Published in final edited form as:

Crit Care Med. 2018 December ; 46(12): e1136–e1144. doi:10.1097/CCM.0000000000003423.

Peripherally Inserted Central Catheters (PICCs) in the ICU: A Retrospective Study of Adult Medical Patients in 52 Hospitals

Sushant Govindan, MD MSc^{1,4}, Ashley Snyder², Scott A. Flanders, MD², and Vineet Chopra, MD MSc^{2,3,4}

¹Division of Pulmonary and Critical Care, Department of Medicine, University of Michigan Health System

²Division of Hospital Medicine, Department of Medicine, University of Michigan Health System

³Center for Clinical Management Research, Ann Arbor VA Healthcare System

⁴Patient Safety Enhancement Program, Ann Arbor VA Medical Center all in Ann Arbor, MI

Abstract

Objective: To quantify variation in use and complications from PICCs placed in the intensive care unit vs. PICCs placed on the general ward.

Design: Retrospective cohort study

Setting: 52-hospital Michigan quality collaborative

Patients: 27,289 patients with PICCs placed during hospitalization

Methods and Outcomes: Descriptive statistics were used to summarize patient, provider and device characteristics. Bivariate tests were used to assess differences between PICCs placed in the ICU vs. PICCs placed on the ward. Multilevel mixed-effects generalized linear models adjusting for patient and device factors with a logit link clustered by hospital were used to examine the association between PICC complications and location of PICC placement. Variation in ICU PICC use, rates of complications, and appropriateness of use across hospitals was also examined.

Measurements and Main Results: 8,280 (30.3%) patients received PICCs in the ICU vs. 19,009 (69.7%) on the general ward. The commonest indication for PICC use in the ICU was difficult IV access (35.1%) vs. antibiotic therapy (53.3%) on wards. Compared to PICCs placed in wards, PICCs placed in the ICU were more often multi-lumen (59.5% vs. 39.3, $p<0.001$) and more often associated with a complication (OR=1.30, 95% CI=1.18–1.43, $p<0.001$). Substantial variation in ICU PICC use and outcomes across hospitals was observed, with median PICC dwell-time ranging from 3 to 38.5 days ($p<0.001$) and complications from 0–40.2% ($p<0.001$). Importantly, 87% ($n=45$) of ICUs reported median PICC dwell-times ≥ 14 -days, a duration where traditional central venous catheters, not PICCs, are considered appropriate by published criteria.

Correspondence to: Sushant Govindan, MD, Taubman Center FL 3 Rm 3920, 1500 E Medical Center Dr SPC 5360, Ann Arbor, MI 48109, Tel: 734-763-9077, Fax: 734-764-4556, sushantg@med.umich.edu.

Conflicts of Interests: The authors have no conflicts of interests to disclose.

The remaining authors have disclosed that they do not have any potential conflicts of interest.

Conclusions: PICC use in the ICU is highly variable, associated with complications and often not appropriate. Further study of vascular access decision-making in the ICU appears necessary.

Keywords

intensive care; vascular access; PICCs; CLABSI; VTE; complications

Introduction

Central venous access is one of the most common components in the care of critically ill patients (1–4). Each year, over 7 million central venous catheters (CVCs) are placed in the United States alone (3, 5). Moreover, between 50–80% of critically ill patients require central venous access at some point during their stay in the intensive care unit (ICU) (1, 2). While invasive lines are often placed for life-saving reasons, they are associated with substantial morbidity and mortality (6, 7). Mechanical complications occur at a rate of 5–19% and may necessitate device removal (3). Similarly, central line-associated bloodstream infection (CLABSI) continues to occur in thousands of critically ill patients every year (8), and catheter-associated venous thromboembolism (VTE) impacts 14% of critically ill patients (9). Therefore, the risks and benefits of central venous access must be weighed carefully and often in the ICU.

Over the past decade, central venous access patterns in the ICU have changed with increasing use of peripherally inserted central catheters (PICCs) (10). Multiple reasons underlie growing PICC use in the critically ill patient: ease of insertion (11), perceived safety compared to traditional CVCs (12), ability to facilitate transitions in care (13), and variation in intensivist staffing leading to challenges with inserting traditional CVCs (14). However, use of PICCs in the ICU may also lead to increased risk of complications (9, 15, 16). A systematic review comparing PICCs to CVCs showed that PICCs are 2.5 times more likely to experience VTE compared to CVCs, and critically ill patients were at highest risk for PICC-related VTE (9). ICU status is also associated with a significantly increased risk for PICC-related CLABSI (17).

Recently, appropriateness criteria for PICC use in ICU and ward settings were introduced (18). However, few large-scale studies describe the epidemiology of PICC use in the ICU. Furthermore, it is not known whether practice patterns regarding PICC use in the ICU vary across hospitals, nor to what extent recommendations from these criteria are being followed. Better understanding practice variation, particularly device-specific utilization patterns, is the first step to implementing vascular access decision aides. Therefore, using data from a multihospital quality collaborative in Michigan, we compared the use of PICCs placed in the ICU vs. PICCs placed on the general ward. We assessed differences in patient-, PICC, provider-characteristics and outcomes. We then characterized the site-specific variation regarding PICC use and vascular outcomes in critically ill patients across hospitals.

Methods

Study Setting and Population

This study used data from the Michigan Hospital Medicine Safety Consortium (HMS), a 52-hospital, state-wide quality collaborative supported by Blue Cross Blue Shield of Michigan and Blue Care Network. The setting and design of HMS have been previously described (19–21). Briefly, HMS hospitals have been collecting data on PICC use and outcomes in a sample of hospitalized patients since 2014. Although data collection began across all hospitals in 2014, some pilot hospitals were collecting data since November 2013. In addition, some hospitals place <200 PICCs per year and are defined as “low-volume” sites; as rates of use and outcomes might vary at these sites, they were also included. The collaborative collects data on adult medical patients admitted to a general ward or ICU within a participating hospital who had a PICC placed for any reason during the course of clinical care.

At each hospital, a dedicated and trained medical record abstractor uses a standardized template to collect data directly from the patient medical record. Patients with PICCs are sampled every 14 days, and data from the first 17 cases that meet eligibility requirements are abstracted. To ensure adequate representation of critically ill patients, 7 of the 17 records include patients with a PICC placed in the ICU. Patients are excluded if they are under 18 years old, pregnant, admitted to a nonmedical service (i.e. surgery), or admitted under observation status. Following PICC placement, all patients are followed until PICC removal, death, or 70-days, whichever occurs first. For this analysis, complete data on PICCs placed from November 2013 to May 2017 were included.

Definitions

Patient, device, and provider characteristics known to be associated with VTE, CLABSI, or catheter occlusion were identified using two validated conceptual models (22, 23). Detailed patient demographics, including venous thromboembolism and central line associated bloodstream infection within six months of PICC placement, were abstracted from the medical record. The presence of additional central venous catheters was identified and recorded.

Information regarding device and insertion characteristics were obtained from vascular nursing or interventional radiology notes. Indication for index PICC placement was determined through evaluation of the physician order for PICC placement, interventional radiology insertion note, or vascular access note. PICCs were recorded as placed in the ICU if placement was documented in the ICU or placement occurred on or after the date of ICU admission but prior to the date of ICU discharge. PICCs placed in the emergency room or outpatient setting were excluded from the analysis. Additionally, data on the delivery of certain infusates through the PICC, including specific antibiotic agents and packed red blood cells, were collected.

PICC complications were defined as major vs. minor events. Major events included VTE, (defined as symptomatic, radiographically confirmed [i.e., positive ultrasound or computed tomography], upper extremity deep vein thrombosis [DVT] or pulmonary embolism [PE]).

CLABSI was defined according to the Centers for Disease Control and Prevention National Healthcare Safety Network (CDC NSHN) criteria (13). Cases of suspected CLABSI without supportive microbiologic findings (eg. PICC removed without confirmatory blood cultures) were also identified and included. Minor events included catheter occlusion, which was captured when documented in the medical record or when tissue plasminogen activator was administered for problems with aspiration or infusion

Outcomes

The primary outcome of interest was the difference in composite rate of CLABSI, VTE, and catheter occlusion during the study period by location of PICC placement (ICU vs ward). Secondary outcomes included (a) PICC utilization characteristics and (b) differences in complications by location of PICC placement. Additionally, site-level variation in PICC use and the composite rate of CLABSI, VTE and occlusion for ICU-placed PICCs were assessed.

Statistical Analysis

Descriptive statistics were used to tabulate patient and PICC characteristics. T-, chi-square, and Wilcoxon rank-sum tests assessed differences between PICCs placed in the ICU vs. PICCs placed on the ward, by patient and PICC characteristics. Multilevel mixed-effects generalized linear models with a logit link, binomial distribution and clustered by hospital evaluated for an association between adverse events and location of PICC placement. These were adjusted for patient, provider and device characteristics in accordance with validated models (22, 23).

For PICCs placed in the ICU, differences in complication rates by number of lumens, gauge, operator inserting the device, and presence of a CVC were assessed using chi-square and Fishers exact test. Variation in PICC indications, number of lumens, median dwell-time, and adverse outcomes across hospitals were evaluated using chi-square and Kruskal-Wallis test, respectively. Results were expressed as percentages, means, medians, and odds ratios with corresponding 95% confidence intervals. Statistical significance was assessed at $p < 0.05$. Stata v14 (StataCorp, College Station, TX) was used for all analyses.

Ethical and Regulatory Oversight

The University of Michigan Medical School's Institutional Review Board reviewed this study and deemed it "not regulated" status.

Results

During the study period, a total of 27,289 patients with PICCs were included in the analysis. A total of 8,280 (30.3%) patients received PICCs in the ICU while 19,009 (69.7%) received PICCs on the general ward. Of the 52 hospitals included, 85.4% (n=41) were teaching institutions, 83.3% (n=40) were nonprofit, and the average bed size was 339 beds.

Indication for PICC placement varied by location of device placement. For example, difficult intravenous (IV) access or blood draws was the commonest indication for PICC use

in the ICU (35.1%), representing twice the rate of the same indication (16.6%) for PICCs placed on the ward ($p<0.001$). Alternatively, over half (53.3%) of PICCs placed on the general ward were placed for IV antibiotic therapy compared to 19.8% of PICCs placed in the ICU for the same reason ($p<0.001$) (Table 1). With respect to device characteristics, ICU PICCs were more often double or triple lumen compared to ward PICCs (59.5% vs. 39.3%, 35.6% vs. 2.8%, respectively; $p<0.001$). Importantly, PICCs placed in the ICU also had a shorter median dwell time than ward PICCs (9 vs. 16 days, $p < 0.001$) and were more often in place for ≥ 14 days when compared to PICCs placed on the general ward (67.1% vs. 46.6%, $p<0.001$). (Table 2).

Variation in Complications Between ICU and Ward PICCs

After adjustment, patients with PICCs placed in the ICU were associated with higher odds of experiencing the composite outcome (CLABSI, VTE, or catheter occlusion) compared to patients with a PICC placed on the wards (OR=1.30, 95% CI=1.18–1.43, $p<0.001$). With respect to individual adverse events, patients with PICCs placed in the ICU were associated with a higher odds of developing catheter occlusion (OR=1.91, 95% CI=1.74–2.09, $p<0.001$) and VTE (OR=1.43, 95% CI=1.22–1.68, $p<0.001$). No significant differences in CLABSI were observed by location of PICC placement (OR=0.99; 95% CI=0.81–1.21, $p=0.906$), though overall event rates were low (Table 3).

ICU PICC Use and Outcomes: Aggregate Analysis and Variation by Hospital (Site)

Amongst only ICU PICCs, vascular access nurses placed 6,268 PICCs (75.7%), while interventional radiology placed 933 PICCs (11.3%) (Table 2). Composite complication rates and number of lumens did not differ by operator inserting the catheter. Patients with another CVC in place while in the ICU had higher rates of CLABSI (4.8% vs. 1.9%, $p<0.001$), VTE (7.1% vs. 5.0%, $p=0.013$), and catheter occlusion (18.1% vs. 15.3%, $p=0.040$) than those who did not. Compared to single-lumen devices, multi-lumen PICCs were associated with higher rates of the composite outcome (21.8% vs 8.3%, $p<0.001$), including greater rates of CLABSI (2.3% vs. 0.8%, $p=0.036$), VTE (5.4% vs. 1.8%, $p<0.001$), and catheter occlusion (16.0% vs. 6.5%, $p<0.001$). Larger gauge PICCs (5Fr or higher) were also associated with increased rates of the composite outcome (21.6% vs 13.5%, $p<0.001$), including VTE (5.4% vs 3.1%, $p=0.042$) and catheter occlusion (15.9% vs 10.6%, $p=0.004$).

Indication for ICU PICC placement varied significantly across hospitals ($p<0.001$). While difficult access was the most common indication across the cohort (35.1%), the proportion of patients with this indication in ICUs ranged from 0–100%. The number of PICC lumens used in critically ill patients also varied across sites, with median single lumen use rates of 4.2% (IQR=2.0–8.0%) but ranging from 0–100% ($p<0.001$) (Figure 1A). Similar findings were observed for double and triple lumen PICC use across hospitals ($p<0.001$). Median PICC dwell across sites significantly varied, with an overall median of 9.0 days (IQR=8.0–10.3 days; range of 3–38.5 days [$p<0.001$]). Eighty-seven percent ($n=45$) of hospitals reported a median PICC dwell-time of ≥ 14 days (Figure 1B).

Complications experienced by patients with PICCs placed in the ICU significantly varied across sites ($p<0.001$). The prevalence of the composite outcome (VTE, CLABSI, or

catheter occlusion) ranged from 0–40.2% ($p<0.001$), with a median 14.1% (IQR=9.7–25.3%). Individual complications for ICU PICCs also varied widely (Figure 2). A total of 13 hospitals occupied the lowest 25th percentile for complication rates among all included hospitals, and more than half ($n=7$) of these were low-volume sites. The 13 hospitals with the lowest complication rates also trended towards lesser inappropriate PICC use (64.2% vs. 67.1%, $p=0.597$) and fewer multi-lumen devices (83.5% vs. 92.2%, $p=0.108$).

Discussion

In this study of 27,289 patients in 52 hospitals, we found significant differences in patterns of use and outcomes between PICCs placed in the ICU vs. those placed in general wards. ICU PICCs were more often multi-lumen, larger gauge devices, potentially leading to higher rates of complications. However, no difference in CLABSI outcomes between ward and ICU PICCs were observed, likely due to low number of overall events. The majority of PICCs placed in the ICU (67.1%) had a dwell-time of less than 14 days, a duration where traditional CVCs are considered more appropriate than PICCs. Importantly, substantial variation in PICC-associated outcomes were observed in the ICU, highlighting how these devices are not necessarily innocuous in critically ill patients. This is the first paper to specifically characterize the epidemiology of PICC use and associated outcomes in the ICU across a large cohort of multiple hospitals and serves to inform future quality improvement work

Vascular access practices and outcomes have long been a focus of patient safety and quality improvement in the ICU (24–27). However, growing use of PICCs (1, 28) is changing practice in critically ill patients (9, 29). Given the substantial morbidity and mortality associated with vascular access complications (6, 7), continuous evaluation and quality improvement efforts are needed. This is particularly important given that granular decisions regarding vascular access impact important patient outcomes (30, 31), as demonstrated in this study. Intensive care practitioners must understand how these choices profoundly impact the care of their patients.

Recently, efforts to standardize better the use of PICCs in hospitalized patients have been made (18). The Michigan Appropriateness Guide for Intravenous Catheters (MAGIC) was developed using the RAND/UCLA Appropriateness Methodology to help practitioners improve choice, care and maintenance of PICCs in hospitalized patients. Using a modified Delphi approach, 15 panelists representing multiple disciplines (e.g., critical care, radiology, vascular nursing, etc.) reviewed data from systematic reviews of the literature to rate 665 clinical scenarios. For each scenario, panelists were asked to rate the risk and benefits of PICC use compared to other devices, regardless of cost. Given the risk of VTE associated with PICCs, MAGIC panelists rated PICC use in ICU settings as appropriate only when the expected duration of such use is 15 days or more (9, 32, 33). CVCs are preferred over PICCs for durations of 6–14 days if central access is needed, given their overall lower risk of thrombosis. If peripheral access is necessary for 5 days or less, peripheral IV devices, including midline catheters, are appropriate.

Hospitals implementing MAGIC report improved outcomes (34). Our study extends this work and sheds light on the lack of standardized practice regarding PICC use in the ICU. For example, a specific recommendation from MAGIC is to avoid PICCs in the ICU when the anticipated duration is under 15 days. However, only 13% of hospitals (n=7) had a median PICC duration in the ICU of 15 days or longer. Dissemination of guidelines into clinical practice is challenging and requires specific implementation strategies (35, 36). While it can be difficult to project the expected duration of vascular access, contextual and provider-specific factors such as patient safety culture (37) and provider awareness of guidelines (38) may also influence device use. Further work is needed to understand the barriers and facilitators in effectively deploying tools such as MAGIC in ICUs on a local, regional, and national level.

There are limitations to our study. First, the HMS consortium is focused on medical patients given the stipulations within our quality collaborative; lack of surgical patients limits generalizability of findings. Second, our data focuses on PICC use and outcomes and suffers from lack of a suitable comparator, namely CVCs. However, mounting evidence suggests PICCs are associated with similar or greater risk of adverse events to CVCs in the ICU setting (39). While future work evaluating both devices is necessary, our data serves to highlight the risks of PICC use in this setting. Such an understanding of device-specific utilization patterns is essential to effectively develop future decision support tools. Finally, data used in this study were collected through review of medical records. While this allowed for a granular assessment of multiple variables, these data are susceptible to reporting bias. However, because we used trained abstractors and a systematic approach to collect data, we believe this risk was minimized.

There are several strengths to this study. First, the nature of the study with a large sample size of 29,289 patients provides a robust, real-world view of PICC use and outcomes. Second, the multi-center aspect of the study with 52 hospitals means that these results are generalizable to medical patients in healthcare settings from a variety of contexts. Third, the fact that the database is composed from primary data collection by trained abstractors allows for a detailed assessment of key clinical variables that are often absent in secondary databases.

Conclusion

Vascular access decisions are some of the most important aspects to caring for critically ill patients. While much work has already been done to improve outcomes in the ICU (40–42), increasing use of PICCs has changed the landscape. Our study demonstrates that more lumens and larger gauge catheters are associated with higher complication rates in the ICU. Importantly, we also show substantial variation in ICU PICC use across hospitals, which highlights important ways in which practice can be improved. Additional efforts are needed to better understand how critical care practitioners make decisions regarding vascular access in the ICU. In doing so, the medical community will be better equipped to design and implement targeted interventions towards improving vascular outcomes in critically ill patients on a regional and national scale.

Acknowledgments

Sources of Funding: This work was supported by U.S. National Institutes of Health – T32-HL007749 (SG) and AHRQ 1-K08-HS022835–01 (VC).

Copyright form disclosure: Dr. Govindan received support for article research from the National Institutes of Health. Dr. Flanders' institution received funding from AHRQ and BCBS of Michigan, and he received funding from Expert Witness consulting and Wiley Publishing (royalties).

References

1. Climo M, Diekema D, Warren DK, et al.: Prevalence of the use of central venous access devices within and outside of the intensive care unit: results of a survey among hospitals in the prevention epicenter program of the Centers for Disease Control and Prevention. *Infect Control Hosp Epidemiol* 2003; 24: 942–945. [PubMed: 14700410]
2. Lindgren S, Pikwer A, Ricksten SE, et al.: Survey of central venous catheterisation practice in Sweden. *Acta Anaesthesiol Scand* 2013; 57: 1237–1244. [PubMed: 24102163]
3. McGee DC, Gould MK. Preventing complications of central venous catheterization. *N Engl J Med* 2003; 348: 1123–1133. [PubMed: 12646670]
4. Taylor RW, Palagiri AV. Central venous catheterization. *Crit Care Med* 2007; 35: 1390–1396. [PubMed: 17414086]
5. Raad I Intravascular-catheter-related infections. *Lancet* 1998; 351: 893–898. [PubMed: 9525387]
6. Day I Thrombosis: a major contributor to the global disease burden. *J Thromb Haemost* 2014; 12: 1580–1590. [PubMed: 25302663]
7. Ziegler MJ, Pellegrini DC, Safdar N. Attributable mortality of central line associated bloodstream infection: systematic review and meta-analysis. *Infection* 2015; 43: 29–36. [PubMed: 25331552]
8. Centers for Disease C, Prevention. Vital signs: central line-associated blood stream infections--United States, 2001, 2008, and 2009. *MMWR Morb Mortal Wkly Rep* 2011; 60: 243–248. [PubMed: 21368740]
9. Chopra V, Anand S, Hickner A, et al.: Risk of venous thromboembolism associated with peripherally inserted central catheters: a systematic review and meta-analysis. *Lancet* 2013; 382: 311–325. [PubMed: 23697825]
10. Trerotola SO, Stavropoulos SW, Mondschein JJ, et al.: Triple-lumen peripherally inserted central catheter in patients in the critical care unit: prospective evaluation. *Radiology* 2010; 256: 312–320. [PubMed: 20574104]
11. Krein SL, Kuhn L, Ratz D, et al.: Use of Designated Nurse PICC Teams and CLABSI Prevention Practices Among U.S. Hospitals: A Survey-Based Study. *J Patient Saf* 2015.
12. Pikwer A, Akesson J, Lindgren S. Complications associated with peripheral or central routes for central venous cannulation. *Anaesthesia* 2012; 67: 65–71. [PubMed: 21972789]
13. Chopra V, Flanders SA, Saint S. The problem with peripherally inserted central catheters. *JAMA* 2012; 308: 1527–1528. [PubMed: 23073947]
14. Hyzy RC, Flanders SA, Pronovost PJ, et al.: Characteristics of intensive care units in Michigan: not an open and closed case. *J Hosp Med* 2010; 5: 4–9. [PubMed: 20063391]
15. Fletcher JJ, Wilson TJ, Rajajee V, et al.: A Randomized Trial of Central Venous Catheter Type and Thrombosis in Critically Ill Neurologic Patients. *Neurocrit Care* 2016; 25: 20–28. [PubMed: 26842716]
16. 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: 879–882. [PubMed: 22948189]
17. Chopra V, Ratz D, Kuhn L, et al.: PICC-associated bloodstream infections: prevalence, patterns, and predictors. *Am J Med* 2014; 127: 319–328. [PubMed: 24440542]
18. Chopra V, Flanders SA, Saint S, et al.: Michigan Appropriateness Guide for Intravenous Catheters P. The Michigan Appropriateness Guide for Intravenous Catheters (MAGIC): Results From a

- Multispecialty Panel Using the RAND/UCLA Appropriateness Method. *Ann Intern Med* 2015; 163: S1–40. [PubMed: 26369828]
19. Grant PJ, Greene MT, Chopra V, et al.: Assessing the Caprini Score for Risk Assessment of Venous Thromboembolism in Hospitalized Medical Patients. *Am J Med* 2016; 129: 528–535. [PubMed: 26551977]
 20. Greene MT, Flanders SA, Woller SC, et al.: The Association Between PICC Use and Venous Thromboembolism in Upper and Lower Extremities. *Am J Med* 2015; 128: 986–993 e981. [PubMed: 25940453]
 21. Greene MT, Spyropoulos AC, Chopra V, et al.: Validation of Risk Assessment Models of Venous Thromboembolism in Hospitalized Medical Patients. *Am J Med* 2016; 129: 1001 e1009–1001 e1018.
 22. Smith SN, Moureau N, Vaughn VM, et al.: Patterns and Predictors of Peripherally Inserted Central Catheter Occlusion: The 3P-O Study. *J Vasc Interv Radiol* 2017; 28: 749–756 e742. [PubMed: 28292637]
 23. Chopra V, Anand S, Krein SL, et al.: Bloodstream infection, venous thrombosis, and peripherally inserted central catheters: reappraising the evidence. *Am J Med* 2012; 125: 733–741. [PubMed: 22840660]
 24. Berenholtz SM, Pronovost PJ, Lipsett PA, et al.: Eliminating catheter-related bloodstream infections in the intensive care unit. *Crit Care Med* 2004; 32: 2014–2020. [PubMed: 15483409]
 25. Marsteller JA, Sexton JB, Hsu YJ, et al.: A multicenter, phased, cluster-randomized controlled trial to reduce central line-associated bloodstream infections in intensive care units*. *Crit Care Med* 2012; 40: 2933–2939. [PubMed: 22890251]
 26. Pronovost P, Needham D, Berenholtz S, et al.: An intervention to decrease catheter-related bloodstream infections in the ICU. *N Engl J Med* 2006; 355: 2725–2732. [PubMed: 17192537]
 27. Pronovost PJ, Goeschel CA, Colantuoni E, et al.: Sustaining reductions in catheter related bloodstream infections in Michigan intensive care units: observational study. *BMJ* 2010; 340: c309. [PubMed: 20133365]
 28. Alexandrou E, Spencer TR, Frost SA, et al.: 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: 536–543. [PubMed: 24145843]
 29. Chopra V, O'Horo JC, Rogers MA, et al.: 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: 908–918. [PubMed: 23917904]
 30. Herc E, Patel P, Washer LL, et al.: A Model to Predict Central-Line-Associated Bloodstream Infection Among Patients With Peripherally Inserted Central Catheters: The MPC Score. *Infect Control Hosp Epidemiol* 2017; 38: 1155–1166. [PubMed: 28807074]
 31. Chopra V, Ratz D, Kuhn L, et al.: Peripherally inserted central catheter-related deep vein thrombosis: contemporary patterns and predictors. *J Thromb Haemost* 2014; 12: 847–854. [PubMed: 24612469]
 32. Fallouh N, McGuirk HM, Flanders SA, et al.: Peripherally Inserted Central Catheter-associated Deep Vein Thrombosis: A Narrative Review. *Am J Med* 2015; 128: 722–738. [PubMed: 25697969]
 33. Chopra V, Kaatz S, Conlon A, et al.: The Michigan Risk Score to predict peripherally inserted central catheter-associated thrombosis. *J Thromb Haemost* 2017; 15: 1951–1962. [PubMed: 28796444]
 34. Swaminathan L, Flanders S, Rogers M, et al.: Improving PICC use and outcomes in hospitalised patients: an interrupted time series study using MAGIC criteria. *BMJ Qual Saf* 2017.
 35. Grimshaw J, Eccles M, Thomas R, et al.: Toward evidence-based quality improvement. Evidence (and its limitations) of the effectiveness of guideline dissemination and implementation strategies 1966–1998. *J Gen Intern Med* 2006; 21 Suppl 2: S14–20.
 36. Crossing the Quality Chasm: A New Health System for the 21st Century. Washington (DC); 2001.
 37. Pronovost P, Sexton B. Assessing safety culture: guidelines and recommendations. *Qual Saf Health Care* 2005; 14: 231–233. [PubMed: 16076784]

38. Cabana MD, Rand CS, Powe NR, et al.: Why don't physicians follow clinical practice guidelines? A framework for improvement. *JAMA* 1999; 282: 1458–1465. [PubMed: 10535437]
39. Zochios V, Umar I, Simpson N, et al.: Peripherally inserted central catheter (PICC)-related thrombosis in critically ill patients. *J Vasc Access* 2014; 15: 329–337. [PubMed: 24811591]
40. Latif A, Halim MS, Pronovost PJ. Eliminating Infections in the ICU: CLABSI. *Curr Infect Dis Rep* 2015; 17: 491. [PubMed: 26031963]
41. Marang-van de Mheen PJ, van Bodegom-Vos L. Meta-analysis of the central line bundle for preventing catheter-related infections: a case study in appraising the evidence in quality improvement. *BMJ Qual Saf* 2016; 25: 118–129.
42. Ranji SR, Shetty K, Posley KA, et al.: Closing the Quality Gap: A Critical Analysis of Quality Improvement Strategies (Vol 6: Prevention of Healthcare-Associated Infections). Rockville (MD); 2007.

Figure 1: Variation by Site: (A) PICC Lumens and (B) PICC Dwell-time.

*Low volume PICC site: defined as hospitals that place less than 200 PICCs per year in hospitalized general medical patients.

Figure 2: Variation by Site in Vascular Outcomes.

*Low volume PICC site: defined as hospitals that place less than 200 PICCs per year in hospitalized general medical patients.

Table 1:

Patient Demographics *

Patient Characteristics, n(%)	Intensive Care Unit		Ward		P-value
	N=8,280	%	N=19,009	%	
Gender					0.136
Female	4198	50.70	9453	49.73	
Age, mean (SD)	64.2 (15.7)		64.0 (16.8)		0.400
Race					0.889
White	6112	73.82	14190	74.65	
Black	1686	20.36	3848	20.24	
Asian	54	0.65	116	0.61	
American Indian/Native Islander	35	0.42	87	0.46	
Other	141	1.70	351	1.85	
Payer					<0.001
Medicare	4801	57.98	10866	57.16	
Medicaid	1121	13.54	2385	12.55	
Other Insurance	1730	20.89	4497	23.66	
No Insurance	148	1.79	264	1.39	
Body mass index, mean (SD)	31.3 (10.6)		30.4 (9.8)		<0.001
Charlson, median (IQR)	3 (2–5)		3 (1–5)		<0.001
Smoking status					<0.001
Never	2894	34.95	7875	41.42	
Former	2969	35.86	6859	36.08	
Current	2081	25.13	3830	20.14	
Mechanical ventilation	4187	50.57	510	2.68	<0.001
Vasopressor use	2319	28.01	391	2.06	<0.001
Hemoglobin at time of placement, median (IQR)	10 (8.6–11.8)		10.3 (8.9–11.8)		<0.001
Medical History					
History of Cancer	1677	20.25	4743	24.95	<0.001
History of VTE	1453	17.55	3265	17.18	0.455
History of CLABSI	52	0.63	241	1.27	<0.001
Indication for PICC					
Antibiotics	1638	19.78	10211	53.27	<0.001
Blood transfusion or blood products	26	0.31	63	0.33	0.817
Chemotherapy	55	0.66	684	3.60	<0.001
Difficult access/blood draws	2904	35.07	3156	16.60	<0.001
Medications requiring central access	2188	26.43	1266	6.66	<0.001
Multiple incompatible fluids	366	4.42	142	0.75	<0.001
Parenteral nutrition	327	3.95	1327	6.98	<0.001

Patient Characteristics, n(%)	Intensive Care Unit		Ward		P-value
	N=8,280	%	N=19,009	%	
Medications requiring central access per hospital policy	23	0.28	13	0.07	<0.001
Unknown	1427	17.23	1955	10.28	<0.001

* ICU: intensive care unit. SD: standard deviation. IQR: interquartile ratio. VTE: venous thromboembolism. CLABSI: central line-associated bloodstream infection. PICC: peripherally inserted central catheters.

Table 2:

Provider and Device-Related Characteristics

Provider and Device-Related Characteristics, n(%)	Intensive Care Unit		Ward		P-value
	N=8,280	%	N=19,009	%	
Number of PICC placement attempts					<0.001
1	7175	86.65	16692	87.81	
2	724	8.74	1385	7.29	
3 or more	298	3.60	570	3.00	
Number of lumens					<0.001
1	398	4.81	10922	57.46	
2	4923	59.46	7467	39.28	
3 or more	2938	35.59	522	2.75	
Line thickness, median (IQR)	5 (5–5)		5 (4–5)		<0.001
PICC Inserted By					<0.001
Adv Prac Prof	923	11.15	2207	11.61	
Interventional Radiologist	933	11.27	4210	22.15	
Physician	45	0.54	189	0.99	
Vascular Access Nurse	6268	75.70	12204	64.20	
Other/unknown	111	1.34	199	1.05	
Type of attending at time of PICC placement					<0.001
Critical Care	4198	50.70	100	0.53	
General Internist	1878	22.68	6544	34.43	
Hospitalist	1165	14.07	8449	44.45	
ID/Heme-Onc/Medicine Sub Specialist	883	10.66	3581	18.84	
Other	156	1.88	335	1.76	
Antimicrobial coated PICC	554	6.69	1278	6.72	0.922
Antithrombotic coated PICC	148	1.79	407	2.14	0.057
CVC in place at time of abstraction	2140	25.85	1135	5.97	<0.001
PICC dwell time in days, median (IQR)	9 (5–19)		16 (7–39)		<0.001
Administration of anticoagulant	6952	83.96	14024	73.78	<0.001
Tip migration	379	4.58	566	2.98	<0.001
Tip position confirmation through PICC tip detector system	4032	48.70	8962	47.15	0.018
Infusates through PICC (Cefepime, Piperacillin-tazobactam, or Vancomycin)	3054	36.88	6481	34.09	<0.001
Transfusion through PICC line	810	9.78	1279	6.73	<0.001
Heparin and saline solution flush (SASH)	1935	23.37	5780	30.41	<0.001
Right arm placement	5779	69.79	13400	70.49	0.254

* *ICU*: intensive care unit. *IQR*: interquartile ratio. *CVC*: central venous catheter. *PICC*: peripherally inserted central catheters.

Table 3:

Vascular Outcome Differ Significantly Between PICCs Placed in the ICU and PICCs Placed Outside the ICU*

Outcomes, n(%)	Ward	Intensive Care Unit	Ward vs Intensive Care Unit, Ward Reference Group			
	<i>N</i> =19,009	<i>N</i> =8,280	<i>OR</i> (95% <i>CI</i>) ^a	<i>P</i> -value	<i>OR</i> (95% <i>CI</i>) ^b	<i>P</i> -value
Composite Outcome (CLABSI, VTE, or catheter occlusion)	2387 (12.56)	1749 (21.12)	1.79 (1.66, 1.92)	<0.001	1.30 (1.18, 1.43)	<0.001
CLABSI: Physician diagnosis	35 (0.18)	13 (0.16)	0.84 (0.44, 1.60)	0.590	0.90 (0.44, 1.81)	0.758
CLABSI: Line sepsis/bacteremia	129 (0.68)	49 (0.59)	0.85 (0.61, 1.19)	0.342	0.78 (0.54, 1.13)	0.185
CLABSI: Line removal for suspected CLABSI	254 (1.34)	110 (1.33)	1.09 (0.87, 1.37)	0.462	0.93 (0.72, 1.20)	0.574
CLABSI: Modified NHSN defined CLABSI	147 (0.77)	56 (0.68)	0.89 (0.65, 1.22)	0.458	0.81 (0.57, 1.13)	0.214
CLABSI: Composite definition	387 (2.04)	183 (2.21)	1.13 (0.94, 1.36)	0.186	0.99 (0.81, 1.21)	0.906
Catheter Occlusion	1629 (8.57)	1290 (15.58)	1.85 (1.71, 2.01)	<0.001	1.91 (1.74, 2.09)	<0.001
Confirmed VTE	548 (2.88)	432 (5.22)	1.81 (1.58, 2.07)	<0.001	1.43 (1.22, 1.68)	<0.001

^a Unadjusted

^b Adjusted for gender, age, race, BMI, smoking status, and Charlson Comorbidity Index (CCI) in all cases. Specific adjustment by type of adverse event as follows: CLABSI = history of cancer, history of CLABSI, dwell time, and concurrent CVC; VTE = history of cancer, history of VTE, line thickness, number of placement attempts, anticoagulant administration, and tip migration; Catheter Occlusion = dwell time, tip migration, hemoglobin at time of PICC placement, arm of PICC placement, PICC detector system used for PICC placement, infusion of Cefepime, Piperacillin-tazobactam, or Vancomycin through PICC, blood transfusion through the PICC, flush with heparin and saline solution; Composite Outcome = all listed variables