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Complication rates among peripherally inserted central venous catheters and centrally inserted central catheters in the medical intensive care unit☆

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ABSTRACT

Purpose: There are limited contemporary data describing the rates of catheter-related deep vein thrombosis (CRDVT) and central line–associated bloodstream infection for peripherally inserted central venous catheters (PICCs) and centrally inserted central venous catheters (CICCs) in the medical intensive care unit (ICU).
Methods: We performed a retrospective cohort study of 200 PICCs (dual/triple lumen) and 200 CICCs (triple/quadruple lumen) placed in medical ICU adults at Mayo Rochester between 2012 and 2013. Central lines were followed from insertion time until hospital dismissal (primary analysis) or ICU discharge (secondary analysis). Symptomatic CRDVT was determined by Doppler ultrasound. Central line–associated bloodstream infection was defined according to federal reporting criteria.
Results: During 1730 PICC days and 637 CICC days, the incidence of CRDVT when followed until hospital dismissal was 4% and 1% (4.6 and 3.1 per 1000 catheter-days), respectively, $P = .055$. When censored at the time of ICU dismissal, the rates were 2% and 1% (5.3 and 3.7 per 1000 catheter-days), $P = .685$. Only 1 central line–associated bloodstream infection occurred in a PICC following ICU dismissal, $P > .999$.
Conclusions: Thrombotic and infectious complications were uncommon following PICC and CICC insertion, with no significant difference in complication rates observed. Half of PICC DVTs occurred on the general floor, and like all central catheters placed in the ICU, PICCs should be aggressively discontinued when no longer absolutely needed.

1. Introduction

Central venous access is commonly required in the critical care setting for hemodynamic monitoring and medication administration. Although initially used in the outpatient setting [1], peripherally inserted central venous catheters (PICCs) have emerged as viable alternatives to short-term, nontunneled centrally inserted central venous catheters (CICCs) in the intensive care unit (ICU) [2]. Although PICC use in the ICU has become increasingly prevalent, limited contemporary data exist regarding complications from PICC insertion. Prior ICU-based studies evaluating PICC and CICC complications show widely varying rates for central line–associated bloodstream infection (CLABSI) and catheter-related deep vein thrombosis (CRDVT) [2–26]. Importantly, modern practice innovations including the introduction of smaller-gauge PICC catheters, specialized insertion teams [27], and improved central line stewardship [28] may make prior findings outdated. Given the paucity of contemporary data on central line complications specific to the medical ICU (MICU), we performed a retrospective cohort review to define the complication rates associated with PICCs and CICCs in a tertiary, academic medical ICU.

2. Materials and methods

2.1. Study population and catheter type

Our retrospective cohort study included consecutive adult patients (age ≥18) admitted to our 24-bed tertiary care medical ICU in Rochester, MN, who had a new central venous catheter (CVC) placed during their MICU admission on or before June 30, 2013. We had a prespecified target accrual of 200 central line insertions for each type of line. To identify the most recent catheter data, we reviewed records starting at our end date and moving backward until we achieved our target. We included nontunneled, peripherally inserted central catheters and nontunneled, centrally inserted CVCs in our study. Temporary dialysis catheters and "introducer" catheters were excluded because of the

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unique indication for this type of intravenous access. The specific indication for each central line could not be systematically assessed in a retrospective manner. For patients with more than 1 qualifying central line placed during the study period, we included only the most recent line placed for each line type. Our institution uses 5F or 6F, 2- or 3-lumen PowerPICC SOLO*2 peripherally inserted central catheters (Bard Access Systems, Inc, Salt Lake City, UT). Triple-lumen catheters were 7F, with two 18-gauge lumens and one 16-gauge lumen, made by Arrow International (Teleflex Medical, Research Triangle Park, NC). Quadruple-lumen catheters were 8.5F, with two 18-gauge lumens, one 16-gauge lumen, and one 14-gauge lumen made by Arrow International.

2.2. Catheter insertion technique and maintenance

Peripherally inserted CVCs are placed under ultrasound guidance by a specially trained nurse-led "PICC-team" using a microintroducer and Seldinger technique, or by Interventional Radiology. The PICC insertion team chooses the optimal vessel based on a goal vessel-to-catheter ratio of at least of 3:1, which is determined by visual estimate using an onscreen guide included in the Bard Site-Rite 6 vascular ultrasound. Triple- and quadruple-lumen CICCs are placed under ultrasound guidance by the MICU team at the bedside. A chest radiograph confirms central line location. All trainees and attending physicians at our institution undergo structured central line insertion training and competency-based evaluation [29,30]. During central line insertion, a mandatory "central line bundle" is used. These policies require preprocedural hand hygiene; use of maximum sterile technique including mask, cap, full gown, and gloves; head-to-toe patient draping; and allowing the skin antiseptic (typically 2% chlorhexidine solution) to dry before needle insertion. There is at least 1 assistant present, among whose tasks it is to observe for breaks in sterile technique. Use of sterile technique is required postprocedural documentation. Site selection is left to the discretion of the physician, with femoral access discouraged unless necessary. Following insertion, an antimicrobial patch is placed at the site of skin entry. All central line sites undergo daily visual assessments by nursing staff, and catheter dressings are changed approximately every 2 (gauze-covered) to 7 (transparent) days using clean or sterile gloves. The entire medical team performs daily assessment of ongoing need for the CVC, and nursing staff documents the indication. Placement and maintenance of PICCs and CICCs described in this article were part of routine clinical practice and were not protocolized for this study.

2.3. Data collection

Our institution's critical care research group maintains a prospective database that tracks demographic and outcome data for all intensive care admissions, which has been described and validated elsewhere [31]. A separate local data warehouse [32] was queried to identify patients who had new central intravenous access charted during their admission to the MICU. All potential cases were manually reviewed to ensure that they met inclusion/exclusion criteria and to verify the date and time of insertion and removal to ensure accuracy of line-duration data. Patients were followed for line-related complications until the central line was removed or the patient was dismissed from the hospital. Patients were excluded if they declined consent for general retrospective research at our institution. This study was approved by the Mayo Clinic institutional review board, which waived the requirement for written informed consent.

2.4. Outcomes

The primary end points were the overall rate-per-line (incidence) and rate-per-1000-catheter-days of symptomatic catheter-related deep vein thrombosis (CRDVT) and central line–associated bloodstream infection (CLABSI) for PICCs and CICCs placed in the MICU and followed until hospital discharge. For our secondary end points, we repeated this analysis but followed central lines only until the time of ICU discharge. The CICC cases were additionally screened for insertion-related pneumothorax or hemothorax.

2.5. Definitions

Symptomatic CRDVT was defined as a new acute thrombus in a deep vein where a catheter was present or removed within the previous 5 days for which a venous Doppler ultrasound was obtained for the work-up of a new unexplained symptom (eg, swelling, fever [33]). We excluded cases of asymptomatic, incidentally detected catheter-related thrombus if the ultrasound was obtained for alternative reasons. Superficial vein thromboses were excluded. The CRDVT events were identified by manual chart review of ultrasonography reports by the primary author (MN) and confirmed by 2 other reviewers (HY and RCC). *Central line–associated bloodstream infection* was defined using the standard Centers for Disease Control/National Healthcare Safety Network reporting definitions [34]. Although catheter-related bloodstream infection is an alternative criterion for infection event outcomes, we chose to use the CLABSI definition because it is more inclusive and is the standard national reporting definition, which has both patient-safety and administrative relevance. The CLABSI events were detected by manual chart review of the microbiology data by the primary author (MN), confirmed by a second author (KC), and cross-referenced with our hospital's CLABSI reporting database to ensure that no CLABSI events were overlooked.

2.6. Statistics

For comparison of normally distributed, continuous data, we used a 2-sided Student t test assuming either equal or unequal variances according to the associated F test. For continuous data that failed tests for normal distribution, we reported the median and used a nonparametric Wilcoxon rank sums test. For comparison of nominal data, we used a Pearson χ^2 test, or Fisher exact test if the expected event rate was fewer than 5. A P value of .05 was considered statistically significant. All data analyses were performed using JMP statistical software (Version 9.0.3; SAS Institute, Cary, NC).

3. Results

We manually reviewed 612 patient charts to identify 400 consecutively placed central lines that met our inclusion/exclusion criteria, consisting of 200 PICCs and 200 CICCs placed in 371 unique patients between July 20, 2012, and June 30, 2013 (Fig. 1). No patients were lost to follow-up. We found significantly higher baseline severity of disease in the CICC group as reflected in the 24-hour Sequential Organ Failure Assessment (SOFA) and Acute Physiology and Chronic Health Evaluation (APACHE) III scores, invasive ventilator use, and length of hospital stay, but no significant difference with respect to overall in-hospital mortality (Table 1). The laterality of the central lines is specified in Table 2, and the indwelling time distribution is provided in Fig. 2. Overall complications following line placement are outlined in Table 3. In total, we accrued more than 2300 hospital catheter-days of data, with 1730 days of PICC data and 637 days of CICC data. The groups differed with respect to indwelling duration, with PICCs remaining in place for a median of 3.5 days longer. Overall, 8 (4%) of 200 PICC lines and 2 (1%) of 200 CICCs developed symptomatic CRDVT, $P = .055$. We identified only 1 CLABSI out of the 400 central lines, occurring 34 days after placement of a PICC in a neutropenic patient following discharge from the MICU to a step-down care unit. There were no cases of insertion-related pneumothorax or hemothorax in any of the CICCs.

Table 4 provides ICU-specific rates of central line complications, with event data duration censored at the time of ICU discharge. Total indwelling-catheter duration was 750 PICC days and 535 CICC days. Two (100%) of the 2 CICC DVTs occurred in the ICU, whereas only 4

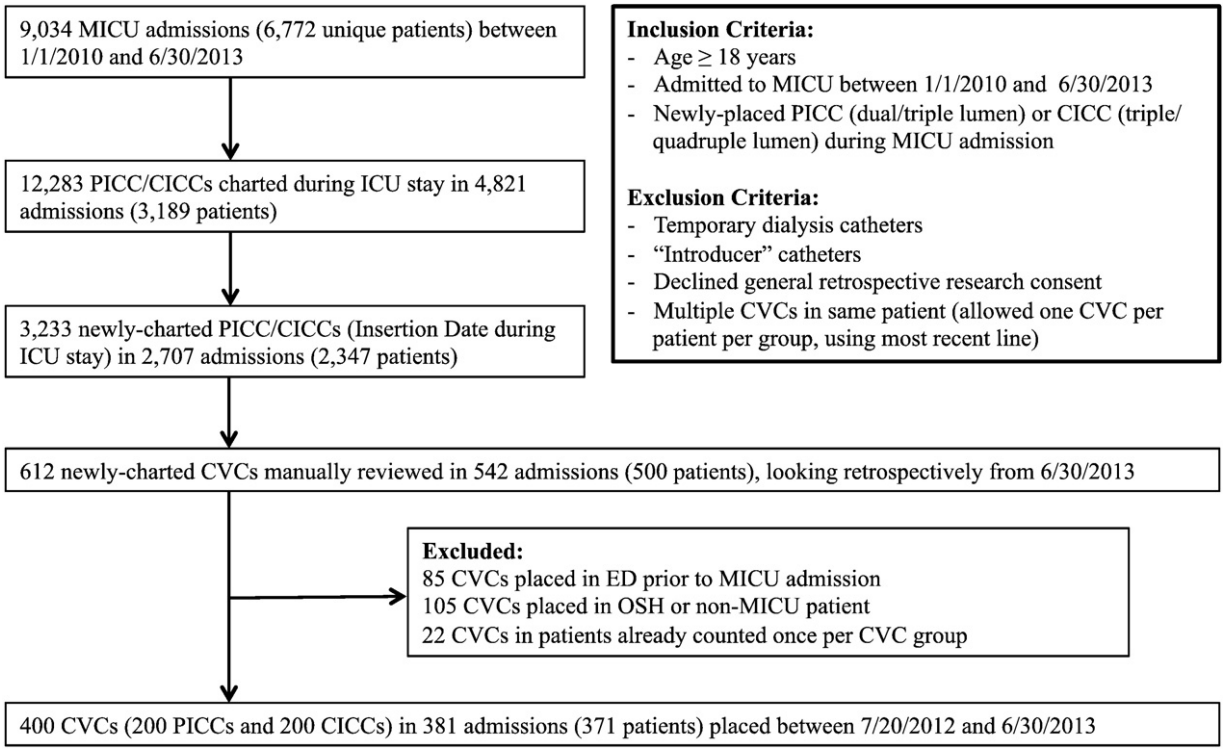

Fig. 1. Study flow diagram. Prespecified target accrual was 200 PICCs and 200 CICCs. Initial data queried over a 3.5-year time window looking retrospectively from June 30, 2013, but target accrual occurred by July 20, 2012. A given patient was represented only once per CVC group, using the most recent catheter placement if there were multiple. OSH indicates outside hospital.

(50%) of the 8 PICC DVTs occurred while in the ICU, $P = .685$. No CLABSI events occurred while in the MICU.

4. Discussion

This retrospective observational study provides an updated comparison of CVC complication rates in the MICU setting, for which there are limited contemporary data. Overall, there were relatively few cases of symptomatic CRDVT and CLABSI. Although we noted a trend toward higher incidence of CRDVTs in PICCs than in CICCs when followed until hospital discharge (4% vs 1%, respectively), there was no significant difference when we limited the analysis to duration and event data accrued solely while in the ICU. One important aspect of our findings is our choice of primary outcome as the complication rate per central catheter rather than the rate per indwelling time, and not unexpectedly, the overall hospital indwelling time was longer for PICCs than CICCs (1730 vs 637 days). This difference may contribute to the greater number of DVT events accrued in PICCs given a longer "at-risk" indwelling time. Nonetheless, considering PICCs as major central lines inserted in the ICU setting, half of the PICC-related DVTs (4 of 8) actually occurred while on the general floor. Although we could not systematically assess the indication for PICC continuation during ICU transfer, in practice, we have noted that reasons of convenience may often play a role in this decision. Our findings support that PICCs carry a small but definite risk of serious thrombotic complications; they are not innocuous equivalents to peripheral intravenous lines, and as with any central catheter placed in the ICU, they should be aggressively discontinued when no longer strictly needed.

Previous ICU-based studies have evaluated PICC-related CLABSI [3–5,8,10,11,13–15,19–22,24,26] and CRDVT [2,5,10,14,16,18,21–25], with others reporting CICC-related CLABSI [9–12,24] and CRDVT [2,6,16,24,25]. Overall, our modern academic MICU-specific complication rates were similar to other ICU settings where these complications are no longer common. Wilson et al [24] authored a neurologic ICU

Table 1
Baseline characteristics

		PICC (n = 200)	CICC (n = 200)	*P* value
Mean age (SD), y		63.8 (17.9)	65.3 (14.1)	.353
Number female, %		84 (42%)	88 (44%)	.686
Mean BMI (SD), kg/m^2		31.1 (12.0)	30.4 (8.9)	.511
Admission source, number (%)	ED	71 (36%)	82 (41%)	.318
	Direct admission	64 (32%)	51 (26%)	
	General floor/other	65 (33%)	67 (34%)	
Median ICU LOS (IQR), d		3.2 (1.6-6.4)	2.8 (1.6-5.2)	.206
Median hospital LOS (IQR), d		9.3 (5.3-15.9)	8.1 (4.6-14.2)	.043*
Mean APACHE III score (SD)		73.2 (26.0)	86.6 (27.8)	<.001*
Mean SOFA score (SD)		6.5 (3.9)	8.9 (4.1)	<.001*
Number requiring invasive ventilation (%)		91 (46%)	111 (56%)	.046*
Number in-hospital mortality (%)		48 (24%)	59 (30%)	.214

The APACHE and SOFA scores were determined at 24 hours after initial ICU admission. BMI indicates body mass index; ED, emergency department; LOS, length of stay; IQR, interquartile range.
* $P \leq .05$.

Table 2
Central venous catheter site

	PICC (n = 200)	CICC (n = 200)
Right arm, n (%)	150 (75%)	
Left arm, n (%)	50 (25%)	
Right internal jugular, n (%)		135 (68%)
Left internal jugular, n (%)		47 (24%)
Right subclavian, n (%)		6 (3%)
Left subclavian, n (%)		2 (1%)
Right femoral, n (%)		7 (4%)
Left femoral, n (%)		3 (2%)

study similar to our own, finding that PICC-related symptomatic DVT was significantly higher compared with CICCs (8.4% or 5.5/1000 days vs 1.4% or 2.2/1000 days). In our study, there was a similar but nonsignificant trend, although our PICC DVT rate was notably lower. One important distinction is that several previous studies have reported CRDVT rates in *asymptomatic* patients via prospective ultrasound surveillance [6,14,16,25]. In this context, PICC-related DVT was seen in up to 58% of lines [14] or 33% for CICCs [6], although the clinical significance of asymptomatic CRDVT is unclear. Furthermore, it is possible that CICC-related DVTs are less often symptomatic and therefore unrecognized because of the larger vein-to-catheter diameter, where more thrombus (or time) would be needed to produce clinical symptoms compared with PICCs.

When considering CLABSI between PICCs and CICCs, Wilson et al [24] in the neurologic ICU found no significant difference with rates of 2.8% (1.8/1000 days) vs 1.4% (2.2/1000 days), and notably, both these rates are higher than our MICU findings. Two other recent studies have reported MICU-specific CLABSI rates, with Al-Tawfiq et al [20] finding a PICC CLABSI rate of 7.3/1000 days and Shuman et al [13] finding an overall CLABSI rate of 2.2/1000 days. We identified only a single PICC infection in 400 central lines evaluated, making our MICU-specific rates generally lower than those reported in other ICU settings. Notably, we used the current Centers for Disease Control and Prevention CLABSI criteria, which require a minimum indwelling time of 2 days. Only 60% of our CICCs (89% of PICCs) were in place longer than 48 hours. As outlined in our "Materials and methods" section, Mayo has a rigorous set of policies surrounding central line placement and maintenance. Among the policies we would highlight is a requirement that all

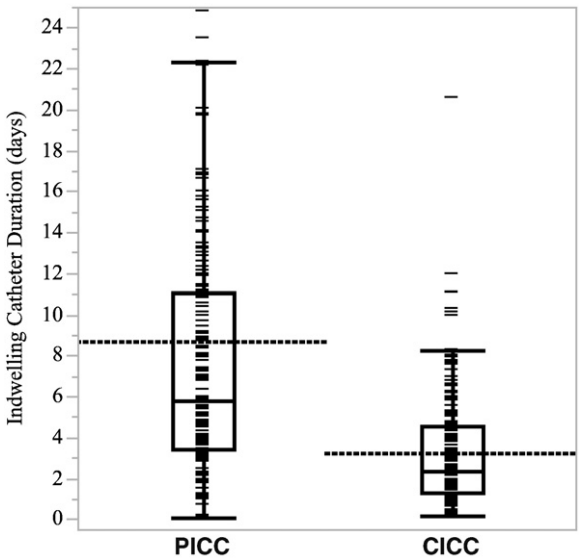

Fig. 2. Catheter-duration distribution. Central venous catheters were followed from the time of insertion in the MICU until removal or hospital discharge. Solid box outlines 25th, 50th (median), and 75th percentiles, with 10th and 90th percentiles bounded by T-bars. Dotted line represents the mean indwelling time. Note that y-axis was cropped at 25 days, whereas maximum PICC duration was 76 days.

Table 3
Complication rates for PICCs and CICCs followed from MICU insertion until hospital discharge

		PICC (n = 200)	CICC (n = 200)	*P* value
Indwelling hospital catheter days	Total days	1730	637	
	Median days (IQR)	5.9 (3.5-11.1)	2.4 (1.3-4.6)	<.001*
CRDVT	n (%)	8 (4%)	2 (1%)	.055
	Per 1000 hospital catheter-days	4.6	3.1	
	Median time-to-DVT (range), d	5.2 (2.3-18.8)	3.3 (1.7-4.8)	
CLABSI	n (%)	1 (0.5%)	0 (0%)	>0.999
	Per 1000 hospital catheter-days	0.46	0	

* $P \leq .05$.

providers pass an observed simulation to certify proper sterile technique. The daily central-line-need assessment (with required documentation) by the entire medical team may contribute to our relatively short indwelling times. Taken together, Mayo's comprehensive and well-defined implementation of central line standards may help minimize CVC complications and serve as a model of central line stewardship, although further research would be needed.

4.1. Strengths

The greatest strength of our study is the data integrity. Rather than rely on automated data abstraction or billing data, frequently used in other studies, we manually reviewed every chart to ensure that it met our study criteria and to detect complications. We often found irregularities in central line charting that would have caused an automated query to misrepresent the total catheter duration, an important value in determining the event rates. Other strengths include a specific population, reducing the variability seen in prior studies.

4.2. Limitations

Our study has several limitations worth noting. The first major limitation is its retrospective design with the inherent concerns of all observational study designs, particularly unmeasured bias and confounding. We were unable to assess the specific indication for each central line placement and therefore could not analyze potential differences. Another limitation was our ability to identify only symptomatic CRDVT. Because of a smaller number of accrued catheter days in CICCs, we had limited power to detect CLABSI, and this also means that our unadjusted CRDVT rate may bias against PICCs, which remained in place longer at continued risk for developing this complication. The low overall event rates prevent an adjusted analysis by indwelling duration time and also create the potential for a type II error in our analysis. Our study implicitly excludes patients admitted with a primary diagnosis of active malignancy or recent solid organ or bone marrow transplant, who

Table 4
Complication rates for PICCs and CICCs followed from MICU insertion until MICU discharge

		PICC (n = 200)	CICC (n = 200)	*P* value
Indwelling MICU catheter days	Total days	750	535	
	Median days (IQR)	2.3 (1.0-4.5)	2.0 (1.1-3.8)	.266
CRDVT	n (%)	4 (2%)	2 (1%)	.685
	Per 1000 MICU catheter-days	5.3	3.7	
	Median time-to-DVT (range), d	6.1 (2.3-18.8)	3.3 (1.7-4.8)	
CLABSI	n (%)	0	0	–
	Per 1000 MICU catheter-days	0	0	

receive ICU care in a separate mixed surgical/medical ICU at our institution. Their unique comorbidities may confer higher-than-average risk for central line complications, meaning that our results may underreport the rates in a broader MICU population. Although Mayo Rochester is a major academic referral center performing more than 2000 MICU admissions annually, our single-center study may limit generalizability.

5. Conclusions

Overall, in this contemporary retrospective single-center study, we found relatively few events of symptomatic CRDVT and CLABSI among PICCs and CICCs inserted in our MICU. Although there was a (nonsignificant) trend toward a higher incidence of PICC-related DVT when followed until hospital dismissal, there was no significant difference between groups when censored at ICU dismissal, at which point indwelling times were more similar. Half of PICC-related DVTs occurred while on the general floor, and as with any central catheter placed in the ICU, PICCs should be aggressively discontinued when no longer absolutely needed.

Acknowledgments

Author contributions

MN, the guarantor of this article, had full access to the data and takes responsibility for the integrity of the methods used for data collection, and the appropriateness and honesty of the analysis. RC personally reviewed the final data set and statistical analysis, and takes responsibility for the integrity of the submission as a whole. MN, RC, HY, and KC contributed to the study design. MN collected the primary data, with potential complication events manually reviewed and verified by MN, HY, KC, and RC. MN and RC conducted the statistical analysis and figure generation, with important input from HY and KC. MN drafted the main text with significant critical revision offered by HY, KC, and RC. All authors reviewed the final manuscript and agreed to its submission.

Other contributions

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Conflicts of interest and source of funding

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