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# Patterns, appropriateness and outcomes of peripherally inserted central catheter use in Brazil: a multicentre study of 12 725 catheters

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## ABSTRACT

**Background** Little is known about peripherally inserted central catheter (PICC) use, appropriateness and device outcomes in Brazil.

**Methods** We conducted an observational, prospective, cohort study spanning 16 Brazilian hospitals from October 2018 to August 2020. Patients  $\geq 18$  years receiving a PICC were included. PICC placement variables were abstracted from medical records. PICC-related major (deep vein thrombosis (DVT), central line-associated bloodstream infection (CLABSI) and catheter occlusion) and minor complications were collected. Appropriateness was evaluated using the Michigan Appropriateness Guide for Intravenous Catheters (MAGIC). Devices were considered inappropriate if they were in place for  $\leq 5$  days, were multi-lumen, and/or were placed in patients with a creatinine  $> 2.0$  mg/dL. PICCs considered appropriate met none of these criteria. Mixed-effects logistic regression models adjusting for patient-level and hospital-level characteristics assessed the association between appropriateness and major complications.

**Results** Data from 12 725 PICCs were included. Mean patient age was  $66.4 \pm 19$  years and 51.0% were female. The most common indications for PICCs were intravenous antibiotics (81.1%) and difficult access (62.7%). Most PICCs (72.2%) were placed under ultrasound guidance. The prevalence of complications was low: CLABSI (0.9%); catheter-related DVT (1.0%) and reversible occlusion (2.5%). Of the 12 725 devices included, a total of 7935 (62.3%) PICCs were inappropriate according to MAGIC. With respect to individual metrics for appropriateness, 17.0% were placed for  $\leq 5$  days, 60.8% were multi-lumen and 11.3% were in patients with creatinine  $> 2.0$  mg/dL. After adjusting for patient and hospital-

level characteristics, multi-lumen PICCs considered inappropriate were associated with greater odds of major complications (OR 2.54, 95% CI 1.61 to 4.02).

**Conclusions** Use of PICCs in Brazilian hospitals appears to be safe and comparable with North America. However, opportunities to improve appropriateness remain. Future studies examining barriers and facilitators to improving device use in Brazil would be welcomed.

## INTRODUCTION

In the last two decades, indications for the use of peripherally inserted central catheters (PICCs) have expanded substantially.<sup>1</sup> However, like all central venous catheters, PICC use is not without risks including infection and deep vein thrombosis (DVT).<sup>2–5</sup> Therefore, placement of PICCs using evidence-based standards along with meticulous care and management are fundamental to patient safety.

Technologies related to PICC insertion, device characteristics, identification of best practices and advent of vascular access teams have improved the safety of these catheters. Data from two contemporary meta-analyses reflecting modern insertion approaches and current practices show that smaller-diameter PICCs, single-lumen devices and proper tip

location can lead to fewer harmful events.<sup>6,7</sup> Furthermore, with the publication of the Michigan Appropriateness Guide for Intravenous Catheters (MAGIC) guidelines, the ability to examine appropriateness of PICC use at hospitals has emerged.<sup>8–11</sup> Findings from the USA, for example, have found that inappropriate use of PICCs often occurs in patients with chronic kidney disease (CKD) and in patients where PICCs are used for short duration, such as those with difficult venous access. Likewise, a study conducted by Verma *et al* in five academic hospitals in Toronto, Canada found that inappropriate PICC use most often occurred in patients with CKD. Although these findings provide important insights in the USA and Canada, little is known about patterns of PICC use, device appropriateness and outcomes in developing nations.<sup>10,11</sup> Specifically, less is known about PICC use and outcomes in South American nations.

Brazil is one of the most industrialised and largest countries in South America, yet little is known about vascular catheter use, appropriateness and outcomes in this nation. Understanding PICC use in Brazil is thus important as it would serve as a useful marker of device use in South America. Therefore, we leveraged a research partnership between the University of Michigan and Brazilian investigators and performed a prospective, multicentre cohort study to examine use of PICCs, appropriateness and patient outcomes in this country.

## METHODS

### Study design and site recruitment

We conducted an observational study spanning 16 acute care facilities in Brazil, including hospitals from the northeast, southeast and southern regions of the country. The study design followed that of the Michigan Hospital Medicine Safety Consortium (HMS) located in Ann Arbor, Michigan, USA.<sup>12</sup> Briefly, a coordinating centre was launched at *Hospital de Clínicas de Porto Alegre* (HCPA), an 831-bed, university-affiliated tertiary care centre located in Rio Grande do Sul. Members of the coordinating centre travelled to Michigan to learn the HMS data collection protocol and understand data collection techniques from the Michigan team. In March 2018, investigators from the coordinating centre attended a national vascular access conference held in São Paulo and met with vascular access leaders from across the nation to introduce the study and recruit sites. In total, invitations were sent to 28 sites who expressed interest in the study at the conference and representatives from 16 hospitals agreed to participate. Site representatives provided consent to participate in the study, agreed to obtain ethical and regulatory approval from their hospitals, secured buy-in from leadership, infusion therapy, and vascular access teams, and agreed to collect and submit de-identified data from patient records (including follow-up events) to the coordinating centre. All

information related to the project including study variables, duration, sample selection and authorship criteria was provided to each participating hospital prior to the start of the study.

### Patient selection and data collection

Data were collected from October 2018 to August 2020. Patient selection criteria, data collection process and definitions for study variables mirrored those of the HMS Consortium.<sup>12</sup> In brief, patients  $\geq 18$  years of age who were admitted to an adult emergency, medical, surgical, or critical care service and received a PICC for any clinical indication were eligible for inclusion. As pregnant patients are considered vulnerable and PICCs are used for very different reasons (eg, hyperemesis) in this population, they were excluded. Data were collected at each participating site using templated data collection forms via the Research Electronic Data Capture (REDCap) electronic data capture tool hosted at HCPA.<sup>13,14</sup> All teams received a data collection manual containing definitions of the variables of interest and how to record them in REDCap. To ensure data quality, researchers at participating hospitals were trained via a face-to-face seminar on how to navigate the instrument and input data prior to collection. In addition, the coordinating centre in Brazil performed in-person site visits in 2018 and 2019 to conduct random data audits. These site visits and data audits were transitioned to virtual meetings in 2020 due to the COVID-19 pandemic. Researchers were required to pass a minimum of five training cases showing accurate data collection and abstraction before formal data collection commenced. All data were collected prospectively after PICC insertion by trained staff at each site who accessed patient medical records to collect relevant information. Patients were followed until PICC removal, death or end of the follow-up period (30 days elapsed following PICC insertion), whichever occurred first.

To manage data integrity and completeness, the coordinating centre also conducted weekly audits of incoming data from all sites. Sites that did not complete the minimum number of cases for the week or had missing data in submitted cases received a report identifying the need for submission of additional cases or completion of missing data. This degree of care and rigour was necessary, as we were collecting data across disparate sites throughout Brazil and many had not previously participated in vascular access research of this nature.

### Patient and PICC characteristic variables

Variables collected included gender, age, ethnicity, weight, body mass index (BMI), number of comorbidities, CKD, acute renal failure requiring dialysis, creatinine, use of anticoagulant drugs, antiplatelet agents, history of venous thromboembolism (30 days prior or within 30 days) and active cancer (defined as a

cancer-related diagnosis at admission or active chemotherapy). The indication for PICC insertion (presented as a list on which respondents could select all that were relevant), location of procedure (hospital unit), number of puncture attempts, number of catheter lumens, insertion technique, tip location and localisation method, tip position and catheter-to-vessel ratio (CVR) were also collected. The indication for PICC use was abstracted directly from the medical provider order or the catheter insertion note. Because site of insertion can affect PICC outcomes, we also collected data specific to the PICC insertion zone according to the Zone Insertion Method (ZIM) published by Dawson.<sup>15</sup> In this model, the ideal site of PICC insertion is in the 'green zone', defined as the middle third of the upper arm, because the vein diameter is larger as the basilic vein ascends toward the axilla. The proximal half of the green zone is referred to as the ideal zone; the red zone is not recommended for PICC insertion whereas the yellow zone should be considered with caution.<sup>15</sup>

### Outcomes

The main outcomes of interest included catheter dwell time, reason for removal, device-related complications and device appropriateness. Device-related complications were classified as major (catheter-related thrombosis and central line-associated bloodstream infection (CLABSI)) or minor (accidental traction, suspected CLABSI, catheter occlusion, hyperemia/erythema, bleeding/bruise and phlebitis). Catheter-related thrombosis was defined by the presence of a positive compression ultrasound or comparable radiographic study (eg, CT scan) showing the presence of thrombus in a deep vein of the upper extremity in a patient with symptoms (eg, pain in the arm, oedema). Pulmonary embolism (PE) was captured when a patient underwent CT (or relevant imaging study) with a report confirming presence of the same. We defined confirmed CLABSI in accordance with the Center for Disease Control National Healthcare Safety Network criteria and according to the *Agência Nacional de Vigilância Sanitária* recommendations, and suspected CLABSI when medical records indicated a PICC was removed for suspected infection in the absence of microbiological testing.<sup>16 17</sup> Catheter occlusion (reversible vs irreversible) was defined as present if a pulsatile saline flush or thrombolytic was instilled by a clinician for 'inability to aspirate', 'slow flow', or problems infusing or aspirating through a PICC lumen.

Minor complications were defined as follows: accidental dislodgement was considered when all or a portion of the catheter was removed unintentionally by a patient or provider. Exit-site complications included any one of the following: hyperemia/erythema at the insertion site, bleeding/bruise at the insertion site and phlebitis. Phlebitis was defined as redness, swelling or pain over the vein where the catheter was placed.

For all PICCs, we assessed catheter appropriateness according to the MAGIC criteria. Devices were considered inappropriate if they were in place for  $\leq 5$  days, were multi-lumen instead of single-lumen catheters, and/or were placed in patients with creatinine  $>2.0$  mg/dL.<sup>8</sup> PICCs were considered inappropriate if they met one or more of these criteria. Frequency of inappropriate PICC use was calculated as the proportion of PICCs that were inappropriate divided by the total number of devices. We further stratified complications (DVT/PE, confirmed/suspected CLABSI, reversible/irreversible occlusion) based on whether a catheter was considered appropriate versus inappropriate, according to MAGIC criteria.<sup>8</sup>

### Statistical analysis

Descriptive statistics (eg, mean, median, proportion) with measures of dispersion (eg, SD, IQR) were used to summarise the data. Any variables not documented in medical records (eg, zone of insertion, tip position, insertion technique) were reported as missing. Complications and reasons for removal stratified by PICC appropriateness criteria were compared using  $\chi^2$  statistics. All statistical tests were two sided, with  $p < 0.05$  considered statistically significant.

To examine the association between measures of appropriateness (use  $< 5$  days, multi-lumen catheter use and insertion in patients with CKD) and major complications (DVT/PE, confirmed/suspected CLABSI and occlusion), we fit mixed-effects logistic regression models with hospital-specific intercepts. These models each adjusted for relevant patient, provider and device characteristics in accordance with previously published conceptual models.<sup>18-20</sup> Analyses were performed in SPSS, V.22.0 (IBM Corp) and SAS, V.9.4 (SAS Institute).

### Ethical and regulatory oversight

Each participating hospital obtained ethical and regulatory approval prior to participation, including determining the need for written patient consent. Some centres ( $n=3$ ) sought waiver of the requirement for individual informed consent and instead submitted a Data Use Agreement to their Ethics Committees for approval. When approved, this document allowed collection of all data related to the study directly from the electronic medical record without patient consent. The remaining 13 hospitals required and obtained written informed consent from patients. All hospitals therefore received ethical and regulatory approval in accordance with their local practices.

### RESULTS

From October 2018 to August 2020, data from 12 725 PICCs placed in 11 135 patients across 16 Brazilian hospitals were collected. Participating hospitals ranged in size from 141 to 1085 beds (mean, 480 beds) and included private, public, and academic medical

centres. The mean patient age was  $66.4 \pm 19$  years; ( $n=6457$ , 51.0% were female; and the mean BMI was  $26.4 \pm 4.6 \text{ kg/m}^2$ ). Overall, patients had a median of three comorbidities, with hypertension (48.6%), diabetes (25.7%) and hyperlipidaemia (17.7%) being the most common. With respect to renal function, 1392 patients (11.3%) had a creatinine  $>2.0 \text{ mg/dL}$ ; 971 (69.8%) of these patients had established CKD and 190 (13.6%) were on dialysis at the time of PICC insertion. Most patients had multiple documented indications for PICC insertion with the most common being intravenous antibiotic therapy (81.1%) and difficult venous access (62.7%). Intravenous antibiotics were documented as the only indication in 14.8% of insertions while difficult venous access was the sole indication in 2.7% of cases. Placement of PICCs for administration of vesicant drugs, total parenteral nutrition and chemotherapy was relatively infrequent. PICCs were inserted predominantly in medical/surgical inpatient units (59.1%) and intensive care units (32.1%). The right basilic was the most common vein of insertion (50.8%), followed by the left basilic (27.7%). The first-attempt success rate was 90.0% (table 1).

#### Provider, device and insertion characteristics

Insertions were performed predominantly by vascular access team nurses (92.9%), followed by vascular surgeons (7.0%). Overall, 57.5% of PICCs were double lumen, and 39.2% were single lumen. With respect to the site of insertion, 98.3% were inserted in the 'green' or 'ideal' zone and 72.2% were placed under ultrasound guidance using a micro-introducer. Intracavitary ECG was used to establish final tip location in 49.5% of all insertions whereas 75.0% of PICCs had tips radiographically or electrocardiographically identified as optimally located at the cavoatrial junction. The mean CVR was less than 45% in 12456 patients (99.7%), indicating adherence to best practice and ample capacity for blood flow around the catheter (table 1).

#### Device complications and outcomes

Upper-extremity DVT was the most prevalent major complication, occurring in 129 (1.0%) of PICCs, with more than half of these events ( $n=72$ ) occurring less than 15 days from PICC placement. Confirmed CLABSI occurred in 114 patients (0.9%) but suspected CLABSI was noted in 590 patients (4.6%), most of which resulted in catheter removal. With respect to minor complications, reversible catheter occlusion occurred in 321 (2.5%) and accidental dislodgement in 148 (1.2%) patients. The most common reasons for removing the catheter were hospital discharge (47.7%) and end of therapy (29.4%) (table 2).

**Table 1** General characteristics of patients who underwent peripherally inserted central catheter (PICC) insertion ( $n=12\,725$ )

Category/variable	n (%)
Mean age (SD)	66.4±19
Female gender*	6457 (51)
Race, white or Caucasian*	10453 (85.6)
Body mass index	26.4±4.6
Median number of comorbidities	2 (IQR 1–4)
Chronic kidney disease	971 (7.6)
Acute renal failure requiring dialysis	190 (1.5)
Creatinine $>2.0 \text{ mg/dL}$	1392 (11.3)
Active cancer	3568 (28)
No history of venous thromboembolism	11787 (92.6)
History of venous thromboembolism $>30$ days prior	701 (5.5)
History of venous thromboembolism within 30 days	300 (2.4)
Medications to prevent thromboembolism within 30 days*†	
None	5967 (46.9)
Enoxaparin	3123 (24.5)
Aspirin	1374 (10.8)
Heparin	1222 (9.6)
Indication for PICC placement (multiple choice)*	
Intravenous antibiotic therapy	10318 (81.1)
Difficult intravenous access	7979 (62.7)
Irritant or vesicant drug	4515 (35.5)
Total parenteral nutrition	1033 (8.1)
Chemotherapy	872 (6.9)
Unit of PICC insertion*	
Medical/surgical unit	7515 (59.1)
Intensive care unit	4079 (32.1)
Semi-intensive unit	877 (6.9)
Emergency room	116 (0.9)
Other	138 (1.1)
Puncture attempts*	
1	11458 (90)
$\geq 2$	1265 (10)
Missing	2
Vein and laterality of PICC placement*	
Right basilic	6470 (50.8)
Left basilic	3523 (27.7)
Right brachial	1416 (11.0)
Left brachial	1079 (8.5)
Other	237 (1.9)
Operator type	
Vascular access nurse	11820 (92.9)
Vascular surgeon	889 (7)
Physician	16 (0.1)
Number of PICC lumens*	
Double	7313 (57.5)
Single	4989 (39.2)
Triple	423 (3.3)
PICC insertion zone*	
Ideal zone	7197 (56.6)
Green zone	5304 (41.7)
Yellow zone	193 (1.5)
Red zone	30 (0.2)

Continued

**Table 1** Continued

Category/variable	n (%)
Missing data	1
Insertion technique*	
Ultrasound-guided micro-introduction+tip location	9182 (72.2)
Ultrasound-guided micro-introduction	3346 (26.3)
Direct puncture with ultrasound guidance	84 (0.7)
Missing/unknown	2
Tip location method*	
Intracavitary ECG	6300 (49.5)
X-ray	3468 (27.3)
Intracavitary ECG+X-ray	2873 (22.6)
Ultrasound*	45 (0.4)
Transoesophageal echocardiogram	29 (0.2)
Fluoroscopy	10 (0.1)
Missing data	2
Vessel ratio (%) with Site-Rite 8*	16±7
Vessel ratio (%) with Site-Rite 5	
<25	2342 (60)
26–33	1124 (28.8)
34–44	422 (10.8)
>45	19 (0.4)
Missing data	233
TIP position*	
Zone A—atrial cavity junction	9542 (75)
Zone B—superior vena cava	2895 (22.8)
Zone C—brachiocephalic vein	287 (2.3)
Missing data	1

Site-Rite 8 and Site-Rite 5 are portable ultrasound systems used specifically for vascular access applications and for insertion of PICCs at the bedside. They allow visualisation of target vessels and surrounding anatomy as well as visualisation and measurement of catheter size relative to the vessel (catheter/vessel ratio). They also allow catheter tip localisation during placement by means of intravascular ECG-guided technology. The devices are made by Bard Brasil-Access (Bard-Brasil, São Paulo, Brazil). Created by the authors.  
\*Mean and SD.  
†Most frequently prescribed agents.

### Appropriateness of PICC use according to MAGIC

Of the 12 725 PICCs included in the study, a total of 7935 PICCs (62.3%) met one or more criteria for inappropriateness according to MAGIC. With respect to individual metrics (n=2164, 17.0%), PICCs were in place for 5 or fewer days and were thus considered inappropriate according to MAGIC. The most common indication associated with short-term PICC use was intravenous antibiotic therapy (n=1696, 78.4%). A substantial proportion of PICCs placed were also inappropriate because they were multi-lumen devices (n=7736, 60.8%). Of these, n=1350 (17.4%) were placed for indications of total parenteral nutrition, infusion of incompatible drugs and infusion of chemotherapy with additional lumen needs; thus use of more than one lumen may have been clinically necessary. Finally, a total of n=1392 (11.3%) PICCs were placed in patients with creatinine >2.0 mg/dL without nephrology approval (figure 1).

Patients whose PICCs were considered inappropriate according to MAGIC experienced greater complications than those who were considered appropriate. For example, patients who received multi-lumen PICCs had a significantly higher rate of suspected or confirmed CLABSI versus those who received single-lumen PICCs (5.9% vs 4.1%, p<0.001, respectively). Similarly, with respect to DVT, patients who received multi-lumen PICCs had a significantly higher rate of DVT compared with patients who received single-lumen PICCs (1.2% vs 0.7%, p=0.005, respectively). Finally, patients with CKD had a higher rate of confirmed or suspected CLABSI (7.0% vs 4.8%, p=0.001, respectively) but similar rates of DVT (0.9% vs 1.0%, p=0.088, respectively) compared with those whose creatinine was <2.0 mg/dL. After adjustment for patient, provider and device characteristics, multi-lumen PICCs were observed to be associated with greater odds of major PICC complications (OR 2.54, 95% CI 1.61 to 4.02). Similar associations between multi-lumen device use were also observed for the individual outcomes of CLABSI, catheter occlusion and DVT/PE. Associations between device dwell and CKD were underpowered to detect significant differences (table 3).

### DISCUSSION

In this large, prospective, multicentre study, we provide important insights into indications of PICC use, patterns of use, insertion techniques, appropriateness and outcomes in hospitalised adults across 16 Brazilian hospitals. Our findings suggest that while PICCs are largely used for appropriate indications and appear to have low rates of complications in Brazil, opportunities for improvement in duration of use and appropriateness remain. Specifically, policies aimed at encouraging more single-lumen device use, avoidance of PICCs with short dwell time and in patients with CKD could help improve patient safety. These findings can help inform local and national quality and policy efforts and serve as a research agenda for vascular access providers in Brazil.

The placement of any central venous catheter carries risk of complications that can increase morbidity, mortality and cost.<sup>21</sup> PICCs play a pivotal role in hospitalised patients because they provide dependable and reliable central venous access for medium-term and long-term intravenous drug therapy.<sup>22</sup> Results of recent studies have emphasised their benefits for patient safety when appropriate indications are respected and proper care is provided.<sup>6–8 23</sup> In this first-of-a-kind study from Brazil, PICC insertion was predominantly performed by vascular access nurses, with a success rate close to 90%. The most common indication for PICC use was intravenous antibiotic therapy, and thus many devices were used for extended periods of time. The advent and growth of nurse-led vascular access teams in Brazil has been pivotal to safety of PICC use

**Table 2** Complications of peripherally inserted central catheters (PICCs) by dwell time (n=12 725)

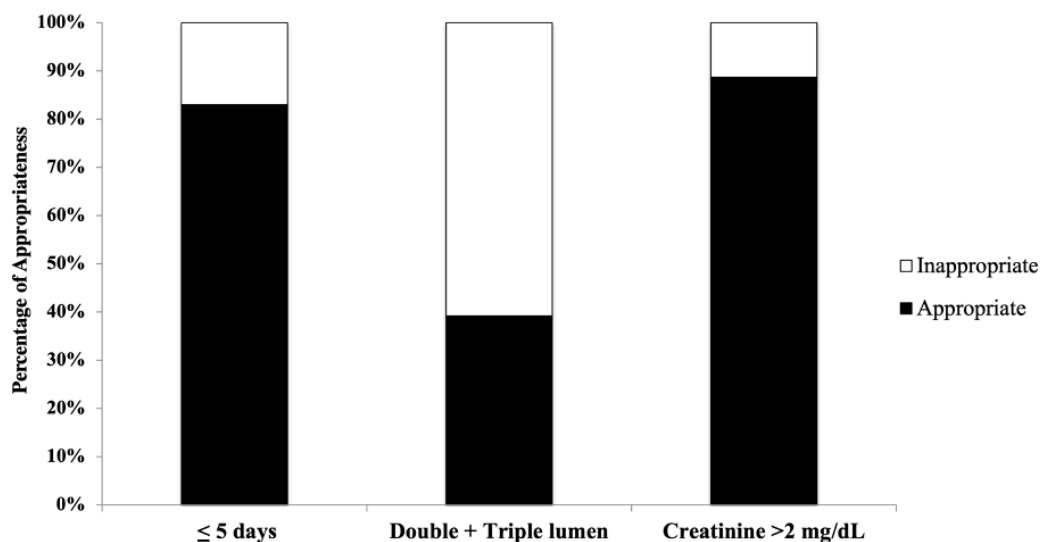
Category/variable	All PICCs (n=12 725) (100%)	PICC ≤5 days (n=2164) (17%)	PICC ≥6 days (n=4807) (37.8%)	PICC ≥15 days (n=5747) (45.2%)	P value
Complications					
Major complications*					
Deep vein thrombosis	129 (1.0)	15 (0.7)	57 (1.2)	57 (1.0)	0.169
Confirmed CLABSI	114 (0.9)	9 (0.4)	29 (0.6)	76 (1.3)	<0.001
Pulmonary embolism	3 (0)	0 (0)	1 (0)	2 (0)	0.659
Minor complications*					
Suspected CLABSI	590 (4.6)	22 (1.0)	196 (4.1)	372 (6.5)	<0.001
Reversible occlusion	321 (2.5)	8 (0.4)	48 (1.0)	265 (4.6)	<0.001
Accidental traction	148 (1.2)	49 (2.3)	41 (0.9)	58 (1.0)	<0.001
Irreversible occlusion	48 (0.4)	7 (0.3)	10 (0.2)	31 (0.5)	0.020
Hyperemia/erythema	88 (0.7)	3 (0.1)	27 (0.6)	58 (1.0)	<0.001
Bleeding/bruise	103 (0.8)	13 (0.6)	33 (0.7)	57 (1.0)	0.010
Phlebitis	18 (0.1)	4 (0.2)	9 (0.2)	5 (0.1)	0.332
Reason for withdrawal*					
Hospital discharge	6066 (47.7)	1224 (56.6)	2849 (59.3)	1993 (34.7)	<0.001
End of therapy	3747 (29.4)	602 (27.8)	1763 (36.7)	1382 (24.0)	<0.001
Death	1474 (11.6)	344 (15.9)	524 (10.9)	606 (10.5)	<0.001
Suspected CLABSI	536 (4.2)	19 (0.9)	178 (3.7)	339 (5.9)	<0.001
Catheter exchange	251 (2.0)	48 (2.2)	58 (1.2)	145 (2.5)	<0.001
Accidental traction	215 (1.7)	74 (3.4)	66 (1.4)	75 (1.3)	<0.001
Confirmed CLABSI	99 (0.8)	7 (0.3)	27 (0.6)	65 (1.1)	<0.001
Occlusion	52 (0.4)	9 (0.4)	10 (0.2)	33 (0.6)	0.013

Created by the authors.  
\*Data are n (%).  
CLABSI, central line-associated bloodstream infection.

in the country, as successful placement and event-free device survival has been linked to such teams.<sup>24 25</sup>

Nurse-led vascular access teams composed of specialised inserters have gained recognition in recent decades as an important mediator of improved PICC outcomes.<sup>24 25</sup> These teams adhere to evidence-based

practices including ultrasound guidance during insertion, selection of catheter gauge and lumens according to the vessel size, insertion of the catheter in ideal sites using evidence-based techniques (eg, ZIM)<sup>15</sup> and ensuring optimal tip position,<sup>26</sup> thus leading to fewer complications, such as infection and thrombosis.<sup>15 26–28</sup>



**Figure 1** Appropriateness criteria of the MAGIC. All PICCs were evaluated according to three appropriateness criteria: dwell ≤5 days, use of multi-lumen catheters and placement in patients with creatinine >2.0. We expressed the proportion of PICCs that were appropriate by dividing PICCs that met these three criteria with the total number of devices. MAGIC, Michigan Appropriateness Guide for Intravenous Catheters; PICCs, peripherally inserted central catheters.

**Table 3** Association between MAGIC appropriateness measures and major complications

Single vs multi-lumen device use				
	Single lumen PICC, n (%)	Multi-lumen PICC, n (%)	OR (95% CI)	P value
All complications (DVT+CLABSI+occlusion)	329 (6.6)	819 (10.6)	2.54 (1.61 to 4.02)	0.001
DVT+CLABSI (no occlusion)	199 (4)	602 (7.8)	2.13 (1.67 to 2.72)	<0.001
Reversible/irreversible occlusion	135 (2.7)	258 (3.3)	3.40 (1.67 to 6.94)	0.003
DVT/PE (thrombosis)	36 (0.7)	95 (1.2)	2.04 (1.32 to 3.14)	0.004
Confirmed/suspected CLABSI	165 (3.3)	511 (6.6)	2.08 (1.62 to 2.67)	<0.001
Short-term vs long-term use				
	PICC in place ≥5 days, n (%)	PICC in place <5 days, n (%)	OR (95% CI)	P value
All complications (DVT+CLABSI+occlusion)	1086 (10.3)	62 (2.9)	0.28 (0.21 to 0.38)	<0.001
DVT+CLABSI (no occlusion)	757 (7.2)	44 (2)	0.29 (0.22 to 0.38)	<0.001
Reversible/irreversible occlusion	373 (3.5)	20 (0.9)	0.30 (0.13 to 0.68)	0.007
DVT/PE (thrombosis)	116 (1.1)	15 (0.7)	0.67 (0.41 to 1.10)	0.102
Confirmed/suspected CLABSI	647 (6.1)	29 (1.3)	0.22 (0.16 to 0.31)	<0.001
Presence or absence of chronic kidney disease (CKD)				
	No CKD (%)	CKD (%)	OR (95% CI)	P value
All complications (DVT+CLABSI+occlusion)	1000 (8.8)	148 (10.6)	1.12 (0.89 to 1.42)	0.304
DVT+CLABSI (no occlusion)	687 (6.1)	114 (8.2)	1.18 (0.94 to 1.48)	0.139
Reversible/irreversible occlusion	354 (3.1)	39 (2.8)	0.99 (0.67 to 1.46)	0.938
DVT/PE (thrombosis)	118 (1)	13 (0.9)	0.85 (0.37 to 1.97)	0.686
Confirmed/suspected CLABSI	573 (5.1)	103 (7.4)	1.27 (0.97 to 1.65)	0.075

Results were estimated using mixed-effects logistic regression with hospital random intercepts to account for hospital-level correlation. Patient and device-level adjustments include age, gender, active cancer, history of DVT/PE, ICU placement, other catheters placed at time of insertion, vessel ratio, insertion zone and tip position. Created by the authors.

CLABSI, central line-associated bloodstream infection; DVT, deep vein thrombosis; ICU, intensive care unit; MAGIC, Michigan Appropriateness Guide for Intravenous Catheters; PE, pulmonary embolism; PICC, peripherally inserted central catheter.

It is important to note that, in all centres included in this study, PICC placement was performed by dedicated vascular access teams. Therefore, the positive results observed in our cohort may be at least partly attributable to this team approach.

Almost all the devices (n=12 501, 98.3%) were inserted in the 'green' zone via the micro-introduction technique and 75.0% achieved a documented optimal position in the cavoatrial junction. The CVR—a key predictor of catheter-related DVT—was optimal in almost all insertions in our study, a finding that reflects adherence to recommended guidelines.<sup>27 29</sup> These process measures indicate a high degree of concordance with evidence-based practices. Almost half of all devices included were double lumen, and were placed in patients where concerns regarding drug interaction, concomitant use of total parenteral nutrition, haemodynamic instability or administration of vasopressors were being considered.<sup>8 27</sup> Data from a retrospective cohort conducted in the USA showed that the number of lumens of catheter increases the risk of CLABSI (double lumen, OR 5.21, 95% CI 2.46 to 11.04; triple lumen, OR 10.84, 95% CI 4.38 to 26.82).<sup>30</sup> Even though the rate of infection was low in our study, almost all events

occurred in patients with double-lumen PICCs. Selection of the right number of lumens and implementation of daily PICC maintenance strategies, following safe guidelines, may minimise the incidence of this complication and represents an opportunity for improvement in Brazil.<sup>28 30 31</sup>

Major complications such as thrombosis occurred at a low rate, especially compared with previous studies of PICC-related thrombosis.<sup>3 7</sup> A recent study that also used advanced tip location techniques found a similarly low thrombosis rate.<sup>23</sup> During the 30-day follow-up period, of the total 129 cases of PICC-related thrombosis, 76 (58.9%) were observed in the first 10 days. Data and guidelines indicate that short-term PICC use is not recommended because thrombotic complications often occur early in the dwell of a catheter.<sup>8 9</sup> Better understanding of patient, device and operator factors that may lead to less short-term PICC use and fewer thromboses appears necessary.<sup>20</sup> An alternative strategy to avoid the use of PICC for a short period (≤5 days) may be use of midline catheters. Available evidence indicates that midlines can easily be placed at bedside and are reasonable when the expected intravenous duration of therapy is less than 14 days. However, use of midlines may

be constrained by infusate pH and osmolarity restrictions which may necessitate use of a central venous catheter such as a PICC.<sup>32 33</sup>

Reversible catheter occlusion and accidental dislodgement were the most common minor complications, occurring in 2.5% and 1.2% of catheters, respectively. In a study with 13 000 PICCs conducted in North America, occlusion developed in 1716 PICCs (12.0%) in 1684 patients.<sup>34</sup> Catheter occlusion is one of the most common complications of PICC placement, and good catheter maintenance and management practices can contribute to its reduction.<sup>35</sup>

Considering the three MAGIC appropriateness criteria analysed in this study, two (dwell time and creatinine  $\leq 2.0$  mg/dL) were met by over 80% of catheters. However, when considering indications for multi-lumen PICCs (total parenteral nutrition, administration of incompatible drugs, administration of chemotherapy concomitantly with other drugs), the decision to place this device was rated as inappropriate approximately half of the time.<sup>8</sup> In addition, these devices were more often associated with major complications. These findings are comparable with findings from North America, where the major drivers of inappropriate PICC use are use of multi-lumen devices and short-term device use.<sup>10 11</sup> This gap presents an opportunity for practice improvement and patient safety. Studies that implemented educational interventions, indications for multi-lumen catheters and modification of electronic medical records to make single-lumen PICCs the default option, have been associated with reductions in multi-lumen catheter use and attendant healthcare costs.<sup>31 36</sup>

Our study has limitations. First, this was an observational study that collected data from medical records at various hospitals. Missing data, variation in documentation practices and differences in policies and procedures are therefore likely given these diverse settings. Relatedly, we recruited a ‘coalition of the willing’ to partner with us during this study; selection bias and limited generalisability of our findings to the rest of the country are therefore likely. Second, we can only describe association, not causation, from practices related to PICC care and outcomes. However, abundant evidence points to the use of practices such as single-lumen catheters and CVR measurement as being associated with safety. Third, given varying sample sizes across hospitals, we are unable to perform meaningful comparisons across sites to examine practices, complications and appropriateness. This will be the topic of future work.

Despite these limitations, our study has several strengths. First, ours is among the largest, prospective multicentre studies examining PICC use and outcomes using detailed chart-level abstractions,

weekly data integrity checks and rigorous data collection techniques in South America, providing new and unique insights into vascular catheter use in this region. Second, we operationalised and examined PICC appropriateness using MAGIC in a relatively low-resource setting, showing that these criteria be used as a benchmarking tool to evaluate PICC use in these environments. Third, we provide unique quantitative insights on patterns of PICC use, safety and outcomes from Brazil. Our findings thus have important safety, quality and policy implications for patients, payors, and government in this region and around the world.

## CONCLUSION

PICCs are commonly used in Brazil for medium-term to long-term therapies, especially intravenous antibiotic administration. Adoption of good practices for PICC insertion and care mediated by vascular access teams appears to have contributed to low rates of infection and thrombosis. Although overall appropriateness of catheter use was high, opportunities for improvement in patients with renal disease and use of multi-lumen catheters remain. Future work targeting these domains would be welcomed.

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