	Patients in the ambulatory care setting using the Glasgow outpatient antibiotic therapy service	Midline catheter, PICC, TCVC	Line infections were associated with duration of line use, female sex, and TCVCs; dwell time was significantly associated with risk for line infection
Bates et al, 2012 (107)	NA	Guidelines for diagnosis of DVT	Identify and recommend strategies for diagnosis of DVT in ambulatory adults	Eligible studies included those that addressed diagnostic accuracy and clinical outcomes	PICC, CVC	For diagnosis of UEDVT, initial evaluation with combined modality US over other tests, including venography and D-dimer, is recommended
Baumgarten et al, 2013 (108)	NR	Prospective cohort study	Evaluate a training and implementation program to reduce CLABSI in the home health care environment	Ochsner home infusion outpatients who received PICC lines were included; a checklist for best dressing practices and order sets were evaluated	PICC	After institution of a checklist and an order set to standardize care in home infusion patients, PICC infection rates decreased by 46% compared with prior years
Baxi et al, 2008 (109)	1350 PICCs	Retrospective cohort study	Evaluate the association between post-placement and risk for PICC-related BSI and DVT	Hospitalized patients from February to August 2007 at a quaternary medical center in Michigan	PICC	Post-placement adjustment of PICCs was not associated with CLABSI or DVT. Factors associated with CLABSI were diabetes, immune suppression, and number of lumens; lumens were associated with risk for DVT and catheter thrombosis
Baxi et al, 2013 (110)	1652	Retrospective cohort study	Evaluate the association between post-placement and risk for PICC-related BSI and DVT	Hospitalized patients from February to August 2007 at a quaternary medical center in Michigan	PICC	Post-placement adjustment of PICCs was not associated with CLABSI or DVT. Factors associated with CLABSI were power-capable PICCs, diabetes, immune-suppression and number of lumens; lumens were also associated with risk for DVT and thrombosis
British Committee for Standards in Haematology, 1997 (69)	NA	Guidelines	British Committee for Standards in Haematology guidelines that review basic principles of the care of patients with CVCs	2007 update to the 1997 guidelines that provide major recommendations for use of several devices in hospitalized and ambulatory patients	CVC, PICC, port	Major recommendations in this update include use of US during insertion, use of CVCs for short-term access when peripheral access is not possible, and use of tunneled catheters or ports for longer-term access. These guidelines recommend avoidance of PICCs in inpatient settings because of thrombosis risk
Bellesi et al, 2013 (58)	24	Prospective cohort study	Evaluate the efficacy and safety of PICCs as long-term VADs for chemotherapy administration	Patients undergoing hematopoietic stem cell transplantation with PICCs inserted between May and November 2008 in Italy	PICC	The rate of CLABSI with PICCs was similar to that of conventional CVCs
Bonciarelli et al, 2011 (111)	NA	Guideline	Define recommendations for the correct and safe use of implantable venous access devices for diagnostic procedures	Patients using ports for radiodiagnostics	Port	Patient safety, cost-effectiveness, and efficiency are important aspects in the use of ports in radiodiagnostics, especially in patients with cancer
Bonizzoli et al, 2011 (112)	239	Prospective cohort study	Assess rates of thrombosis after PICC placement in a cohort of critically ill patients	Patients discharged from the ICU with a central venous device at Careggi Teaching Hospital, Florence, Italy, from January to August 2008	CVC, PICC	Higher risk for DVT in patients with PICCs was noted (27.2% vs. 9.6%). Female sex and the left basilic vein as the access site were associated with PICC-related DVT
Bottino et al, 1979 (113)	81	Prospective cohort study	Assess risks related to long-term use of peripherally inserted silicone elastomer CVCs in cancer populations	Patients with cancer requiring prolonged IV therapy, including chemotherapy	PICC	Although 6% of catheters were removed for phlebitis, peripherally inserted silicone elastomer CVCs may be used for long-term central venous access
Burg and Myles, 2005 (114)	79	Cross-sectional survey	Identify complications associated with antepartum PICC use	Antepartum patients with IV therapy records at St. Mary's Health Center from January 2000 to March 2005	PICC	PICCs had a low risk for complications and were otherwise effective for long-term IV access. One patient had a DVT, and 6% had PICCs removed for other complications
Burns and Lamberth, 2010 (5)	NA	Review	Discuss resources, costs, policies, and procedures related to developing vascular access teams	A review of the formation of vascular access teams in 2 hospitals and the costs and benefits associated with these programs	PICC, midline catheter, CVC	Vascular access teams, though associated with upfront costs, have important downstream benefits and cost savings
Butler et al, 2011 (115)	185	Retrospective cohort study	Examine the association between PICC placement and subsequent risk for catheter-related infection in hemodialysis patients	Patients requiring hemodialysis with catheter placements and exchanges at 1 university hospital from September 2003 to September 2008	PICC	Prior PICC use was 2.46 times more likely to be associated with catheter-related infection compared with patients who never received this device
Caparas and Hu, 2014 (38)	54	Prospective, controlled, randomized clinical trial	Assess whether vancomycin can be safely administered through a new midline catheter compared with PICCs	Patients scheduled to receive short-term IV vancomycin at a single medical center in Queens, New York	Midline catheter, PICC	Short-term midline catheters were safe and cost-effective for delivering vancomycin for durations ≤6 d
Cape et al, 2013 (116)	66	Retrospective cohort study	Analyze PICC-related complications in pregnant women who received PICCs for various clinical indications	Pregnant women with PICCs inserted between January 2000 and June 2006 at 1 medical center	PICC	PICC insertion in pregnant women was associated with high rates of bacteremia and thrombosis.

Continued on following page

Table 1–Continued

Study, Year (Reference)	Participants, *n*	Design	Focus or Overview	Study Sample and Characteristics	Device	Findings and Comments
Catalano et al, 2011 (117)	500	Prospective cohort study	Analyze rates of catheter-related thoracic DVT in patients with cancer by using multidetector CT	Cancer patients who had a CVAD and underwent CT for any reason	CVC, PICC, port	CVC-related thrombosis is common in patients with cancer and can be difficult to detect by clinical means
Chakravarthy et al, 2005 (118)	31	Randomized, controlled clinical trial	Evaluate the incidence of PICC-related DVT in ICU patients	Critically ill patients who received a PICC during routine clinical care at 1 academic medical center	PICC	PICC-related DVT in critically ill patients is common (65%) and largely asymptomatic; vigilance for DVT in this population is suggested
Chemaly et al, 2002 (119)	2063	Retrospective cohort study	Assess the safety of PICCs used for long-term IV antibiotic administration	Patients at the Cleveland Clinic Foundation who had a PICC placed for IV antibiotics between January 1994 and October 1996	PICC	PICC use was associated with UEDVT. Patients who were younger, had prior VT, or received amphotericin infusion through the PICC were at greater risk for DVT
Cheong et al, 2004 (120)	17	Retrospective cohort study	Document the frequency of PICC complications in patients with solid tumors	Patients with solid tumors treated at Flinders Medical Centre, South Australia, between January 2000 and March 2001	PICC	Compared with patients without cancer, a high rate of complications (sepsis, thrombosis, blockage, and leakage) was found in patients with cancer who received PICCs
Chittick et al, 2013 (121)	265	Prospective cohort study	Compare patients with early- and late-onset PICC-related CLABSI to assess risk factors	Patients who developed PICC-related CLABSI at 1 academic center	PICC	There are significant differences in the microbiological characteristics of patients with early- and late-onset CLABSI; these differences may influence choice of antibiotic and strategy of prevention
Chopra et al, 2012 (17)	NA	Review	Describe evolution of PICCs and their adoption in modern medicine; evaluate early studies of DVT and CLABSI; provide focus for areas of uncertainty and risk	Human studies with specific keywords related to PICCs, CLABSI, and DVT; full text, abstracts, and posters were included	PICC	Introduction of a conceptual model, highlighting uncertainties and knowledge gaps pertaining to PICCs and specific adverse outcomes
Chopra et al, 2012 (9)	NA	Review	Examine the risk and benefit of PICC use in hospitalized patients	Evaluation of PICC decision making and changes in the epidemiology of CVC use in hospital settings	PICC	Highlights the need for more PICC research and caution in placing PICCs, given the risk for adverse events
Chopra et al, 2013 (22)	144	Cross-sectional survey	Web-based survey designed to understand hospitalist experience, practice, opinions, and knowledge related to PICC use, care, and management in Michigan	Hospitalists from 10 academic and community hospitals in Michigan	PICC	Substantial variation in hospitalist experience, practice, opinions, and knowledge regarding PICCs was observed
Chopra et al, 2013 (21)	2112	Cross-sectional survey	Web-based survey designed to understand hospitalist experience, practice, opinions and knowledge related to PICC use, care, and management across the United States	Hospitalist providers who are members of the Society of Hospital Medicine across the United States	PICC	Hospitalist knowledge and experiences related to PICCs varied, with knowledge gaps related to the rationale for PICC tip positioning and outcomes related to PICC use. Treatment of complications varied substantially, including in duration of anticoagulation and catheter removal in the setting of PICC-related DVT
Chopra et al, 2013 (15)	57 250	Systematic review and meta-analysis	Risk for CLABSI with PICCs vs. CVCs	Twenty-three studies including adults who had either a PICC or CVC and reported CLABSI	PICC, CVC	Hospitalized patients are just as likely to develop CLABSI with PICCs as with CVCs; in outpatients, PICCs were associated with a lower risk for CLABSI
Chopra et al, 2013 (16)	29 503	Systematic review and meta-analysis	Risk for DVT with PICCs vs. nontunneled CVCs	64 studies including adult patients with PICCs or CVCs	CVC, PICC	Patients with cancer and those with critical illness had the highest rate of PICC-related DVT; PICCs were associated with 2.5 times greater risk for DVT compared with CVCs
Chopra et al, 2014 (122)	747	Retrospective cohort study	Identify rates; patterns; and patient, provider, and device characteristics associated with PICC-related CLABSI	Patients who underwent PICC placement between June 2009 and July 2012 at a VA medical center in Michigan	PICC	PICC-related BSI was associated with hospital length of stay, ICU status, and number of PICC lumens
Cortelezzia et al, 2003 (123)	126	Retrospective cohort study	Analyze the incidence of thrombotic and infectious complications in CVCs vs. PICCs in cancer patients	Patients with hematologic cancer and low platelet count with either a CVC or a PICC; patients received DVT prophylaxis at the discretion of the provider	CVC, PICC	Thrombosis occurred more frequently with PICCs than with CVCs; patients who received LMWH were less likely to experience DVT than those who received heparin
Cotogni et al, 2013 (59)	254	Prospective cohort study	Evaluate the incidence of VAD-related complications in cancer patients who receive home parenteral nutrition	Cancer patients who received parenteral nutrition between June 2008 to November 2009 at a university hospital in Italy	PICC, tunneled catheter, port	Home parenteral nutrition was safe and well tolerated in patients with cancer; risk for complications across devices was low and acceptable
Couban et al, 2005 (124)	255	Multicenter, randomized, placebo-controlled clinical trial	Assesse whether low-dose daily warfarin reduces the incidence of symptomatic CVC thrombosis in patients with cancer	Patients who required a CVC for at least 7 d were randomly assigned to receive 1 mg warfarin daily vs. placebo	CVC	Symptomatic CVC-associated thrombosis was less common than previously thought in this population; daily 1-mg doses of warfarin did not reduce symptomatic CVC-related thrombotic events
Crnich and Maki, 2002 (125)	NA	Review	Invited article that examined use of novel approaches, such as securement devices, dressings, catheter coatings, and lock solutions, in preventing CLABSI	Examining the risk for IVD-related infections, pathogenesis, prevention, and novel technology available for control of BSI associated with long-term devices	CVC, port, PICC	Newer technologies may help reduce CLABSI.; identification, adaptation, and evaluation of these novel approaches is necessary

Continued on following page

Table 1–Continued

Study, Year (Reference)	Participants, *n*	Design	Focus or Overview	Study Sample and Characteristics	Device	Findings and Comments
Curigliano et al, 2007 (126)	188	Prospective cohort study	Evaluate the efficacy and safety of low-dose aspirin for prevention of VTE	Patients with stage II–IV breast cancer with CVCs for continuous chemotherapy from April 2000 to March 2004 in a single center	CVC	Although no control or comparison arm was included, low-dose aspirin was a reasonably well tolerated method of DVT prevention in this population
Daneman et al, 2012 (127)	348	Retrospective cohort study	Assess the risk for recurrent bacteremia in patients with recent CLABSI within 6 weeks	Bacteremic patients undergoing PICC insertion at an academic health center were reviewed for risk for recurrent infection	PICC	Recurrent bacteremia within 30 d of PICC insertion occurred in 33 patients but often involved a different organism (25 patients); after adjudication, only 3 of 8 recurrent infections were determined to be "true" relapses (0.9%)
Dariushnia et al, 2010 (68)	NA	Guidelines	Guidelines from the Society of Interventional Radiology that were written for quality improvement programs seeking to assess central venous access procedures	Comprehensive review of indications for central venous access, QI efforts, and management of complications	PICC, CVC, port	These guidelines provide target success rates for insertion of various catheters as well as major complication rates and suggested thresholds for venous access devices
Dawson et al, 2013 (128)	NA	Review	Examined published evidence on midline catheters in reducing the risk for CLABSI	Calls for greater use of midline catheters as part of a multifaceted effort to reduce CLABSI in hospitals	CVAD, CVC, PICC, midline catheter	Midline catheters are effective tools for intermediate-duration infusions that are peripherally compatible. They can be used for blood draws and infusion and, as part of a multifaceted approach, can reduce hospital rates of CLABSI
Debourdeau et al, 2013 (36)	NA	Guidelines	Establishment of good clinical practices guidelines for the management of CRT in patients with cancer	Guideline examined prophylaxis and treatment of thrombosis associated with CVCs in patients with cancer	CVC	Dissemination and implementation of these guidelines is a public health priority in order to reduce CRT
DeLemos et al, 2011 (129)	35	Prospective cohort study	Evaluation of PICCs as an alternative to CVCs in neurosurgical critical care settings	Neurologic critical care patients at 1 center who had PICCs (as opposed to CVCs) for IV access and monitoring	PICC, CVC	Use of PICCs (rather than CVCs or pulmonary artery catheters) reduced procedural and infection risk
Del Principe et al, 2013 (56)	71	Retrospective cohort	Assess rates of catheter-related thrombosis in relation to catheter exit site infection	Patients with acute myeloid leukemia who underwent CVC placement before each chemotherapy cycle	CVC	Patients with sepsis and exit-site infections had significantly higher rates of thrombosis than those without these events, independent of other factors
Diaz et al, 2012 (130)	50	Prospective cohort study	Determine baseline CLABSI rates for ED-inserted CVCs and describe indications, duration of use, and natural history of these devices	Patients at a level I trauma, academic ED who required central catheter insertion	CVC	No CLABSI events occurred; notably, 42% of CVCs had no date of removal, suggesting the need to improve documentation in this regard
Di Nisio et al, 2010 (131)	NA	Systematic review	Examine the utility of US to diagnose PICC-related DVT	17 articles assessing diagnostic accuracy of tests for clinically suspected UEDVT	CVC, PICC	Compression US is an acceptable alternative to venography, given high sensitivity and specificity for catheter thrombosis
Duerksen et al, 1999 (132)	NR	Prospective cohort study	Assess type of CVC and complications associated with delivery of parenteral nutrition	Patients at St. Boniface General Hospital in Winnipeg, Manitoba, Canada, who received a CVC for nutrition between 1987 and 1997	CVC, PICC, tunneled catheter	Over the 10-year study, use of PICCs increased to replace CVCs in providing parenteral nutrition; PICCs did not increase risk for sepsis or thrombosis compared with historical cohorts
Durrani, 2009 (133)	623	Retrospective cohort study	Test whether anticoagulants can prevent VT in patients with PICCs	Patients admitted to a single medical center between January 2004 to July 2009 who received a PICC and antiplatelet agents	PICC	Receipt of aspirin or clopidogrel during hospitalization did not affect the risk for PICC-related DVT
Elia et al, 2012 (41)	100	Randomized controlled trial	Compare survival rates between standard-length catheters vs. long peripheral catheters inserted by US	100 patients in an urban high-dependency unit were randomly assigned to receive either short or long peripheral catheters	PIVC	Both short and long peripheral catheters placed with US have a high success rate; catheter failure occurred more frequently in the short catheter group (45% vs. 14%; $P = 0.001$)
El Ters et al, 2012 (49)	282	Case-control study	Assess the association between history of PICC use and subsequent malfunctioning or nonfunctioning arteriovenous fistula	Hemodialysis outpatients in 7 Mayo Clinic units in Rochester, Minnesota	PICC	A strong and independent association (3.2 times greater odds of a nonfunctioning fistula) was noted in patients who had received prior PICCs
Evans et al, 2010 (73)	1728	Prospective cohort study	Assess the prevalence and risk factors associated with symptomatic PICC-related DVT in hospitalized patients	Patients with PICC insertions at a large university-based health system	PICC	PICC insertion in patients who have cancer, undergo surgery lasting greater than 1 h, or have experienced prior thrombosis is associated with greater risk for DVT; Catheter gauge is a strong and modifiable factor associated with PICC DVT
Evans et al, 2013 (74)	5018	Prospective cohort study	Assess whether small-diameter PICCs may reduce the risk for DVT in hospitalized patients	All patients with PICC insertions at 1 hospital from January 2008 to December 2010	PICC	Use of smaller-gauge PICCs was associated with substantially lower rates of DVT
Faganani et al, 2007 (134)	1410	Prospective cohort study	Evaluate the association between antiplatelet therapy and risk of subsequent catheter-related thrombosis	Patients attending 1 of 18 participating hospitals who had solid or hematological tumors and a CVC, PICC, or port	CVC, PICC, port	Antithrombotic prophylaxis did not prevent catheter-related VT in this high-risk cohort
Fearonce et al, 2010 (135)	31	Retrospective cohort study	Compare the use and safety of PICCs vs. CVCs in a cohort of patients admitted to a burn ICU	Burn patients at a single center who received one or more PICCs between July 2005 and June 2007	PICC, CVC	Compared with PICCs, CVCs had a higher rate of catheter-related BSI; PICCs were associated with greater risk for DVT

Continued on following page

Table 1–Continued

Study, Year (Reference)	Participants, *n*	Design	Focus or Overview	Study Sample and Characteristics	Device	Findings and Comments
Fletcher and Bodenham, 2000 (70)	501	Retrospective cohort study	Assess the incidence rate and clinical significance of PICC-related DVT in critically ill patients in a neurologic ICU	479 patients who received 501 PICCs during clinical care in a neurologic ICU at a quaternary academic medical center	PICC	The incidence of symptomatic PICC-related DVT was 8.1%; PE attributable to the PICC occurred in 15% of patients, often requiring anticoagulation or superior vena cava filter placement
Fletcher et al, 2011 (136)	2150	Retrospective cohort study	Understand the incidence rate and significance of symptomatic PICC-related DVT in critically ill patients in a neurosurgical ICU	PICCs placed in neurosurgical ICU patients between March 2008 and February 2010	PICC, CVC	PICCs are associated with a high rate of DVT; placement in a hemiparetic arm and infusion of mannitol or vasopressors through the PICC were associated with greater odds of DVT
Freixas et al, 2013 (137)	2176 health care workers	Quasi-experimental before-after study	Determine the effect of a multimodal intervention to reduce the incidence of CLABSI outside the ICU	Adult patients hospitalized in non-ICU settings between 2009 and 2010 at 11 affiliated hospitals in Catalonia, Spain	PIVC, CVC	Implementation of the program reduced CLABSI and CVC utilization; PIVC utilization remained unchanged
Frizzelli et al, 2008 (138)	848	Prospective cohort study	Evaluate risk for US-confirmed DVT in patients who received a CVC during cardiac surgery	Patients recovering in the ICU after heart surgery for 5–7 d from 6 centers were included	CVC	CVC-related DVT was a frequent outcome, occurring in 386 patients (48%). Patients who received prophylactic anticoagulation did not experience PE. Screening via US in this high-risk cohort may be valuable to prevent PE
Furuya et al, 2011 (139)	441 hospitals	Cross-sectional study	Assess the implementation of elements embedded within the central line "bundle" across US hospitals and effect on subsequent CLABSI rates	Hospitals must have conducted National Healthcare Safety Network CLABSI surveillance in 2007 to be included	CVC	Reduction in CLABSI was only observed in ICUs that had a CLABSI policy, monitored adherence, and had >95% adherence rate
Gong et al, 2012 (140)	180	Prospective cohort study	Compare PICC complications via use of a modified Seldinger technique with US guidance vs. the traditional method of placement	Patients with cancer who had PICCs at the Department of Chemotherapy in Jiangsu Cancer Hospital	PICC	PICCs placed using a modified Seldinger approach and US were less likely to experience thrombotic complications
Göransson and Johansson, 2012 (141)	83	Prospective cohort study	Investigate the association between prehospital PIVC placement and frequency of phlebitis	Hospitalized patients who underwent PIVC placement before hospitalization by ambulance crews in Stockholm, Sweden	PIVC	Of 83 patients, 45% developed thrombophlebitis (54%); no association between thrombophlebitis and prehospital risk factors was found
Grant et al, 2008 (142)	189	Retrospective cohort study	Examine characteristics of patients who developed PICC UEDVT	Patients who underwent PICC placement at UCLA Medical Center between January 2003 and December 2006	PICC	Patients who experienced multiple PICC insertions had a 4-fold greater risk for DVT than those who had only 1 insertion
Grant et al, 2012 (143)	NA	Review	Provide a summative and clinically relevant approach for the diagnosis, management and prevention of UEDVT in high-risk patients with and without catheters	Narrative review	PICC, CVC, port	Pharmacologic thrombosis prophylaxis is not effective in reducing risk for UEDVT in patients with CVCs; anticoagulation is commonly used for treatment of UEDVT and is recommended largely from extrapolation of studies involving lower-extremity DVT
Gregg et al, 2010 (144)	59	Retrospective cohort study	Report success and complications related to US-guided PIVC placement in critically ill patients	Critically ill patients who underwent US-guided PIVC placement as part of their routine care at a single medical center in the United States	PIVC, CVC	Of the 148 PIVCs requested, 147 were placed successfully by US guidance; complications included infiltration (3.4%), inadvertent removal (2.7%), and phlebitis (0.7%). As a result of successful PIVC placement, 40 CVCs were discontinued and 34 CVCs were avoided
Griffiths, 2007 (145)	NA	Review	Overview of midline catheters inserted by nurses for short- and long-term IV infusions	Narrative review	Midline catheter	Nurse involvement in determining the appropriateness of venous access can help improve patient outcomes; midline catheters are one example of a device that can provide both short and long-term infusions with low risk for complications
Grove and Pevec, 2000 (146)	678	Retrospective cohort study	Determine risk factors that may lead to DVT in patients who receive PICCs	Patients with PICC insertions in 1997 cross-referenced with venous duplex exams at 1 hospital	PICC	PICC-related DVT rates were 4.5% for nurses and 2.7% for IRs; the smallest-gauge catheter should be used to decrease risk for thrombosis
Gunst et al, 2011 (2)	121	Prospective cohort study	Assess whether use of PICCs results in reduced rate of BSI compared to antiseptic-coated CVCs	Patients admitted to a surgical ICU for ≥14 d between July 2005 and July 2006	PICC, CVC	The only independent predictor of infection was dwell time; catheter coating and PICC use did not predict infection, though PICCs were associated with infections less frequently than CVCs
Guyatt et al, 2012 (35)	NA	Guidelines	Summary of evidence for the recommendations on antithrombotic therapy and prevention of thrombosis	Summary recommendations related to therapy and prevention of thrombosis including catheter-related DVT	PICC, CVC	This summary is the 9th edition of the American College of Chest Physicians Antithrombotic Guidelines; a methods article with recommendations and grading of the evidence are included
Hadaway, 2001 (147)	NA	Review	Address the risk for catheter-related BSI and hub disinfection methods and practice	Narrative review	CVC, PICC	Clinicians should closely follow manufacturer instructions regarding disinfection technique and chemical composition of disinfectant used

Continued on following page

Table 1–Continued

Study, Year (Reference)	Participants, *n*	Design	Focus or Overview	Study Sample and Characteristics	Device	Findings and Comments
Hadaway et al, 2011 (148)	554 health care workers	Survey-based study	Assess the knowledge gap of health care workers about practice with needleless connectors	Health care workers were invited to participate in a 22-question survey	CVC, PICC	Among respondents (response rate, ~14%), a significant gap of knowledge regarding needleless connectors; cleansing practices; and flushing, clamping sequence
Hadaway, 2012 (149)	NA	Review	Analysis of 45 studies to assess knowledge gaps and inadequate clinical practices associated with catheter-related BSI	Narrative review	CVADs, IV	Insertion techniques and other clinical practices differ greatly among countries; these variations may increase the risk for BSI. Catheters should be changed only when clinically indicated
Hadaway, 2012 (150)	NA	Review	Describe currently used needleless connectors and their potential for complications associated with differing medical practices	Narrative review	Needleless connectors	Device design, user knowledge deficits, and improper hygiene can influence risk for infections; such interventions as scrubbing the connection surface, flushing, changing the needleless connectors, and intermittent IV administration can reduce risk for infection
Harnage, 2007 (151)	32 ICU beds	Prospective cohort	Assess the effect of a newly developed PICC bundle on catheter-related BSI	Patients with PICCs in 2 ICU units in 1 California hospital	PICC	A PICC bundle that combined practice and technology successfully decreased catheter-related BSI
Harnage, 2012 (152)	NR	Retrospective cohort study	Evaluate sustainability and lessons learned after implementation of a PICC bundle at 1 medical center	Patients in 1 California hospital	PICC	Catheter stabilization and zero-displacement IV connections helped reduce CLABSI
Hornsby et al, 2005 (88)	NR	Prospective cohort study	Analysis of the creation and effect of 2 full-time vascular access specialty positions at 1 medical center	500-bed facility in Saginaw, Michigan	PIVC PICC	More PICCs were placed proactively at the beginning of hospital stays. Peripheral catheter restarts were replaced with PICCs and delayed discharges related to PICC placement were reduced
Hoshal, 1975 (86)	35	Prospective cohort study	Examine the feasibility of using peripherally inserted silicone elastomer CVCs for total IV nutrition	Patients receiving total IV nutrition at 1 medical facility	PICC	This first-ever report of PICCs found that peripherally inserted silicone elastomer CVCs were safe, effective, and durable for delivery of total IV nutrition in outpatients
Hughes, 2011 (153)	NA	Systematic review	Examine PICC-related thrombosis incidence, morbidity and effect of US guidance on outcomes	Systematic review	PICC	PICC-related DVT is common, especially among patients with cancer. Although limited, available evidence suggests US can reduce risk for thrombosis
Hughes, 2014 (154)	31	Prospective cohort study	Assessing the feasibility of SecurAcath (Interrad Medical, Plymouth, Minnesota), a subcutaneous device, on inadvertent PICC migration	Patients at 1 cancer hospital who received PICCs and the SecurAcath device during clinical care	PICC	A single case of migration among 32 patients was recorded; however, some initial problems with infection and pain occurred
Infusion Nurses Society, 2011 (32)	NA	Guidelines	Review of current literature for the development of standards of practice for nurses working with VADs	Standards for insertion, care, and management of VADs for nursing professionals	PIVC, CVC, PICC, tunneled catheter, port	Topics ranging from patient care, access devices, and infusion therapies to safe and effective methods for working with VADs were included; basic requirements in education and competencies for insertion and management of devices are also outlined
Itkin et al, 2014 (155)	332	RCT	Evaluate the risk for DVT in PICCs that are reverse-tapered vs. PICCs that are not	Patients 18–90 years of age requiring PICC insertion at a quaternary academic medical center	PICC	Although tapering of PICCs did not influence risk for PICC-related DVT, up to three quarters of patients experienced asymptomatic thrombosis in this study, suggesting a high overall rate of thrombosis
Jin et al, 2013 (156)	NA	Systematic review	Describe potential repositioning techniques for PICCs that were malpositioned during or after insertion	Systematic review	PICC	Malpositioning of PICCs can occur from the right ventricle to peripheral veins. Repositioning techniques, including manual advancement or catheter replacement, are often necessary
Joffe and Goldhaber, 2002 (157)		Review	Examine the pathogenesis, signs, and symptoms of UEDVT and the association between the increasing incidence of UEDVT and CVCs	Narrative review	CVC, PICC	Secondary thrombosis related to CVC use is on the rise; thrombolysis reserved for specific instances
Johansson et al, 2013 (6)	NA	Systematic review	Examine the advantages and disadvantages of PICCs vs. CVCs on the basis of available evidence	48 studies were assessed for eligibility, of which 11 were included in the qualitative analysis; 9 of the 11 were excluded owing to low quality	PICC, CVC, port	PICCs are commonly used in oncology; however the quality of the evidence supporting use of these devices is limited
Johansson et al, 2013 (158)	23 oncology departments	Survey-based study	National survey to examine use of PICCs in adult oncology departments in Sweden	Heads of 23 adult oncology departments in Sweden	PICC	Twenty-two of 23 sites responded (96%). Vascular nurses most often placed PICCs with US in most sites; 9 of 16 sites reported having specific indications for type of device used; one third of departments did not place PICCs

Continued on following page

Table 1–Continued

Study, Year (Reference)	Participants, *n*	Design	Focus or Overview	Study Sample and Characteristics	Device	Findings and Comments
Johnston et al, 2012 (159)	102	Randomized trial	Test whether PICC valve technology influences rate of occlusion	102 ICU patients who received PICCs were randomly assigned to receive to 1 of 3 different PICCs in a single hospital	PICC	The study was terminated early because of 4 episodes of hemolysis in blood samples taken from a single type of PICC; valved PICCs did not seem to influence rates of PICC occlusion on the basis of available data
Jones et al, 2010 (160)	101	Prospective cohort study	Determine factors associated with, and rates of resolution after, catheter-associated UEDVT	Symptomatic patients positive for UEDVT after undergoing duplex US from January 2001 to June 2006 at 1 medical center	CVC	Catheter-associated UEDVT may resolve if the catheter is removed within 48 hours of diagnosis; CVC reinsertion is associated with a high rate of UEDVT regardless of anticoagulation
Kallen et al, 2010 (161)	NA	Review	Emphasize the importance of prevention and reduction of CLABSI outside the ICU in health care facilities	Sheds light on the changing epidemiology of CVCs, with many devices now being found outside the ICU; the authors call for attention to CLABSI outside the ICU	PICC, CVC	Improvement of epidemiologic practices to include non-ICU sites is needed to monitor and reduce rates of CLABSI
Kelly, 2013 (162)	NA	Review	A guide to help practitioners safety insert VADs and reduce complications	Focuses on providing up-to-date knowledge and evidence related to PICC insertion, use, and outcomes	PICC	Practitioners should have access to training programs that are designed to minimize risk and improve patient safety; knowledge of anatomy and physiology can help reduce PICC-related complications
King et al, 2006 (163)	1296	Case-control study	Evaluate clinical conditions and therapies associated with increased risk for PICC-related DVT	Patients who underwent PICC placement at 1 hospital over 3 years	PICC	The overall incidence of PICC-related DVT was 2%. Patients with cancer were 2.5 times more likely to develop PICC-related DVT; prophylactic anticoagulation did not lower this risk
Lamperti et al, 2012 (164)	NA	Systematic review	International panel recommendations on US-guided vascular access	Studies published between 1985 and 2010 were included; the GRADE and GRADE-RAND methods were used for recommendations	CVC, PIVC	US use is safe, effective, and necessary when inserting CVCs and arterial catheters
Latham et al, 2013 (165)	10	In vitro and in vivo	Determine the equivalency of hemodynamic pressure measurements from PICCs vs. CVCs	Medical ICU patients in an academic hospital with both a PICC and CVC in place	PICC, CVC	PICCs are equivalent to CVCs when static and dynamic pressure in vitro were measured in a selected cohort of ICU patients
Lee et al, 2006 (55)	444	Prospective cohort study	Examine the incidence, risk factors, and long-term complications associated with CVC use in patients with cancer	Consecutive patients with cancer who underwent CVC insertion at 1 medical center in Canada	CVC	History of prior CVC insertion was associated with greater risk for subsequent thrombosis
Lee, 2008 (79)	NA	Review	Current standards of practice for diagnosis, prevention, and treatment of VTE in cancer patients	Narrative review	CVC, PICC, port	Patients with cancer are a unique subset with regard to thrombosis; consideration of the risk for DVT in relation to device type is necessary
Lelkes et al, 2013 (166)	384	Retrospective cohort study	Evaluate the efficacy of electromagnetic detection via the Sherlock II system for optimal PICC positioning	384 patients who underwent bedside PICC placement using the Sherlock II tip location system	PICC	97.7% of patients who underwent placement had a catheter tip that was deemed appropriately positioned on follow-up chest radiography
Leroyer et al, 2013 (167)	222	Prospective cohort study	Report complications after PICC placement in a French teaching hospital	Patients having undergone PICC placement in IR at a teaching hospital in Bordeaux, France	PICC	PICCs were associated with several complications including obstruction (20.5%), DVT (2.5%), and infection (10%); 34% of PICCs were removed owing to complications
Leung et al, 2006 (168)	120	Retrospective cohort study	Review indications for PICC insertion, dwell time, and removal in Chinese patients so as to determine technical requirements for new catheters	Patients who received fluoroscopically guided PICC into distal superior vena cava via the antecubital region of the forearm	PICC	Oozing, phlebitis, and occlusion often occurred in patients with thrombocytopenia and leukemia; devices that prevent platelet consumption may be valuable in preventing these types of events
Leung et al, 2011 (14)	276	Retrospective cohort study	Evaluate factors associated with PICC failure by comparing periods after the rollout of nursing care improvements	Patients with medical records who underwent silicone-rubber-constructed 4-French single-lumen PICCs in Taipei, China	PICC	After nursing education–based interventions, complications such as oozing, wound leakage, and phlebitis were reduced
Li et al, 2014 (13)	100	RCT	Compare the effects of PICC placement using B-mode US with modified Seldinger technique vs. blind insertion	100 patients undergoing chemotherapy were recruited and randomly assigned to blind vs. guided placement group	PICC	B-mode US with modified Seldinger technique reduced complications and patient costs compared with the blind approach
Liu et al, 2014 (39)	NA	Systematic review	Examine the efficacy of US guidance for the placement of PIVCs	Patients with difficult PIVC access	PIVC	Routine use of PIVC guidance with US is not strongly supported by the literature; use of this technology should be reserved for providers who are adequately trained under appropriate conditions

Continued on following page

Table 1–Continued

Study, Year (Reference)	Participants, *n*	Design	Focus or Overview	Study Sample and Characteristics	Device	Findings and Comments
Lobo et al, 2009 (7)	777	Retrospective cohort study	Assess risk for VT in general hospitalized patients who received PICCs	Patients who received a PICC while hospitalized at a single facility as part of their clinic care	PICC	The incidence of PICC-related DVT was 4.89%; PICCs that did not terminate in the SVC had a 2.61 times greater for thrombosis than those in this area. PICC-related DVT was 10-fold greater in patients with a history of thrombosis
Loupus et al, 2008 (169)	44	Retrospective cohort study	Report the risk for PICC-related DVT in patients with cervical spine cord injuries compared with other populations	Quadriplegic patients with PICCs at 1 medical center	PICC	The incidence of PICC-related DVT was 7.1% per PICC insertion and 9.1% per person
Maki et al, 2006 (170)	NA	Systematic review	Define and report the risk for BSI with various IVDs	200 studies reporting BSI rates that were prospective, published, and included a device of interest	PIVC, midline catheter, CVC, PICC	Expressing BSI per 1000 IVD-days is a better estimate of risk; all types of IVDs pose a risk for BSI. Dwell time is a significant aspect of risk; risk for BSI varies by device type.
Malinoski et al, 2013 (171)	184	Prospective cohort study	Determine which CVC is associated with the greatest risk for DVT in surgical critical care patients	Patients with a CVC in a surgical ICU at 2 trauma centers	CVC, PICC	CVCs placed in the internal jugular vein and PICCs placed in arm veins had the greatest risk for catheter-associated DVT
Marnejon et al, 2012 (172)	400	Case–control study	Identification of risk factors associated with PICC-related DVT by comparing cases of PICC-DVT to controls	Consecutive patients with and without DVT after PICC insertion at 1 hospital in Ohio	PICC	Patients with a history of trauma or renal failure, those with had left-sided insertions, and those who received vancomycin were at greater risk for thrombosis than controls
Marschall et al, 2014 (173)	NA	Guideline	Provide evidence-based recommendations to assist acute care hospitals in CLABSI prevention	Expert-guidance document that was sponsored by multiple medical societies aiming to identify best practices to prevent CLABSI	CVC, PICC, port	This compendium of evidence-based strategies provides key direction for focusing on high-risk populations and maximizing strategies proven to reduce risk for CLABSI
Mermel et al, 1995 (40)	238	Prospective cohort study	Evaluate risk and benefits from use of 2 midline catheters in the hospital setting	238 patients in a single medical center received 251 midline catheters to assess the risk associated with use of this device in hospitalized patients	Midline catheter	The mean duration of midline catheter use was 9 d, and the overall risk for CRBSI was 0.8 per 1000 catheter-days; 2 severe unexpected reactions occurred during the study that may have been related to a particular midline catheter manufacturer and/or catheter material
Mermis et al, 2014 (174)	117	Retrospective cohort study	Assess potential risk factors for symptomatic PICC-related DVT and implement a QI project to reduce PICC-related DVT in patients with cystic fibrosis	Adult patients with cystic fibrosis who received a PICC between July 2006 to March 2013	PICC	QI strategies that focus on using smaller-diameter 4-French PICCs and avoiding PICCs in high-risk patients are likely to meet with success in patients with CF
Merrell et al, 1994 (175)	460	Prospective cohort study	Evaluate the use of PICCs for ongoing venous access in general medical and surgical patients in a VA medical center	General and surgical patients with PICCs in a VA medical center between 1985 and 1988; insertion was done by trained nurses	PICC	PICCs were associated with a mean duration of use of 27 d. Complications, including phlebitis, bacteremia, mechanical failure, and local infection, were uncommon
Meyer, 2011 (176)	1307	Retrospective cohort study	Evaluate the effectiveness of clinical practice changes to reduce PICC-related thrombosis	Patients who underwent PICC insertion at Duke University Medical Center for various clinical indications	PICC	Practices for reduction of PICC-related DVT included US guidance and verification of tip location; routine measurement of vein diameters also proved helpful in reducing thrombosis risk
Meyer, 2012 (3)	NA	Review	Explore the effect of an alternative workflow, including a centralized procedure room	Patients who underwent PICC insertion at Duke University Medical Center for various clinical indications	PICC	Centralizing PICC operations in medical facilities is an efficient model for device placement, improved nursing productivity and work culture, and decreased patient care delays
Milstone and Sengupta, 2010 (177)	NA	Review	Examine the relationship between PICC dwell time and CLABSI risk, as well as strategies such as catheter replacement to prevent CLABSI	Narrative review	PICC	The hazard risk for CLABSI with PICCs is nonlinear but constantly increasing over time; replacement of PICCs as a strategy to prevent CLABSI cannot be recommended on the basis of available data
Minkovich et al, 2011 (178)	269	Retrospective cohort study	Determine the incidence and risk factors associated with PICC malposition in patients with head and neck cancer who were undergoing surgery	Patients undergoing free flap reconstructive surgery for head and neck cancer at 1 academic medical center	PICC	PICCs inserted without imaging guidance were more commonly associated with malpositioning; left-sided PICCs had a lower risk for malpositioning
Miyagaki et al, 2012 (179)	26	RCT	Compare the performance of 2 major PICCs with different material and tip design	Patients undergoing gastrointestinal surgery who underwent PICC placement between August 2010 and December 2010 at 1 facility in Osaka, Japan	PICC	No difference in durability and complications between the Groshong (with distal side slits) and polyurethane catheter (with open-ended tip) was noted
Mollee et al, 2011 (52)	727	Prospective cohort study	Determine the incidence of and risk factors for CLABSI in patients with cancer	Adults who underwent CVC placement in one hematology–oncology unit in Australia	PICC, CVC, tunneled catheter	Nontunneled and tunneled catheters had greater risk for CLABSI than PICCs (odds ratio, 3.55 and 1.77, respectively)

Continued on following page

Table 1–Continued

Study, Year (Reference)	Participants, *n*	Design	Focus or Overview	Study Sample and Characteristics	Device	Findings and Comments
Morden et al, 2014 (180)	NA	In vitro	Determine the rate and cause of displacement of CT power-injectable PICCs during contrast material and saline flush injection	In the laboratory setting, in vitro modeling of CT-induced PICC displacement was examined while varying rates and nature of power injection	PICC	Higher rates of saline flush were associated with greater movements of the PICC tip
Moureau et al, 2002 (181)	50 470	Retrospective cohort study	Document the natural history of CVCs and determine the rate of complications in patients receiving home infusions	Patients who underwent home infusion care and placement of a CVC	PICC, CVC, midline catheter, port, tunneled catheter	Catheter dysfunction is almost twice as likely as infection in this population; this results in delays in therapy, rehospitalizations, and device replacement
Moureau et al, 2013 (89)	NA	Guidelines	Standardize definitions of and recommendations for training and insertion of CVADs by the World Congress of Vascular Access	Consensus of an expert panel to develop minimal criteria for training and certification of catheter placements	CVC, PICC	A global rating scale rather than number of procedures performed should be used to determine clinical competence; standardized education, simulations, and supervised insertions are recommended for operators placing these devices
Mukherjee et al, 2001 (182)	385 PICCs	Retrospective cohort study	Determine the incidence of and risk factors for CRT in patients with gastrointestinal cancer	All PICC insertions between June 1999 and May 2000, found in the PICC register in 1 hospital in the United Kingdom	PICC	The overall rate of thrombosis was 5.2%. Because of the risk for bleeding, anticoagulation was not deemed wise in this setting. Future studies examining upper vs. lower gastrointestinal tract tumors are needed
Nash et al, 2009 (183)	524	Retrospective cohort study	Determine incidence of PICC-related DVT in patients with and without *Burkholderia cepacia* complex infection; investigate association between PICC-related DVT and erythrocyte sedimentation rate	Patients with cystic fibrosis who underwent PICC insertion at a single institution over 6 y	PICC	Patients with *B. cepacia* complex had a higher incidence of DVT; higher erythrocyte sedimentation rates in patients with PICC-related DVT may suggest that inflammation is a risk factor for subsequent thrombosis
National Kidney Foundation, 2002 (48)	NA	Guidelines	Define the approach to diagnosis, evaluation, management and venous access in patients with CKD	NA	PICC, CVC, small-bore catheters	Use of PICCs is not recommended in patients with advanced or progressive renal insufficiency
National Kidney Foundation, 2013 (44)	NA	Guidelines	Update to the earlier guidelines to provide recommendations on diagnosis, evaluation, management, and venous access in patients with CKD	NA	PICC, CVC, small-bore catheters	Venous preservation for fistula placement is a cornerstone of managing patients with CKD
Nifong and McDevitt, 2011 (184)	NA	In vitro experimental study	Calculated relative flow rates as related to the ratio of the catheter to vein diameter	Simulation study that examined risk for thrombosis in relation to cross-sectional vessel diameter	PICC	PICCs may decrease venous flow rates by as much as 93% by occupying much of the luminal diameter. Using the smallest-gauge catheter may prevent venous stasis and reduce risk for DVT
Nunoo et al, 2011 (185)	1648	Prospective cohort study	Investigate the contribution of PICCs to VTE rates in patients undergoing colonic resection	Patients who underwent major bowel resection over 3 y in a single hospital system	PICC	Patients with PICCs were 11 times more likely to develop subsequent VTE
O'Brien et al, 2013 (75)	1328	Quasi-experimental before–after study	Address the frequency of inappropriate venous catheter use and effect of a QI program to reduce PICC lumens	Patients receiving CVCs at McGill University Health Center from May 2011 to January 2012	PICC	A hospital-wide effort to decrease the insertion of multilumen PICCs without an appropriate rationale resulted in decreased costs and complications from PICCs
O'Grady and Chertow, 2011 (186)	NA	Review	Review for diagnosis, management, and treatment of CLABSI outside the ICU specifically directed towards non-critical care providers	Detection, surveillance, and management of CLABSI outside ICUs is challenging and may require unique and novel approaches as compared to the ICU setting	CVC, PICC	Infectious disease specialists should be consulted when necessary; input regarding retaining or removing the catheter and type of antibiotic therapy are key to ensuring safe outcomes
Oliver and Jones, 2014 (187)	NA	Review	Determine whether EKG-guided PICC placement is the preferable method for PICC positioning	Narrative review of the literature that summarizes available evidence for EKG-guided placement	PICC, CVC	Best practices and recommendations should be established to use EKG as a gold standard for checking CVC placement
Ong et al, 2006 (188)	317	Retrospective cohort study	Determine the frequency and risk factors for PICC-related DVT at 1 medical center	Symptomatic patients with a positive upper-extremity venous duplex scan over 3 y were reviewed to determine risk factors associated with UEDVT	PICC	Patients with PICCs, those receiving chemotherapy, and those with cancer were most likely to experience DVT
Paauw et al, 2008 (189)	56	Prospective cohort study	Determine the incidence of PICC-associated DVT with and without prophylactic anticoagulants	Inpatients with PICCs used for parenteral nutrition or antibiotics at 1 medical center	PICC	Prophylaxis for DVT with heparin and LMWH was associated with a lower rate of DVT in patients with PICCs, although these results were not adjusted for confounders
Pari et al, 2011 (190)	70	Prospective cohort study	Initial application and results of implementation of a clinical pathway to choose the best venous access for individual patients	Patients with PICCs inserted through the new 'Shared Clinical Pathway' tool at 1 cancer center	PICC	Use of the pathway improved patient quality of life, decreased costs, and improved workflow

Continued on following page

Table 1–Continued

Study, Year (Reference)	Participants, *n*	Design	Focus or Overview	Study Sample and Characteristics	Device	Findings and Comments
Patel et al, 2007 (191)	1788	Retrospective cohort study	Determine whether the use of open-ended PICCs for invasive monitoring can decrease the risk for CLABSI	Patients before and after the introduction of a hemodynamic monitoring with PICCs in a closed medical–surgical ICU at an academic medical center	PICC	Open-ended PICCs may be associated with a shorter catheter dwell time, reduced BSIs, and an overall decrease in antibiotic use
Patel et al, 2014 (192)	70	RCT	Compare the safety and cost of PICCs vs. ports used to deliver chemotherapy	Patients with nonhematologic cancer receiving chemotherapy either through a PICC or a port	PICC, port	Ports were associated with a lower risk for complications in this population; there was no difference in cost using a PICC vs. port approach
Paz-Fumagalli et al, 1997 (193)	113	Prospective cohort study	Investigate the effect of PICC placement in patients with spinal cord injury who were at high risk for infusion phlebitis	All patients with a spinal cord injury and a peripheral IV from July 1993 to December 1994 who were evaluated at least once by the nursing IV team	PICC, CVC	Although they were associated with DVT, PICC use was associated with a reduced risk for phlebitis
Penney-Timmons and Sevedge, 2004 (194)	NA	Retrospective cohort study	Evaluate outcome data for PICCs placed in hospitalized patients, by using an existing data set	Hospitalized patients with PICCs	PICC	Complications, including exit-site and BSIs, phlebitis, and thrombosis, occurred frequently in this population; changes in nursing practice informed by accumulating evidence helped decrease the risk for these events
Periard et al, 2008 (195)	60	RCT	Compare the safety, efficacy, and cost-effectiveness of PICCs to PIVCs	Hospitalized patients requiring IV therapy for ≥5 days were randomly assigned to receive either PICCs or PIVCs in this single-center study	PIVC, PICC	PICCs are efficient for hospitalized patients requiring IV therapy for ≥5 d however, risk for asymptomatic DVT may be higher than previously reported in persons who receive PICCs
Periard, 2010 (196)	NA	Review	Review of the relationship between insertion site and risk for thrombosis in patients with cancer	Patients with leukemia and PICCs placed at different sites	PICC	Studies suggest there may be an association between PICC placement and thrombosis risk; smaller PICCs inserted into larger veins are least likely to develop thrombosis
Petree et al, 2012 (197)	NA	Systematic review	Determine effective methods for health care providers to reduce PICC-related BSI during device insertion	Evaluate and report on practices at the time of insertion that may reduce the risk for CLABSI in hospitalized patients	PICC	Continuing education is less expensive than the cost of CLABSI; needleless connectors, positive-pressure valves, and proper securement with anchoring devices were most effective in reducing CLABSI
Pikwer et al, 2012 (12)	NA	Systematic review	Examine risks and complications associated with central vs. peripheral routes for central venous cannulation	Compare risks associated with PICCs with those of traditional CVCs	PICC, CVC	Catheter tip malpositioning, thrombophlebitis, and catheter dysfunction occurred more frequently with PICCs than CVCs. No difference in rates of infection between CVCs and PICCs were found in the 12 included studies
Pingleton et al, 2013 (80)	NA	Quasi-experimental before–after study	Reduction of VTE in hospitalized patients by using education and system-wide operational plans	Hospitalized patients at a single university-based medical center in the United States	PICC	After implementation of specific action plans, use of PICCs dropped from 360 insertions to <200 insertions over 2 years; rates of VTE in hospitalized patients similarly declined
Pittiruti et al, 2009 (198)	NA	Guidelines	Guidelines for CVC access, care, diagnosis, and therapy of complications	Guideline statement drafted by the European Society for Clinical Nutrition and Metabolism	PICC, CVC, port	Provides recommendations on use, care, and management of problems related to vascular devices for parenteral nutrition
Pittiruti et al, 2012 (199)	89	Retrospective cohort study	Examine outcomes related to use of power-injectable PICCs in ICU settings	Critically ill patients undergoing power-injectable PICC placement	PICC	PICCs that were power-capable were associated with multiple therapeutic advantages and low risk for complications in critically ill patients
Pittiruti and Lamperti, 2015 (71)	NA	Review	Review the literature on the incidence of cardiac tamponade after PICC insertion	Case reports and case series of PICC receipt; review of sentinel events	PICC	Late cardiac tamponade after PICC insertion in adults is rare
Pongruangporn et al, 2013 (200)	162	Nested case–control study	Evaluate the role of patient-, provider-, and device-specific risk factors in PICC-related BSI	Hospitalized patients at a single university hospital in the United States	PICC	The PICC BSI rate was 3.13 per 1000 catheter-days (similar to that of other CVCs); PICC BSI was associated with device (number of lumens) and patient factors, such as *Clostridium difficile* infection and congestive heart failure
Potet et al, 2013 (61)	101	Prospective cohort study	Examine the safety of PICC insertion in patients with profound thrombocytopenia	143 PICC insertions in 101 patients with cancer at 1 cancer center	PICC	PICC placement was associated with a high rate of technical success and few adverse events in patients with severe thrombocytopenia
Qui et al, 2014 (201)	551	Retrospective cohort study	Study the incidence of, risk factors for, and outcomes of spontaneous PICC dislodgements in patients with cancer in China	551 patients with cancer diagnoses receiving care at 1 center in China	PICC	The incidence rate of spontaneous dislodgement was 4.1%; patients who developed dislodgement had a substantially greater risk for subsequent PICC-related DVT (relative risk, 17.46)

Continued on following page

Table 1–Continued

Study, Year (Reference)	Participants, *n*	Design	Focus or Overview	Study Sample and Characteristics	Device	Findings and Comments
Raad et al, 1994 (202)	72	Case series	Assess the frequency of thrombotic and infectious complications of CVC use in patients with cancer	72 cancer patients in a 500-bed tertiary care center were included; postmortem examinations of catheterized veins were performed	CVC	Thrombosis resulting from vascular catheters included fibrin sleeve to occlusive thrombosis. Septicemia was more common in patients with occlusive thrombosis than in patients with nonmural thrombosis, suggesting an association between these 2 outcomes
Richters et al, 2014 (203)	439	Retrospective cohort study	Report the incidence and risk factors for gram positive bacteremia and thrombosis in patients who received CVCs	439 patients undergoing stem cell transplantation	CVC	Duration of neutropenia and left-sided placement was associated with bacteremia. Persistent bacteremia and tip colonization were associated with thrombosis
Rickard et al, 2012 (84)	3283	RCT	Routine vs. clinically warranted replacement of peripheral IVs in hospital setting	Hospitalized patients at 3 hospitals in Australia	PIVC	Compared with routine removal, PIVCs can be removed as clinically indicated without increasing adverse events; this practice can reduce cost substantially, according to the authors
Robinson et al, 2005 (204)	NA	Prospective cohort study	Effect of dedicated PICC team on patient care and costs associated with PICC insertion	Hospitalized patients receiving care at a single medical center in Boston, Massachusetts	PICC	Introduction of a dedicated PICC team decreased inappropriate PICC placement, wait times to insertion, and overall costs
Romagnoli et al, 2010 (205)	49	Prospective cohort study	Risk for PICC-related DVT in patients with cancer	52 PICCs placed in 49 patients with cancer in a single medical center in Feltre, Italy	PICC	3 patients (5.7%) developed PICC-related DVT; all patients received anticoagulation with LMWH for ≥3 mo; no PE was reported
Rooden et al, 2005 (206)	NA	Systematic review	Review of the literature on diagnosis of, risk factors for, and complications of CVC-related DVT	NA	CVC, PICC	US is recommended as the diagnostic test of choice; various patient and device factors are associated with DVT; and routine prophylaxis to prevent thrombosis is not warranted on the basis of the available data
Ros et al, 2005 (207)	36	Retrospective cohort study	Evaluate PICC-related DVT in patients with head and neck cancer	36 patients with head and neck cancer at 1 medical hospital in Spain	PICC	The rate of PICC-related DVT was 11.1%, suggesting a high rate of thrombosis in this patient population
Rosenthal, 2008 (208)	NA	Review	Evaluate advantages, considerations, and management of midline catheters compared with other devices, with the aim of identifying utility of these devices in patients	Narrative review	Midline catheter	Midline catheters are ideal for isotonic infusions that may last beyond 5 d
Rupp et al, 2012 (34)	NA	Guidelines	Practice guidelines for central venous access prepared by the American Society of Anesthesiologists	Provides updated recommendations on insertion site selection, use of US, and verification of catheter location	CVC, PICC	The guidelines indicate a preference for upper-extremity insertion sites, use of US to guide insertion when placing CVCs and PICCs, and confirmation of the venous location of the catheter and catheter tip location using various techniques
Rutkoff, 2014 (209)	257	Quasi-experimental before–after design	Evaluate the efficacy of antimicrobial (minocycline–rifampin)-coated PICCs in reducing PICC-related BSI	Hospitalized patients at 1 medical center in California	PICC	Antimicrobial PICCs resulted in significant decreases in CLABSI from 4.10 to 0.47 infections per 1000 catheter-days
Saber et al, 2011 (54)	NA	Patient-level systematic review and meta-analysis	Examine risk factors for CRT in patients with cancer	Patients from 5 RCTs and 7 prospective studies including 5636 patients were included	CVC, PICC, port	Thrombosis risk was increased with PICCs, history of DVT, subclavian venipuncture insertion, and improper catheter tip position
Safdar and Maki, 2005 (81)	115	Prospective cohort study	Examine risk for infection with PICCs in hospitalized patients compared with that associated with CVCs	115 hospitalized patients who had 251 PICCs placed were included (from within a larger RCT)	PICC	Risk for PICC-related BSI was 2–5 per 1000 catheter-days, a number that was greater than rates reported in outpatient settings and those related to cuffed or tunneled CVCs
Sansivero et al, 2011 (210)	50	Prospective cohort study	Evaluate the efficacy of a novel catheter securement device	50 patients referred for PICC insertion to a nursing vascular access team and to IR	PICC	A novel securement system resulted in a favorable complication profile, with cost savings related to reduced dressings and disposable securement systems
Santolim et al, 2012 (211)	NA	Quasi-experimental before–after design	Understand the effect of a protocol to select IVDs in a Brazilian hospital in a QI project	University patients in Brazil and vascular access nursing team	PICC, CVC, port	Implementation of a protocol resulted in decreased rates of phlebitis and improved nursing satisfaction
Sasaduesz et al, 1999 (50)	34	Prospective cohort study	Evaluate the effect of small-bore tunneled catheters as a means to preserve veins compared with PICCs	34 patients with end-stage renal disease at 1 single academic medical center	PICC, small-bore catheter	Two minor insertion complications (arterial puncture and catheter damage during suturing) occurred. This approach resulted in a novel form of access, preserving peripheral veins and limiting risk for central vein stenosis in this patient population
Schimp et al, 2003 (212)	264	Retrospective cohort study	Evaluate incidence and outcomes related to UEDVT in patients with gynecologic cancer	264 women who received 325 total catheters at a university hospital	PICC, port	13 patients developed catheter-related DVT; 11 of the patients had ports and 2 had PICCs. No patients developed PE

Continued on following page

Table 1–Continued

Study, Year (Reference)	Participants, *n*	Design	Focus or Overview	Study Sample and Characteristics	Device	Findings and Comments
Seeley et al, 2007 (213)	233	Retrospective cohort study	Develop a risk-prediction model and identify factors associated with PICC-related DVT	Hospitalized patients receiving care at a Midwest community hospital	PICC	17 patients developed DVT; logistic regression models found that bed rest, localized tenderness, smoking, anticoagulant use, and osteomyelitis were associated with PICC-related DVT
Sharp et al, 2014 (63)	64	Retrospective cohort study	Evaluate safety and efficacy of midline catheters compared with PICCs in adults with cystic fibrosis	231 midline catheters and 97 PICCs were placed in 64 patients	PICC, midline catheter	Rates of adverse events with PICCs and midline catheters were similar, but removal rates for midline catheters were twice that of PICCs
Shea et al, 2006 (214)	575	Retrospective cohort study	Evaluate risk for PICC-related DVT in patients with inflammatory bowel disease	15 patients met inclusion and exclusion criteria, and 3 had PICC-related DVT	PICC	A 20% incidence of PICC-related DVT in hospitalized patients with inflammatory bowel disease and PICCs was noted. The incidence rate of PICC-related DVT was 2.17% per day
Simcock, 2008 (215)	191	Quasi-experimental design	Understand the effect of use of US on rate of PICC complications	Patients admitted to a UK hospital who received PICCs at various time points	PICC	Rates of DVT, infections, and other complications declined after use of US
Simonova et al, 2012 (76)	NA	In vitro study	Evaluate the ability of tissue adhesives and cyanoacrylate glue to secure intravenous catheters compared with StatLock devices (Bard Medical, Covington, Georgia) in animal models	NA	PICC, CVC	Tissue adhesives compared favorably with StatLock devices and transparent polyurethane dressings to increase the "pull-out" force of catheters
Skaff et al, 2012 (216)	147	Retrospective cohort study	Compare and contrast the use of Hickman (tunneled) catheters and PICCs in patients with acute leukemia receiving induction chemotherapy	147 patients with newly diagnosed acute leukemia who received either a Hickman catheter or a PICC (with or without US guidance)	PICC, tunneled catheter	Hickman catheters inserted after 2007 by IR were associated with fewer complications (bacteremia and exit-site infection); PICCs were associated with less local inflammation but higher rates of phlebitis and blockage requiring lytic treatments.
Skiest et al, 2000 (217)	66	Prospective cohort study	Determine risk for complications in patients with HIV infection who required long-term venous access or treatments and received PICCs	97 PICCs were inserted in 66 patients for various clinical indications	PICC	53% (51 of 97) of PICCs were associated with a complication, for an overall complication rate of 6.1 per 1000 catheter-days; median time to a catheter-related complication was 115 d. Eleven catheters were infected, 7 of which were associated with a bacteremia. The overall noninfectious complication rate was 4.6 per 1000 catheter-days
Smith et al, 1998 (218)	441	Retrospective cohort study	Compare indications for insertion, complications, and economic effect of CVCs vs. PICCs	441 men who received 838 (283 CVC, 555 PICC) consecutively placed venous catheters reflecting 49 365 CVC-days and 11 814 PICC-days	PICC, CVC	A total of 57 (19%) complications were identified in the CVC group and 197 (35%) complications in the PICC group. There were significantly fewer total complications, catheter malfunctions, episodes of phlebitis, and "other" complications in the CVC group than in the PICC group
Smith and Nolan, 2013 (219)	NA	Systematic review	Provide an overview of CVCs and insertion techniques, and consider the prevention and management of common complications	NA	PICC, CVC	To reduce rates of thrombosis related to long-term catheters in patients with cancer, the catheter tip should lie at the junction of the SVC and right atrium. Multilumen catheters may be associated with a slightly higher risk for infection than single-lumen ones. Prophylactic antibiotics before line insertion, antibiotic lock solutions, or antibiotic ointments applied to the insertion site are not recommended
Snelling et al, 2001 (220)	28	Retrospective cohort study	Compare treatment success with tunneled catheters vs. PICCs and examine rate of and risk for complications with both devices in patients with gastrointestinal cancer	16 tunneled catheters and 18 PICCs were inserted in 28 patients undergoing protracted IV infusion therapy	PICC, tunneled catheter	After 120 d, tunneled catheter survival was better than that of PICCs ($P = 0.051$). Complications occurred in 61% of patients with tunneled catheters and 67% of patients with PICCs
Song and Li, 2013 (11)	3012	Retrospective cohort study	Observe and analyze the causes of misplacement of PICC tips in patients with cancer	3012 patients with cancer who received a PICC (1590 men, 1121 women, and 301 children; age range, 1–94 y [median age, 52 y]) for chemotherapy or nutritional support	PICC	Malposition was observed in 237 cases (7.87%), with the most frequent site being the internal jugular, followed by the axillary vein; PICCs were relocated back to the SVC or subclavian vein using various techniques
Sperry et al, 2012 (221)	798	Retrospective cohort study	Evaluate the influence of laterality of PICC insertion (right arm vs. left arm) on the risk for subsequent PICC-related DVT	798 sequential PICC placements at 1 medical center in Washington, DC	PICC	Arm of PICC placement was not associated with symptomatic VTE
Stokowski et al, 2009 (222)	538	Retrospective cohort study	Evaluation of the effect of US on risk for PICC complications	538 patients (both inpatient and outpatient) who received PICCs at a Canadian medical center	PICC	Compared with palpation, PICCs placed via US had lower subsequent rates of thrombosis
Strahilevitz et al, 2001 (223)	40	Retrospective cohort study	Examine outcomes related to PICC use in patients with acute myeloid leukemia	Forty patients who received 52 PICCs during the study period	PICC	PICCs were associated with early mechanical complications and infections; however, the complication rate was deemed "acceptable" in this patient population

Continued on following page

Table 1–Continued

Study, Year (Reference)	Participants, *n*	Design	Focus or Overview	Study Sample and Characteristics	Device	Findings and Comments
Tejedor et al, 2012 (18)	89	Retrospective cohort study	Describe patterns of use of temporary CVCs and PICCs in non-ICU wards	89 patients with 146 CVCs (56% of which were PICCs) at 1 academic medical center	PIVC, CVC, PICC	An average of 4.1 idle days with a CVC and a mean of 3.4 idle days with both a CVC and a PIVC were noted; patients with a PICC had 5.4 d in which they also had a PIVC, compared with 10 d in patients with a CVC
Thakarar et al, 2014 (224)	3273	Retrospective cohort study	Evaluation of tPA use as a marker for in situ thrombosis and risk for subsequent PICC-related CLABSI	3273 patients at a tertiary care center, 40% of whom received tPA	PICC	Use of tPA was associated with 3.59 times greater risk for CLABSI compared with patients who did not receive this treatment
Timsit et al, 1998 (225)	265	Prospective cohort study	Association between catheter thrombosis and catheter infection	265 patients receiving ICU care in a French hospital	CVC	Catheter thrombosis was associated with 2.62-fold greater risk for catheter-related sepsis
Tiwari et al, 2011 (226)	436	Prospective cohort study	Appropriateness of vascular device use in hospitalized patients	436 hospitalized patients who received 876 IVDs over 2909 hospital-days	PIVC, CVC	31% of total catheter-days were adjudicated as inappropriate (using the authors' criteria for appropriate vs. inappropriate use)
Touré et al, 2015 (227)	196	Prospective cohort study	Compare the rates of complications associated with tunneled catheters (Broviac) and PICC in patients receiving home parenteral nutrition	204 catheters were inserted in 196 patients who received care in a home parenteral nutrition program	PICC, tunneled catheter	Complications were similar between both catheter groups; however, catheter infection rates were lower in the PICC group
Tran et al, 2010 (60)	478	Retrospective cohort study	Determine the incidence and outcomes associated with PICC-related DVT	Single-center analysis of patients with hematologic cancer, PICCs, and symptomatic UEDVT	PICC	High incidence of DVT associated with PICCs in patients receiving myelosuppressive chemotherapy; centrally positioned PICCs tunneled into the internal jugular vein were associated with low incidence of thrombosis
Trerotola et al, 2007 (228)	1654 PICCs	Retrospective cohort study	Determine the incidence and location of PICC tip malposition	Single-center analysis of 2367 bedside attempts at insertion	PICC	Tip malposition occurred in 163 cases after bedside insertion; most malpositionings were corrected by catheter exchange (58%) and repositioning (36%)
Trerotola et al, 2010 (229)	50	Prospective cohort study	Evaluate outcomes associated with use of a triple-lumen PICC in the ICU setting	Critically ill patients who received triple-lumen PICCs	PICC	The study was stopped after an interim analysis demonstrated extremely high rates of symptomatic DVT in 20% of patients
Trick et al, 2004 (230)	320	Cross-sectional survey	Evaluate how often CVCs were placed without clinical justification in the medical record	Hospitalized adult patients in a 600-bed public hospital	CVC	Unjustified use of CVCs was more common in patients receiving care outside the ICU; however, most patients received CVCs while in an ICU setting
Tuffaha et al, 2014 (85)	NA	Cost-effectiveness analysis	Assess the cost-effectiveness of clinically indicated vs. routine replacement of PIVCs	Data from an RCT were used to determine cost-effectiveness	PIVC	Clinically indicated replacement strategy was associated with cost-savings per patient of AU$7.60 (95% CI, AU$4.96–AU$10.62)
Turcotte et al, 2006 (231)	NA	Systematic review	Evaluate infectious, thrombotic, phlebitic, and other common complications of PICCs compared with CVC	48 articles were included; complications from PICCs were compared with those from CVCs across several study populations	PICC, CVC	PICCs were associated with a complication profile that was similar to or exceeded that of CVCs. PICCs were more commonly associated with phlebitis and malpositioning than CVCs
Ugas et al, 2012 (232)	NA	Systematic review	Review the evidence on the incidence of central and peripheral venous CRBSIs in critically ill surgical patients, and outline pathways for prevention and intervention	Critically ill ICU patients in surgical ICU settings	PICC, CVC	Diverse definitions of the diagnosis of central and peripheral venous CRBSIs and a small population of patients with PICCs led to inconsistent conclusions and findings
Vesely, 2003 (66)	NA	Review	Summarize the evidence related to optimal tip position of a CVC	Narrative review	PICC, CVC	The scientific evidence at the time did not provide sufficient evidence to support or condemn the placement of a catheter tip in the right atrium
Vidal et al, 2008 (233)	115	Prospective cohort study	Evaluate complications in patients who received PICCs for parenteral nutrition, antibiotics, blood transfusions, and other infusions	115 hospitalized patients who received 127 PICCs for a variety of clinical indications; PICCs were inserted in the nondominant arm in 94 of the 115 patients	PICC	Occlusion (17%), rupture (1.6%), accidental withdrawal (2.4%), infection (3.1%), and VT (2.4%) were the most common complications
Vizcarra et al, 2014 (234)	NA	Infusion Nurses Society guideline/position paper	Identify, promote, and develop recommendations and tools to improve patient safety practices related to the use of short PIVCs	NA; position statement reviewing the literature and recommending best practices	PIVC	Health care provider knowledge, education, and training, along with organizational policies and procedures, should be developed to ensure PIVC safety; in addition, surveillance programs to ensure safety with audits and feedback are necessary to improve device safety
Walker and Todd, 2013 (4)		Survey-based study	Compare insertion cost, patient satisfaction, and infection rates of PICCs inserted by trained nurses and radiologists	Hospitalized patients undergoing PICC insertion in a district general hospital in the United Kingdom	PICC	PICCs placed by IR were associated with greater cost than nurse-led PICC insertions. Patient satisfaction regarding explanation of treatment was higher in the nurse group

Continued on following page

Table 1–Continued

Study, Year (Reference)	Participants, *n*	Design	Focus or Overview	Study Sample and Characteristics	Device	Findings and Comments
Wallis et al, 2014 (235)	3283	RCT	Secondary analysis of an existing RCT data set to evaluate risk factors for PIVC failure	3283 adult medical and surgical patients (5907 catheters) with a PIVC with ≥4 d of expected use	PIVC	PIVC survival is improved by preferential forearm insertion, selection of appropriate PIVC diameter, and insertion by IV teams or other specialists
Walshe et al, 2002 (51)	335	Prospective cohort study	Evaluate complications after PICC insertion in a cohort of adult and pediatric cancer patients	335 patients who received 351 PICCs during hospitalization; patients were cared for either by a home infusion agency (205) or by the hospital staff (146)	PICC	115 (32.8%) of 351 PICCs were removed as a result of a complication, for a rate of 10.9 per 1000 catheter-days; patients with hematologic cancer or bone marrow transplant were more likely to develop a complication
Webster et al, 2013 (83)	NA	Systematic review	Evaluate whether routine changes of PIV catheters every 72–96 h was supported by evidence of efficacy or safety	7 trials with a total of 4895 patients were included in the review	PIVC	No evidence was found to support routine PIVC changes every 72–96 h; consequently, health care organizations may consider policies whereby catheters are changed only if clinically indicated
Wilson et al, 2012 (64)	431	Retrospective cohort study	Analyze and identify risk factors associated with large vein thrombosis in patients with PICCs	Neurosurgical ICU patients	PICC	Surgery for >1 h, history of VTE, receipt of mannitol, and undergoing placement in a paretic arm were identified as risk factors for DVT
Wilson et al, 2013 (236)	431	Retrospective cohort study	Compare risk for complications with PICCs with those associated with CVCs in critically ill patients	Neurosurgical ICU patients	PICC, CVC	During the study period, 431 unique PICCs were placed, with a cumulative incidence of symptomatic thrombosis of 8.4%, CLABSI of 2.8%, and line insertion–related complications of 0.0%
Wojnar and Beaman, 2013 (23)	260	Retrospective cohort study	Evaluate clinical appropriateness of PICC use compared with available recommendations	PICC insertion during hospitalization for any clinical indication; patients were randomly selected from a larger cohort	PICC	Results suggest that each patient had ≥3 indications for PICC placement. However, in 7 patients, use of PICCs did not meet current CDC and Infusion Nurses Society recommendations in that the duration of use was <7 days
Worley et al, 2007 (237)	468	Retrospective cohort study	Evaluate outcomes related to use of PICCs in a specialized headache treatment unit	468 hospitalized adult patients in a specialized headache treatment unit	PICC	Only 2 patients (0.80%) experienced PICC-related DVT; the investigators concluded that patients with PICCs are not at increased risk for UEDVT compared with other hospitalized patients
Worth et al, 2009 (238)	66	Prospective cohort study	Determine the natural history and rate of, and risk factors for, CVC-related complications of CLABSI in a hematology population	106 CVCs (75 PICCs, 31 CVCs) were evaluated in 66 patients, over 2399 CVC-days in an ambulatory cohort	PICC, CVC	DVT occurred in 16 cases (15.1%), exit-site infection in 2 cases (1.9%), and CLABSI in 18 cases (7.5 per 1000 CVC-days). No significant differences were found when complication rates between PICC and CVCs were compared
Xing et al, 2012 (239)	187	Retrospective cohort study	Study the incidence, diagnosis, prevention, and treatment of PICC-related UEDVT in patients with breast cancer	187 patients with breast cancer who received a PICC for chemotherapy	PICC	Four (2.1%) of 188 PICCs were removed as a result of PICC-related UEDVT in 14–112 catheter-days, at a rate of 0.28 per 1000 catheter-days
Yamada et al, 2010 (240)	219	Prospective cohort study	Clarify the degree of patient-perceived comfort and convenience, in addition to procedure-related distress, resulting from use of PICCs in terminally ill patients with cancer	Among 219 patients admitted to a palliative care unit, 39 (18%) underwent PICC placement (a total of 44 procedures were performed because 5 patients underwent PICC insertion twice)	PICC	PICCs were safely inserted in 90% of terminally ill patients with cancer within 20 minutes; although 30% of the patients experienced transient procedure-related distress, >90% felt that the parenteral route was more comfortable and convenient
Yap et al, 2006 (241)	88	Prospective cohort study	Evaluate PICC complication rates in 2003 after introduction of safety measures and compare them with those reported in the same center in 2001 (a historical cohort)	88 PICC lines were inserted in 73 patients under radiologic guidance	PICC	The overall complication rate was 15.9%. Infections developed in 5.7% and thrombotic events occurred in 4.5% of PICCs. The complication rate for 2003 was significantly lower than the rate for 2001 ($P = 0.006$), suggesting that strategies to reduce PICC complications were successful
Yi et al, 2014 (242)	81	Prospective cohort study	Investigate risk factors for PICC-related DVT in patients with cancer	Hospitalized patients with cancer scheduled to receive PICCs between September 2009 and May 2012 at 1 center	PICC	Diabetes increased the risk for PICC-related DVT in patients receiving chemotherapy

Continued on following page

Table 1–Continued

Study, Year (Reference)	Participants, *n*	Design	Focus or Overview	Study Sample and Characteristics	Device	Findings and Comments
Yue et al, 2010 (243)	400	Prospective cohort study	Examine insertion, infectious, and noninfectious complications related to PICC use in patients with cancer at 1 medical center in a province of China	400 ambulatory patients with various types of cancer who received PICCs for chemotherapy	PICC	During insertion, arrhythmia occurred in 1.5% (6 of 400) of patients, difficult catheter threading in 3.75% (15 of 400), and excessive oozing of blood in 0.3% (1 of 400). During the catheter dwell-in period, sensitizing dermatitis occurred in 8% (38 of 400), mechanical phlebitis in 7.5% (30 of 400), catheter occlusion in 9.5% (38 of 400), catheter-associated hematogenous infection in 3% (12 of 400), and VT in 2% (8 of 400)
Zhu et al, 2008 (244)	2170	Retrospective cohort study	Examine adverse events and risk factors associated with such outcomes	Single-center study of patients undergoing PICC placement for various indications	PICC	6 cases of DVT and 2 cases of bacteremia occurred; DVT seemed to be related to advanced cancer, noncentral PICC tip position, coronary artery disease, diabetes, and hyperlipidemia
Zingg et al, 2011 (87)	292	Prospective cohort study	Quantify the indications for catheter placement over dwell time and investigate agreement between health care workers on CVC use	378 CVCs in 292 patients, accounting for 2704 catheter-days	CVC	The most frequent reason (49%) for catheter use was prolonged (>7 d) antibiotic therapy, followed by parenteral nutrition (22.3%). A total of 130 catheter-days (4.8%) were unnecessary, with a higher proportion in non-ICU settings (6.6%). In 35 on-site visits (8.3%) in non-ICU settings, neither the nurse nor the treating physician knew why the catheter was in place
Zochios et al, 2014 (245)	NA	Systematic review	Review the literature surrounding PICCs and highlight the epidemiology, pathophysiology, diagnosis, and management of PICC-related thrombosis in critically ill patients	Systematic review examining risk factors for and diagnosis and treatment of PICC-related DVT in critically ill populations	PICC	The incidence of PICC-related thrombosis in critically ill patients is unclear. US is the preferred diagnostic imaging modality. No RCTs on best treatment of PICC-related thrombosis in the ICU setting to inform practice are available
Zwicker et al, 2014 (53)	NA	Systematic review and guideline	Provide recommendations for diagnosis and management of CVC-associated DVT in patients with cancer	Systematic review of the literature and expert opinion from a guideline writing panel of the International Society on Thrombosis and Haemostasis	PICC, CVC	US is recommended as the initial test of choice. Routine administration of pharmacologic prophylaxis to prevent DVT is not recommended. Anticoagulation with LMWH without removal of the catheter if clinically necessary is recommended

BSI = bloodstream infection; CDC = Centers for Disease Control and Prevention; CKD = chronic kidney disease; CLABSI = central line–associated bloodstream infection; CRBSI = catheter-related bloodstream infection; CRT = catheter-related thrombosis; CT = computed tomography; CVAD = central venous access device; CVC = central venous catheter; DVT = deep venous thrombosis; ED = emergency department; EKG = electrocardiography; ESA = erythropoiesis-stimulating agent; GRADE = Grading of Recommendations Assessment, Development and Evaluation; ICU = intensive care unit; IR = interventional radiology; IV = intravenous; IVD = intravenous device; LMWH = low-molecular-weight heparin; NA = not applicable; NR = not reported; PE = pulmonary embolism; PICC = peripherally inserted central catheter; PIVC = peripheral IV catheter; QI = quality improvement; RCT = randomized, controlled trial; SVC = superior vena cava; TCVC = tunneled central venous catheter; tPA = tissue plasminogen activator; TPN = total parenteral nutrition; UCLA = University California, Los Angeles; UEDVT = upper-extremity deep venous thrombosis; US = ultrasonography; VA = Veterans Affairs; VAD = venous access device; VT = venous thrombosis; VTE = venous thromboembolism.

CONTINUING MEDICAL EDUCATION/MAINTENANCE OF CERTIFICATION ACTIVITY

In addition to CME credit, physicians enrolled in the American Board of Internal Medicine's (ABIM) Maintenance of Certification (MOC) program can earn 8 medical knowledge self-assessment points for successful completing an online activity associated with this article.

To earn 5 CME credits, please take the quiz at www.annals.org/article.aspx?doi=10.7326/M15-0744&atab=7. To earn MOC points, you must take the MOC quiz at www.acponline.org/magicmoc/; successful completion qualifies for 8 MOC points, and this information will be transferred to the ABIM.

These CME and MOC activities are free to ACP members and individual subscribers to *Annals of Internal Medicine*. Others who are interested in completing this MOC activity can learn more about ACP membership and individual subscriptions to *Annals of Internal Medicine* at www.acponline.org.

Plese visit www.acponline.org/magicmoc/ to learn more and take the MOC quiz.

Appendix Table 1. Literature Search Strategy

Search	Query	Items Found, *n*
PubMed (searched 9 March 2013)		
#23	(#8 not (#12 or #21 or #22))	1109
#22	(("Case Reports"[pt] or "case report"[Title]))	1 664 821
#21	(#19 not #20)	455 878
#8	((#3 OR #4) AND #7)	1542
#20	(#16 or #17)	769 402
#19	(#13 or #18)	507 993
#17	((#3 OR #4) AND #7) Filters: Adult: 19+ years	577
#16	adult*[Title/Abstract]	768 894
#13	((#3 OR #4) AND #7) Filters: Child: birth-18 years	417
#18	(pediatric or neonat*[Title])	507 773
#12	(#9 NOT (#10 or 11))	56
#10	((#3 OR #4) AND #7) Filters: Humans	1435
#9	((#3 OR #4) AND #7) Filters: Other Animals	82
#11	(human* or patient*[Title/Abstract])	6 257 942
#7	("Guideline" [Publication Type] OR "Guidelines as Topic"[Mesh] OR "Practice Guideline" [Publication Type] OR "Unnecessary Procedures" [MeSH] or (appropriate* or inappropriate* or indicat* or guideline* or unnecessary[Title/Abstract]))	2 824 018
#4	"peripherally inserted central catheter*" OR "peripherally inserted" or picc*[Title/Abstract]	1474
#3	"Catheterization, Central Venous"[Majr]	8919
CINAHL		325
S24	S20 not S23	
S23	S21 NOT S22	
S22	S20 Limiters–Age Groups: All Adult	
S21	S18 AND S19 Limiters–Age Groups: All Child	
S20	S18 AND S19	
S19	S16 OR S17	
S18	TI (appropriate* or inappropriate* or indicat* or guideline* or unnecessary) OR AB (appropriate* or inappropriate* or indicat* or guideline* or unnecessary)	
S17	TI ("peripherally inserted central catheter*" OR "peripherally inserted" or picc*) OR AB ("peripherally inserted central catheter*" OR "peripherally inserted" or picc*)	
S16	(MH "Catheter Care, Vascular+") OR (MH "Central Venous Catheters+")	
Google Scholar	"peripherally inserted central catheter*" AND (appropriate* or inappropriate* or indicat* or guideline* or unnecessary)	134 (only 131 imported)
ClinicalTrials.gov (searched 9 April 2013)	peripherally inserted central catheter* or picc*	40

Appendix Table 2. Characteristics of MAGIC Panel Members

Panelist	Title	Affiliation	Clinical Specialty	Area of Technical Expertise
Agnes Y. Lee, MD, PhD	Medical Director, Thrombosis Program; Associate Professor of Medicine	University of British Columbia; Vancouver Coastal Health; British Columbia Cancer Agency; Vancouver, British Columbia, Canada	Hematology and oncology	Thrombosis in cancer patients
Anthony Courey, MD	Assistant Professor of Medicine	University of Michigan, Ann Arbor, MI	Critical care	Vascular access and use of ultrasound in critically ill patients
Elie Akl, MD, MPH, PhD	Director, Clincial Epidemiology Unit; Co-director, Center for Systematic Reviews in Health Policy and Systems Research (SPARK)	American University, Beirut, Lebanon; Department of Clinical Epidemiology and Biostatistics, McMaster University, Hamilton, Ontario, Canada	Internal medicine; hospital medicine	Guideline development, thrombosis, evidence-based medicine
Jack LeDonne, MD	Director of Vascular Access Programs; Past President, Association of Vascular Acccess	Greater Baltimore Medical Center, Baltimore, MD	General surgery	Vascular access in general medical and surgical patients
Mauro Pittiruti, MD	Director of Vascular Access Director, GAVeCeLT	Catholic University, Rome, Italy	General surgery	Vascular access
Nancy Moureau, RN	Chief Executive Office; Director of Vascular Education	PICC Excellence, Inc., Hartwell, GA	Vascular access nursing education	Vascular access
Naomi O'Grady, MD, PhD	Director of Procedures, Vascular Access and Concious Sedation	National Institutes of Health Clinical Center, Bethesda, MD	Critical care	Guideline development, central line–associated bloodstream infection, critical care
Nasia Safdar, MD, PhD	Associate Professor of Medicine; Medical Director, Infection Control; Associate Chief of Staff for Research	University of Wisconsin; William S. Middleton Memorial Veterans Hospital; Madison, WI	Infectious diseases	Central line-associated bloodstream infection
Rajiv Saran, MD, MRCP, MS	Professor of Medicine and Epidemiology; Director, US Renal Data System Coordinating Center; Associate Director, Kidney Epidemiology and Cost Center, University of Michigan	University of Michigan Ann Arbor, MI	Nephrology	Chronic kidney disease; vascular access in patients with end-stage renal disease
Lakshmi Swaminathan, MD	Staff Hospitalist; Physician Champion, HMS PICC Quality Improvement Project*	Oakwood Health System, Dearborn, MI	Internal medicine	Hospital medicine; patient safety; quality improvement in hospitalized medical patients
Scott O. Trerotola, MD	Professor of Radiology; Associate Chair and Chief of Interventional Radiology	University of Pennsylvania, Philadelphia, PA	Interventional radiology	Guideline development; vascular access
Dana Wanschneider, RN	Vascular Access Nurse	St. Josephs Mercy Health System, Ann Arbor, MI	Vascular access	Vascular access; nursing
Scott C. Woller, MD	Associate Professor of Medicine	Intermountain Medical Center; University of Utah School of Medicine, Salt Lake City, UT	Internal medicine	Venous thromboembolism; anticoagulation management
Stephen Wiseman, PharmD	Clinical Pharmacy Specialist; Assistant Professor of Pharmacy	University of Michigan; VA Ann Arbor Healthcare System Ann Arbor, MI	Pharmacology	Infectious diseases; home intravenous therapy; management of parenteral therapy
Georgiann Ziegler	Patient Representative	University of Michigan Health System	–	Personally experienced multiple vascular access devices; insights into the patient experience

GAVeCeLT = Gruppo Aperto di Studio 'Gli Accessi Venosi Centrali a Lungo Termine; HMS = Hospital Medicine Safety Consortium; MAGIC = Michigan Appropriateness Guide for Intravenous Catheters; PICC = peripherally inserted central catheter; VA = Veterans Affairs.
* A Blue Cross Blue Shield-funded collaborative quality initative focused on improving PICC use in hospitalized medical patients in 47 particiating hositals in the State of Michigan.

Appendix Table 3. Sample Lists of Thematic Concerns Raised by Panelists*

Theme or Area	Question or Top Concern
Appropriateness of PICC placement and concerns regarding device selection	Is the request for a PICC appropriate for what is needed (i.e., does the entity to be infused require a PICC, or will a midline or peripheral catheter suffice? Overuse of PICC for long-term care when tunneled, cuffed catheters (Hickman, cuffed Groshong, Broviac, etc.) or port would be more appropriate PICCs ordered or maintained for blood draws—is this appropriate? PICCs ordered without trying other devices PICCs ordered when all else fails for 1–3 doses of an infusion—is insertion appropriate?
Issues related to device insertion and selection of PICC characteristics	Is location of the tip of the catheter in the right atrium acceptable? Are dedicated lumens for parenteral nutrition still needed? How many lumens are appropriate for a given use?
Process concerns regarding utilization	Increasing use of PICCs when peripheral catheters may work? How can we drive this down? Unnecessary number/size of PICC lumens Implications of ordering chest radiographs for "PICC placement only" that are otherwise abnormal Patient "requested" PICC line appropriateness How do we resolve disagreement with radiology on where a PICC is located on chest radiograph? Strategies to minimize idle PICC-days When should PICC tips be adjusted for optimal positioning?
Identifying best practices for treatment and prevention of PICC-related DVT	Optimal treatment is undefined. That covers everything from line removal? Anticoagulation? Duration and intensity of anticoagulation Prophylaxis: Is primary prophylaxis indicated in those with "high-risk" factors? What are these factors, and if they are present, how do we provide primary prophylaxis? Prophylaxis: Is secondary prophylaxis indicated? I've had many patients who had a CRT as the index thrombotic event but then re-present with a DVT/PE. Is the risk for recurrence high enough to warrant secondary prophylaxis? If a patient develops DVT and still requires central venous access, should we leave the catheter in situ? If a symptomatic DVT is not improving clinically with a PICC in situ, how long should we wait before removing the PICC or calling IR?
Management of specific complications	If a PICC is pulled out from original position, how far can it migrate out before it has to be pulled/replaced? Is it appropriate to empirically pull a PICC without other evidence of line infection? PICC in place when bacteremia occurs but no evidence of CLABSI—remove or treat through? Optimal timing of placement in bacteremia for long-term antibiotic treatment?

CLABSI = central line–associated bloodstream infection; CRT = catheter-related thrombosis; DVT = deep venous thrombosis; IR = interventional radiology; PE = pulmonary embolism; PICC = peripherally inserted central catheter.
* Edited by the authors for readability. Questions were selected at random from several panelists to illustrate the depth and breadth of focus.

Appendix Table 4. Example Scenarios From Ratings Material

How appropriate is the use of each of the following vascular access devices to obtain venous access for infusion of therapeutics and/or lab draws in a patient who is likely to be hospitalized for a potential duration of:*	Peripheral IV Catheter	US-Guided Peripheral IV Catheter	Midline Catheter	PICC	Nontunneled CVC	Tunneled, Cuffed Catheter	Port
≤5 d?	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9
6–14 d?	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9
15–30 d?	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9
≥31 d?	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9

Compared with PICCs, how preferable is the use of a midline in a hospitalized medical patient who requires venous access for infusion of a nonirritant, nonvesicant therapy for a proposed duration of:	Preference of Midline Catheter vs. PICC†
≤5 d?	1 2 3 4 5 6 7 8 9
6–14 d?	1 2 3 4 5 6 7 8 9
15–30 d?	1 2 3 4 5 6 7 8 9
≥31 d?	1 2 3 4 5 6 7 8 9

CVC = central venous catheter; IV = intravenous; PICC = peripherally inserted central catheter; US = ultrasonography.
* Rating scale: 1 = highly inappropriate; 5 = neutral or uncertain; 9 = highly appropriate.
† Prefer midline catheter = 1; prefer PICC = 9.

Continuing Medical Education/Maintenance of Certification Activity

In addition to CME credit, physicians enrolled in the American Board of Internal Medicine's (ABIM) Maintenance of Certification (MOC) program can earn 8 medical knowledge self-assessment points for successful completing the following module online. To earn 5 CME credits, please take this quiz at www.annals.org/article.aspx?doi=10.7326/M15-0744. To earn MOC points, you must take the MOC quiz at www.acponline.org/magicmoc; successful completion qualifies for 8 MOC points, and this information will be transferred to the ABIM.

These CME and MOC activities are free to ACP members and individual subscribers to *Annals of Internal Medicine*. Others who are interested in completing this MOC activity can learn more about ACP membership and individual subscriptions to *Annals of Internal Medicine* at www.acponline.org.

Question 1: The RAND/UCLA Appropriateness Method was developed to:

A. Examine risks and benefits of medical and surgical procedures, regardless of their cost to estimate the over- or underuse of specific medical and surgical procedures
B. To determine whether specific medical interventions are cost-effective.
C. Develop consensus regarding appropriate medical and surgical procedures from a multidisciplinary panel.
D. To determine whether insurers should cover the cost of an intervention

Question 2: According to the RAND/UCLA Appropriateness Method, which of the following is the hallmark of an "appropriate" rating?

A. When all participating panelists agree on the appropriateness of a clinical scenario.
B. When the expected health benefits exceed the expected negative consequences and the panel median rating is 7 to 9 without disagreement.
C. When the majority of the panel rates the clinical scenario as highly appropriate.
D. When no panel member rates the clinical scenario as inappropriate.

Question 3: According to the RAND/UCLA Appropriateness Method, which of the following indicates an "uncertain" rating?

A. When the panel median ranges from 4 to 6, or there is disagreement regardless of the median.
B. When the panel median ranges from 1 to 3.
C. When the panel median ranges from 7 to 9.
D. When the panel median ranges from 5 to 7.

Question 4: Which of the following information sources was not used to develop the clinical scenarios for rating the appropriateness of various intravenous devices in this document?

A. Systematic reviews of the literature
B. List of controversial topics/key problems generated by experts
C. Clinical areas of ambiguity, controversy, or uncertainty
D. Medicare coverage of the procedure

Question 5: For this project, which of the following elements was NOT used to develop the clinical scenarios or indications that were rated by panelists?

A. Proposed duration of venous access
B. Device characteristics
C. Patient preference
D. Maintenance and care practices

Question 6: In this project, a multidisciplinary panel of experts rated the appropriateness of a number of vascular access devices. Which of the following indications were rated as appropriate for use of peripherally inserted central catheters?

A. Placement in a patient with active cancer for cyclical chemotherapy that can be administered through a peripheral vein, when the proposed duration of such treatment is 3 months or less and peripheral veins are available.
B. Delivery of non–peripherally compatible infusates (e.g., irritants/vesicants) regardless of proposed duration of use.
C. Patient or family requests for a patient who is not actively dying/on hospice for comfort from daily lab draws.
D. Medical or nursing provider request in the absence of other appropriate criteria for peripherally inserted central catheter use.

Question 7: In this project, a multidisciplinary panel of experts rated the appropriateness of practices associated with a number of venous access devices. Which of the following practices were rated as appropriate for peripherally inserted central catheter insertion?

A. Urgent requests for peripherally inserted central catheter placement in a hemodynamically unstable patient in the wards or intensive care unit setting.
B. Routine use of chest radiographs to verify peripherally inserted central catheter tip positioning following uneventful placement via EKG guidance or fluoroscopy by staff who are technically proficient in this technology.
C. Preferential placement of a peripherally inserted central catheter based on the patient's arm dominance.
D. Consult with a relevant specialist (e.g., infectious disease, heme-oncology), operator (vascular access professional), and/or hospital pharmacist prior to ordering a peripherally inserted central catheter to determine optimal device choice and characteristics.

Question 8: Which of the following were rated as an appropriate practice for peripherally inserted central catheter care or maintenance by this multidisciplinary panel?

A. Removal of a peripherally inserted central catheter by a health care team member trained to remove central venous catheters, but not specifically trained to remove a peripherally inserted central catheter.
B. Removal of a peripherally inserted central catheter that is clinically necessary, centrally positioned, and otherwise functional in the setting of arm deep venous thrombosis.
C. Use of normal saline rather than heparin to flush a peripherally inserted central catheter following infusion or phlebotomy.
D. Routine removal and/or replacement of a peripherally inserted central catheter that remains clinically necessary without objective evidence of catheter-associated bloodstream infection in febrile patients.

Question 9: Which of the following was rated as an appropriate practice when caring for peripheral intravenous catheters?

A. Routine replacement or continuation of a peripheral intravenous catheter in the absence of a clinical indication warranting continued use.
B. Removal of a peripheral intravenous catheter in the setting of redness, swelling, pain, or phlebitis over the vein of insertion.
C. Replacement of a peripheral intravenous catheter on the basis of a routine schedule in the absence of redness, swelling, or other signs of inflammation.
D. Removal of a functioning peripheral intravenous catheter because it was inserted in the field (e.g., ambulance or nonhospital site) in the absence of redness, tenderness, or swelling over the insertion site.

Question 10: For the indication of infusion of peripherally compatible fluids, which of the following vascular access devices was rated as neutral for a proposed infusion for 6 to 14 days?

A. Ultrasound-guided peripheral intravenous catheters
B. Midlines
C. Peripherally inserted central catheters
D. Peripheral intravenous catheters

Question 11: For the infusion of peripherally compatible fluids, which of the following vascular access devices were rated as inappropriate for a proposed duration of 31 days or more?

A. Peripherally inserted central catheters
B. Ultrasound-guided peripheral IVs
C. Implanted ports
D. Tunneled catheters

Question 12: According to the Fistula First Breakthrough Initiative, in what stages of chronic kidney disease may use of peripherally inserted central catheters be considered appropriate following expert consultation with nephrology?
A. Stage 1 only
B. Stage 3b or greater
C. Stage 2 only
D. Stage 1 to 3a

Question 13: For the infusion of peripherally noncompatible fluids in critically ill patients, which of the following vascular access devices were rated as appropriate and preferred for a proposed duration of 5 days or less?
A. Nontunneled central venous catheters
B. Tunneled catheters
C. Peripheral intravenous catheters
D. Midlines

Question 14: For patients with difficult peripheral venous access, which of the following pairs of vascular access devices were rated as appropriate and preferred to peripherally inserted central catheters when the proposed duration of use is 14 days or less?
A. Midlines and ports
B. Nontunneled central venous catheters and ports
C. Midlines and central venous catheters
D. Tunneled-cuffed catheters and peripherally intravenous catheters

Question 15: According to our panel, which of the following was rated as appropriate for the treatment of peripherally inserted central catheter-related deep venous thrombosis?
A. Provide at least 1 month of uninterrupted systemic anticoagulation.
B. Low-molecular-weight heparin over warfarin in patients with cancer.
C. Remove the peripherally inserted central catheter and replace this with another device to prevent clot propagation.
D. Refer all patients with peripherally inserted central catheter-related deep venous thrombosis to interventional radiology for evaluation.

Question 16: Among scenarios examining use of vascular access devices in patients that require frequent phlebotomy, which of the following statements are true?
A. Central venous catheters were rated as appropriate and preferred to peripherally inserted central catheters when the expected duration of venous access was 14 days or less in critically ill patients.
B. Ports were rated as appropriate to use in this population, regardless of duration of use.
C. Peripheral intravenous catheters and ultrasound-guided peripheral intravenous catheters were rated as appropriate for use for 5 days or less in patients that require frequent phlebotomy.
D. The most appropriate vascular access device should be determined by patient preference in this setting.

Question 17: Among patients who require frequent phlebotomy for less than 5 days, which of the following resulted in panelist disagreement regarding appropriateness of device use?
A. Midlines
B. Central venous catheters
C. Peripherally inserted central catheters
D. Ports

Question 18: Among patients receiving peripherally compatible infusions in home-based or skilled nursing facilities, which of the following expected durations of use was rated as being appropriate for peripherally inserted central catheter placement?

A. 6 to 14 days
B. Only 15 to 30 days
C. Only more than 30 days
D. More than 15 days

Question 19: Among patients who are likely to require lifelong venous access but are infrequently hospitalized (<5 times per year), when is use of peripherally inserted central catheters considered appropriate according to this panel?

A. When expected duration of venous access is 5 days or less.
B. When the expected duration of venous access is 6 to 14 days.
C. When the expected duration of venous access is 15 or more days.
D. When the expected duration of access is not well-known.

Question 20: In critically ill populations, which of the following expected durations of venous access were rated as appropriate for midline insertion and use?

A. 5 days or less
B. 6 to 14 days
C. 15 to 30 days
D. More than 30 days

Question 21: A patient is diagnosed with active cancer and is recommended multiple cycles of nonvesicant, intermittent chemotherapy that can be administered into a peripheral vein for a total duration of 1 month. Based on the recommendations of this panel, which of the following vascular access devices is considered appropriate for this patient?

A. Peripherally inserted central catheters
B. Intermittent use of peripheral intravenous catheters
C. Ports
D. Tunneled-cuffed catheters

Question 22: A patient with an unknown stage of chronic kidney disease is admitted to the hospital with pneumonia and is likely to require venous access for 5 days or less. However, the patient is a "difficult stick" and nurses are having trouble establishing reliable peripheral access. According to this panel, which of the following are appropriate in this particular setting?

A. Because of the ambiguity regarding the stage of CKD, consultation with nephrology is appropriate prior to peripherally inserted central catheter insertion for any reason.
B. Should the patient be determined to have stage 3b or greater CKD or is possibly a candidate for hemodialysis (with estimated GFR < 45 mL/min), insertion of a peripherally inserted central catheter is appropriate.
C. If peripheral venous access for 5 days or less is likely, placement of a peripheral intravenous catheter in the dorsum of the hand is considered inappropriate.
D. Should longer-term intravenous antibiotics be necessary, placement of a small-bore central catheter for infusion of 14 days of intravenous antibiotics is inappropriate in patients with stage 3b or greater CKD.

Question 23: A patient is being discharged from the hospital to a local skilled nursing facility for continuation of a planned 6 weeks of intravenous antibiotics. According this panel, which of the following vascular access devices are considered appropriate for this patient in this scenario?

A. Nontunneled central venous catheter
B. Peripheral intravenous catheter
C. Midline
D. Peripherally inserted central catheter

Question 24: A patient with an existing peripherally inserted central catheter is admitted to the hospital. A portable chest radiograph performed to ascertain the catheter tip position shows this to be located approximately 1 cm within the right atrium. Based on the recommendations of this panel, which of the following is the most appropriate next course of action?

A. Adjust peripherally inserted central catheter so as to localize the catheter tip in the cavoatrial junction; repeat chest radiography to confirm.
B. No further action is needed; the catheter is well-positioned and okay to use.
C. Withdraw tip so as to localize the catheter tip in the lower third of the superior vena cava.
D. Perform computed tomography to confirm catheter placement.