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Major Article

A novel infection prevention approach: Leveraging a mandatory electronic communication tool to decrease peripherally inserted central catheter infections, complications, and cost



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Key Words:

Premature PICC removal
Central-line associated blood stream infection
PICC team
IR nurse practitioner
PICC removal checklist

Background: Peripherally inserted central catheters (PICCs) removed prematurely for unconfirmed infection or thrombosis lead to subsequent reinsertions and associated complications. To improve clinical quality, a mandatory electronic communication tool (MECT) based on clinical practice guidelines was mandated for all inpatient adult PICCs in an academically affiliated tertiary medical center. This MECT facilitated early communication and specialized evaluation with the PICC team for any complications related to PICCs. **Methods:** A historical cohort study was conducted. Quality and cost measurements for 200 PICCs postinstitution of a MECT were compared with 200 PICCs 12 months prior. PICC removal and complication rates were compared for the 2 cohorts.

Results: Significant outcomes included a central-line associated blood stream infection rate that changed from 1.38/1,000 catheter days to 0/1,000 catheter days, 0 provider-led premature PICC removals, an overall 84% decrease in premature PICC removals (from 16%–2.5%; $P < .0001$), a decrease in the total complication rate from 45.5%–24% ($P < .0001$), and 25% reduction in radiology costs.

Conclusion: A novel infection prevention approach leveraging a MECT resulted in 0 central line-associated bloodstream infections and provider-led premature PICC removals.

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Conflicts of Interest: None to report.

Multiple clinical practice guidelines offer evidence-based recommendations for the prevention and management of intravascular catheter-related infections. Particular attention has been focused on catheter insertion and management practices based on the results of the 2006 Michigan Keystone project.¹ More than 1,500 lives and nearly \$200 million in savings were attributed over an 18-month period to utilizing an insertion checklist and patient safety intervention bundle.¹

In comparison, much less attention has been given to central venous catheter (CVC) removal practices. Clinical practice guidelines and multidisciplinary policies unanimously advocate for removing unnecessary CVCs as a way to prevent intravascular catheter-related infections.² Unfortunately, a hazard of this movement is the unintended premature removal of peripherally inserted central catheters (PICCs) intended for intermediate- to long-term use.

Approximately 40% of adult inpatient PICCs are removed before completion of their intended therapy.^{3–9} Premature PICC removals

are PICCs removed before completion of intended therapy that do not meet the US National Healthcare Safety Network (NHSN) of the Centers for Disease Control and Prevention (CDC) central-line associated blood stream infection (CLABSI) criteria, or catheters removed for suspected deep vein thrombosis (DVT) without imaging confirmation. Of note, there is a significant body of literature supporting continued use of PICCs for necessary therapy, even with confirmed thrombosis.

Common reasons for premature removal include mechanical phlebitis, local cellulitis, catheter malposition, occlusion, mechanical failure, unrelated fever, inadvertent patient removal, and error.^{3,5,7–12} Many of these complications can easily be managed by a specialty team with expertise in the insertion, management, and removal of these catheters without premature removal.

Premature PICC removals for unconfirmed infection or thrombosis are significant due to the need for subsequent reinsertions. PICC reinsertions occur in up to 100% of patients, often within days, to allow for CVC access and completion of therapy.¹³ Because previous catheters and placement attempts increase complications, adherence to clinical practice guidelines is critical to prevent premature removals and subsequent reinsertions for completion of therapy.¹⁴

PICC-associated complications can be as high as 20%–33% in non-pregnant patients and up to 66% in pregnant patients with hyperemesis.^{5,6,8,9,15–17} Typically, 0.6%–6.2% of PICC complications are related to concerns over infection, 9.6%–10.8% due to mechanical concerns, 8.2%–9.7% due to phlebitis, 2.6% due to pain, and 0.5%–0.3% due to suspected venous thrombosis.^{9,17–19} PICC malpositions also occur in 20%–30% of insertions, with more complications associated with patients who have had multiple catheters.^{10,20} Other risks include bleeding, catheter migration, and radiologically guided insertions requiring anesthesia.^{8,10,21,22} Furthermore, preservation of vessels for future vascular access is particularly critical for an aging population living longer with chronic conditions such as hypertension, diabetes, chronic kidney disease (CKD), cancer, bowel obstruction, and organ transplant.²²

The search strategy for premature PICC removal practice initiatives involved reviewing the literature regarding the general care and maintenance of PICCs for continuation of therapy, the appropriate management of PICC complications, and those related to decreasing PICC complications. Although there is a plethora of literature related to the general care and maintenance of these catheters, there is minimal literature relating specifically to initiatives for premature PICC removals. PICC removal information, when available, generally pertained to potential complications related to the inability to remove PICCs and prevention of air emboli, rather than to strategies specific to premature removal prevention.

The review of the literature provides the highest level of evidence-based initiatives for the use of a specialized team for the maintenance of intravascular catheters and education needs; an interdisciplinary, collaborative approach to decrease complications and prevent premature removal of PICCs; the implementation of institutional policies, procedures, and protocols with strong organizational leadership support for the prevention and management of PICC complications; and the use of CVC surveillance and auditing to detect, manage, and prevent complications such as premature PICC removals.

Multiple clinical practice guidelines, including those from the CDC and Society for Healthcare Epidemiology of America, recommend specialization as a contributor to patient safety, outcomes, and satisfaction.^{23–27} Within this team-based system, expert clinicians with competency in PICC use, site care, and catheter maintenance with training to manage potential complications are involved in PICC removal.^{22,28,29} Success is measured through high insertion success rates; decreased infection, DVT, and complica-

tion rates; improved team patient safety practices; increased patient and staff satisfaction with vascular access devices; and cost savings.³⁰

Unfortunately, although specialized nursing-based CVC programs specific to vascular access are increasing due to the CDC category IA recommendation to establish a designated nursing team, a US survey of 53 hospitals published in 2000 revealed that only 19% had a designated vascular team.^{31,32} In other institutions, although specialized teams exist, complications may not be managed appropriately because multiple medical and nursing teams with limited communication manage these catheters across their lifespans.

PICCs have been preserved by encouraging early interdisciplinary communication to facilitate the management of complications.¹³ In 1 study,¹³ of the 32% of PICCs removed before completion of therapy, 21.6% could have been managed without premature removal. Interdisciplinary communication facilitated the exclusion of noncatheter-associated sources of fever and promoted the appropriate management of catheter occlusion, rupture, or partial unintentional removal without removal.^{13,24,25,33}

In September 2012, our institutional review board approved a multidimensional quality improvement study leveraging a mandatory electronic communication tool (MECT) with the primary goal of decreasing premature PICC removal rates and a secondary goal of decreasing PICC-associated complications and costs. The study sought to facilitate the exchange of evidence-based recommendations between interdisciplinary team members utilizing early communication and specialty evaluation.

MATERIALS AND METHODS

Study design, end points, and setting

This historical cohort quality improvement study compared 2 different cohorts separated by time for comparison (12 months separating both cohorts) at an academically affiliated tertiary medical center in Southern California. A 12-month period between the 2 cohorts was chosen to account for changes in new medical house staff at American teaching institutions every June and July. The study units included all adult inpatient areas, including adult medicine, surgery, hematology/oncology, pulmonary/intensive care, geriatrics, orthopedics, emergency department, and the procedure treatment unit.

Following institutional review board approval, baseline data collection of 200 consecutive adult inpatient PICCs (cohort 1) inserted starting September 24, 2011 (12 months preceding data collection for cohort 2) was performed utilizing retrospective chart review. These data were compared with data collected from 200 consecutive adult inpatient PICCs (cohort 2) postinstitution of an MECT starting September 24, 2012. Although all adult inpatients received the intervention after September 24, 2012, data were only collected from the first 200 adult inpatient PICCs in cohort 2 for this study. Postintervention data collection was extended to at least 1 month after the sample of 200 was met for each cohort to evaluate for completion of therapy.

The primary study end point was a 50% decrease in the premature PICC rate from baseline and a 25% decrease in complications and costs related to decreased premature PICC removal. The inclusion criteria for both cohorts was the first 200 adult inpatient PICCs placed during each specified data collection period. Exclusion criteria were pediatric PICCs, adult outpatient PICCs, and adult inpatient PICCs outside the data collection period for both cohorts.

Structural components contributing to premature PICC removals within this health system included the lack of a multidisciplinary team to evaluate vascular access/removals, the lack of a formal referral process for PICC removals, issues with continuity of care, frequent changes in medical house staff within large teaching

institutions, and the lack of an electronic database to track insertion and removal of PICCs. Process components contributing to premature PICC removals included an outdated institutional protocol related to management of PICCs by a specialty team, an outdated PICC removal tool, knowledge gaps with regard to clinical practice guidelines, and minimal awareness of the removal problem by administration and staff.

Multidisciplinary leadership support from the medical director of clinical epidemiology and infection prevention, the chief medical officer, the director of nursing, medical information and technology services, as well as multidisciplinary nursing and medical teams was cemented before implementation. Stakeholders included the PICC service, interventional radiology (IR), infection control, pulmonology/critical care, medicine and nursing leadership, and administrators for all adult inpatient areas. An e-mail letter of leadership support was sent from the chief medical officer and director of nursing to all medical and nursing staff regarding the MECT protocol change. Multidisciplinary auditing was also initiated to evaluate for compliance to the MECT. For successful implementation of evidence-based recommendations and to promote change, strong organizational and administrative support and facilitation was required.^{27,30}

On September 24, 2012, an MECT was instituted for all adult inpatient PICCs during business hours, Monday through Friday 8:00 a.m. through 5:00 p.m., excluding holidays and university closures (Fig 1). As indicated prominently at the top of the MECT, MECTs outside of those restrictions would be evaluated the next business day and would not change standard of care. The MECT would not change a provider's ability to immediately discontinue PICCs for patients meeting CDC criteria for sepsis or deemed high risk. Additionally, the MECT recommended paging the PICC team for any urgent requests.

MECTs could be accessed by the PICC team at any computer using a protected health system 2007 Outlook (Microsoft Corp, Redmond, WA) shared network PICC account, without requiring the provider to find a paper copy. Historically, paper orders had been faxed to the wrong department, or not at all, causing delay of care. Ordering providers were paged to use the MECT if orders were received in alternate fashion. If necessary, the PICC team will then contact multidisciplinary team members, such as a patient's staff nurse, medical team, and specialty teams to coordinate appropriate care, including removal.

The MECT allowed for early communication and specialty management so PICCs not meeting CDC and DVT removal criteria could be salvaged, especially for those patients with limited vascular access. Specialized PICC management may include individualized patient assessment; repositioning malpositioned PICCs; performing over-the-guidewire PICC exchange; declotting occluded PICCs; recommending specific diagnostic or laboratory testing, according to CDC and DVT criteria; preventing accidental PICC reinsertion into thrombosed vessels; and optimal reinsertion management for those with suspected bacteremia or fungemia. The MECT also allows both the PICC team and infection control to monitor PICCs for complication tracking because the MECT is transmitted electronically to both teams.

Multidimensional implementation elements also included daily paging on weekdays to all nurses with patients with PICCs regarding the MECT; a PowerPoint (Microsoft Corp) presentation providing medical and nursing staff with updated instructions and indications for use of the MECT; multidisciplinary (nursing and medicine) communication about the MECT via group e-mail, individually with PICC insertions, and in PowerPoint presentations at committee meetings, not limited to the multidisciplinary infection control committees, the clinical nurse specialist and unit director committee; PICC team, and subspecialty committees; and patient and

family education about the MECT with any PICC insertion or encounter.

Definitions

Premature PICC removals are defined as PICCs removed before completion of intended therapy and do not meet the CDC CLABSI criteria or catheters removed for suspected DVT without imaging confirmation.

The NHSN definition of CLABSI was used to review all positive PICC blood cultures by clinical epidemiology and infection prevention departments. To meet the definition of a CLABSI, the patient with the PICC must have had the PICC in place with a recognized pathogen cultured from 1 or more blood cultures and the organism must not be related to an infection at another site (ie, a secondary bloodstream infection); or a common skin organism was cultured from 2 or more blood cultures drawn on separate occasions (within 2 days of each other) and at least 1 of the following signs or symptoms are present: fever (38°C), chills, or hypotension, and the signs and symptoms and positive blood cultures are not due to infection at another site. The denominator for bloodstream infection rates was 1,000 CVC days.

Statistical methods

The sample size estimate was derived from an estimated rate of premature PICC removals of 20% within this Southern California university health system in 2011. On the basis of published studies, it was assumed that early communication and specialty evaluation would result in a 50% decrease in premature PICC removal rates. To achieve a statistically significant decrease ($P = .05$) in premature PICC removals with a power of 80%, the sample size estimate was 200 PICCs each for the baseline (cohort 1) and intervention group (cohort 2). Analyses were conducted using SPSS version 20 (IBM Corp, Armonk, NY). To analyze the difference in cohorts, χ^2 for homogeneity tests were used, including premature PICC removal and complication rates.

RESULTS

Data collection included demographic characteristics of the study population (Table 1), catheter characteristics (Table 2), procedure outcomes (Table 3), PICC removal rates (Table 4), PICC complication rates (Table 5), and types of PICC imaging used for PICC insertion (Table 5). A total of 400 adult inpatient PICCs represents 100% of the total sample size used for analysis (200 PICCs each for the baseline and intervention group).

The primary desired outcome was a 50% decrease in premature PICC removal rates for adult inpatients before completion of therapy, utilizing a MECT for early communication and specialty evaluation. The premature PICC removal rate for the baseline group (cohort 1) was 16% and for the intervention group (cohort 2) 2.5%. There was an 84.4% decrease in premature PICC removal rates postintervention, which was statistically significant ($P < .0001$) and exceeded expected outcomes. All premature PICC removals in cohort 2 were due to patient self-removal (accidental or due to altered mental status) and none were provider-led. The patient self-removal rates for both cohorts were similar (2% for cohort 1 vs 2.5% for cohort 2). Furthermore, although 10 patients in cohort 2 had confirmed DVT, only 1 had the PICC removed due to DVT. The others had continued use of their PICC for completion of therapy. The total PICC removal rates also decreased ($P < .0001$) due to reinforcement of intermediate- to long-term PICC indications before PICC insertion and removal.



PICC ASSESSMENT/REMOVAL REFERRAL
(M-F 8-5; NO HOLIDAYS)

MRN: _____

Patient Name: _____

(Patient Label)

ASSESSMENT/REMOVAL EVALUATION

Following completion of form, proceed with **Standard of Care**
if Immediate Evaluation Unavailable

☐ **REMOVAL ASSESSMENT FOR DISCHARGE** (Specialty Evaluation only)

☐ **INFECTION EVALUATION:** **D/C PICC ASAP WITH CLABSI, IF APPROPRIATE**
2011 CDC Guidelines: <http://www.cdc.gov/hicpac/pdf/guidelines/bsi-guidelines-2011.pdf>
 CLABSI Criteria: http://www.cdc.gov/nhsn/PDFs/pscManual/4PSC_CLABSCurrent.pdf

☐ **Suspected insertion site infection:**

☐ Purulent drainage from insertion site
☐ Phlebitis at insertion site
☐ Cellulitis at insertion site

☐ **Confirmed systemic infection:**

☐ Bacteremia/Fungemia with AT LEAST 1 POSITIVE BLOOD CULTURE
☐ No alternative source of infection except PICC

☐ **Possible infection (should meet both criteria):**

☐ Systemic signs and symptoms of serious infection:

☐ Fever >100.4°F or 38°C
☐ Chills
☐ Hypotension SBP <90 or MAP <60

☐ No alternative source of infection except PICC

☐ Other: _____

☐ **See for Sepsis Criteria Order set**

☐ **SUSPECTED DVT:** **Imaging confirmation required**

☐ Confirmed DVT Imaging: Doppler, Venogram, Other
☐ Pain
☐ Persistent occlusion

☐ Leaking from insertion site
☐ Swelling

☐ **OTHER COMPLICATION:** _____

☐ Malposition/Dislodged PICC
☐ Damaged PICC
☐ Accidental Removal

Submitted By: _____

Extension: x _____ **Unit:** OUTPT

SEND

PRINT

CLEAR ALL

Catheter care per UCLA Healthcare System Policy: [104](#)

Fig 1. Mandatory electronic communication tool.

Secondary desired outcomes included a 25% decrease in PICC complications and radiology costs due to decreased premature PICC removal rates. There was a statistically significant decrease in the total PICC complication rate from 45.5% for cohort 1 to 34% ($P < .001$) for cohort 2, particularly in PICC malposition ($P < .001$) and suspected infection rates ($P = .03$). This represents a 25.3% decrease in PICC complications, meeting secondary outcomes. Although statistical significance was not achieved ($P = .06$), the greatest clinical significance was noted with CLABSI rates, which dropped from a

CLABSI rate of 1.38/1,000 catheter days (2.5%) from cohort 1 to 0/1,000 catheter days for cohort 2. The CLABSI rate of 1.39/1,000 catheter days was calculated for cohort 1 by dividing the 5 CLABSIs by 3,614 catheter days (total catheter days for cohort 1) and multiplying it by 1,000. The CLABSI rate for cohort 2 was 0/1,000 catheter days because there were no CLABSIs. The secondary bloodstream infection rate for cohort 1 was 2.77/1,000 catheter days (10 secondary bloodstream infections were divided by 3,614 catheter days and multiplied by 1,000) and 1.91/1,000 catheter days for cohort 2

Table 1
Demographic characteristics of the study population

	Baseline group	Intervention group	P value
Total number of peripherally inserted central catheter placements	200	200	
Age (y)	68 (18–100)	63.19 (18–99)	
Gender			.55
Female	110 (55)	104 (52)	
Male	90 (45)	96 (48)	
Unit			
Medical/surgical	89 (44.5)	82 (41)	
Hematology/oncology	34 (17)	54 (27)	
Pulmonary/intensive care unit	44 (22)	28 (14)	
Geriatrics	21 (10.5)	5 (2.5)	
Orthopedics	1 (0.5)	25 (12.5)	
Other	11 (5.5)	12 (6)	
Peripherally inserted central catheter indication			.03
Antibiotics	130 (65)	123 (61.5)	
Intravenous access	27 (13.5)	13 (6.5)	
Chemotherapy	23 (11.5)	39 (19.5)	
Total parenteral nutrition	17 (8.5)	24 (12)	
Pressor	2 (1)	0 (0)	
Other	1 (0.5)	1 (0.5)	
Comorbidities			
Coinfection	183 (91.5)	167 (83.5)	.02
Miscellaneous	146 (73)	84 (42)	<.0001
Cancer	86 (43)	101 (50.5)	.13
Chronic kidney disease	40 (20)	19 (9.5)	<.01
Autoimmune disorders	27 (13.5)	24 (12)	.65
Total parenteral nutrition	22 (11)	30 (15)	.23
Coagulopathy	23 (11.5)	17 (8.5)	.32
Lymph node dissection	14 (7)	6 (3)	.07
Pacemaker/automatic implantable cardioverter defibrillator	12 (6)	15 (7.5)	.55
Vegetative valves	4 (2)	6 (3)	.52
Axillary bypass surgery	2 (1)	1 (0.5)	
Transplant	2 (1)	0 (0)	
Thrombosis			
History of deep vein thrombosis	37 (18.5)	45 (22.5)	.32
History of multiple deep vein thrombosis	22 (11)	24 (12)	.75
History of central venous access device	47 (23.5)	35 (17.5)	.53
Short-term central venous access device	23 (12.5)	11 (5.5)	
More than 1 central venous access device	12 (6)	11 (5.5)	
Implanted port	6 (3)	8 (4)	
Right dialysis catheter	3 (1.5)	4 (2)	
Dialysis graft/fistulas	2 (1)	0 (0)	
Right tunneled central venous catheter	1 (0.5)	1 (0.5)	
Current central venous catheter	36 (18)	22 (11)	.12
Short-term central venous catheter	17 (3)	9 (4.5)	
More than 1 central venous catheter	11 (5.5)	2 (1)	
Right dialysis catheter	2 (1)	5 (2.5)	
Right implanted port	2 (1)	3 (1.5)	
Right tunneled central venous catheter	1 (0.5)	0 (0)	
Other	1 (0.5)	1 (0.5)	

NOTE. Values are presented as n, mean (range), or n (%). Bold values are statistically significant $P < .05$.

(5 secondary bloodstream infections were divided by 2,623 catheter days and multiplied by 1,000).

In cohort 1, imaging required for PICC confirmation, other than chest radiograph (84%), included fluoroscopy (3%), chest radiograph plus fluoroscopy (1.5%), chest radiograph plus fluoroscopy plus venogram (1%), or multiple interventions (4%), such as Doppler ul-

Table 2
Peripherally inserted central catheter characteristics

	Baseline group	Intervention group	P value
Total number of catheters	200	200	
Size			.26
5 French	128 (64)	117 (58.5)	
4 French	72 (36)	83 (41.5)	
Manufacturer			<.0001
Navilyst*	199 (99.5)	0 (0)	
Arrow†	1 (0.5)	0 (0)	
Bard‡	0 (0)	200 (100)	
Other	0 (0)	0 (0)	.26
Number of lumens			
Single	72 (36)	83 (41.5)	
Double	128 (64)	117 (58.5)	
Valve type			
Nonvalved	100 (100)	100 (100)	
Valved	0 (0)	0 (0)	.63
Power injectable			
Yes	190 (95)	192 (96)	
No	10 (5)	8 (4)	

NOTE. Values are presented as n or n (%). Bold values are statistically significant $P < .05$.

*Marlborough, MA.

†Morrisville, NC.

‡Salt Lake City, UT.

trasound to evaluate for thrombosis (Table 6). The total imaging costs for cohort 1 was \$17,924.74 utilizing the Medicare B hospital fee reimbursement schedule. The cost of 168 chest radiographs, including the professional fee, was \$5,493.60 and up to \$12,000 for the 12 referrals to IR for additional fluoroscopic imaging. Eight additional PICCs needed multiple studies and 1 required an upper extremity Doppler study. The cost was estimated to be an additional \$261.60 for the eight multiple studies requiring 2 chest radiograph scans for successful PICC placement and another \$169.54 for the Doppler study. To calculate cost for cohort 1, the 2011 Medicare B hospital fee reimbursement schedule was used, which allows for \$275.29 per ultrasound-guided PICC placement (CPT 36568 PICC placement, CPT 76937 ultrasound); \$32.70 for a portable 1-view chest radiograph, including the professional fee (CPT 71010 and revenue code 0972); \$169.54 for a unilateral upper extremity venous Doppler study (CPT 93971); \$128.66 for venogram of a unilateral extremity (CPT 75820); and \$119.47 for fluoroscopic confirmation (CPT 77001). Other costs when using IR include those related to the radiologist's professional fee, increased technologist and clinical staff use, and disposables amounting to more than \$1,000 per catheter when fluoroscopic assistance is required.

In cohort 2, imaging required for PICC confirmation, other than chest radiograph (89%), included fluoroscopy (5%), and chest radiograph plus fluoroscopy (1%) (Table 6). The total imaging costs for cohort 2 was \$17,863.32 utilizing the Medicare B hospital fee reimbursement schedule. The cost of 178 chest radiograph with the professional fee was \$5,863.32 and up to \$12,000 for the 12 referrals to IR for additional fluoroscopic imaging. For cohort 2, the Medicare B hospital fee reimbursement schedule allows for \$266.98 per ultrasound-guided PICC placement (CPT 36568 PICC placement, CPT 76937 ultrasound); \$32.94 for a portable 1-view chest radiograph, including the professional fee (CPT 71010 and revenue code 0972); and \$119.47 for fluoroscopic confirmation (CPT 77001). Other costs include those related to the radiologist's professional fee, increased technologist and clinical staff use, and disposables amounting to more than \$1,000 per line when fluoroscopic assistance is required.

Despite very little difference in imaging costs for the 2 cohorts (\$17,924.64 in imaging for cohort 1 and \$17,863.32 for cohort 2), there was a 35.4% savings in radiology costs in cohort 2 due to cost

Table 3
Procedure outcomes

	Baseline group	Intervention group	P value
Total peripherally inserted central catheters	200	200	
Catheter indicated			
Peripherally inserted central catheter	197 (98.5)	194 (97)	
Midline catheter	3 (1.5)	6 (3)	
Catheter placed			
Peripherally inserted central catheter	190 (95)	193 (96.5)	
Midline catheter	9 (4.5)	7 (3.5)	
Failed	1 (0.5)	0 (0)	
Arm			.91
Right	147 (73.5)	146 (73)	
Left	53 (26.5)	54 (27)	
Vein			.001
Basilic	114 (57)	149 (73)	
Brachial	71 (35.5)	41 (20.5)	
Cephalic	15 (7.5)	10 (5.0)	
Reinserted peripherally inserted central catheter			1.0
Yes	33 (16.5)	33 (16.5)	
No	167 (83.5)	167 (83.5)	
Malposition			<.001
Yes	34 (17)	10 (5.0)	
No	167 (83.5)	190 (95)	
Reposition			.001
Yes	26 (13)	8 (4)	
No	174 (87)	192 (96)	
Peripherally inserted central catheter provider			
Peripherally inserted central catheter registered nurse	138 (69)	132 (66)	
Interventional radiology nurse practitioner	60 (30)	67 (33.5)	
Interventional radiology physician	2 (1.0)	1 (0.5)	
Interventional radiology referral			1.0
Yes	12 (6)	12 (6)	
No	188 (94)	188 (94)	
Interventional radiology provider			
Registered nurse	4 (2)	1 (0.5)	
Nurse practitioner	6 (3)	11 (5.5)	
Physician	2 (1.0)	1 (0.5)	
Success			
Yes	199 (99.5)	200 (100)	
No	1 (0.5)	0 (0)	
Tip location			
Distal superior vena cava	129 (64.5)	131 (65.5)	
Mid-superior vena cava	44 (22)	40 (20)	
Axillary vein	10 (5)	7 (3.5)	
Proximal superior vena cava	9 (4.5)	16 (8)	
Right atrium	3 (1.5)	4 (2)	
Subclavian vein	2 (1)	1 (0.5)	
Other	3 (1.5)	1 (0.5)	

NOTE. Values are presented as n or n (%). Bold values are statistically significant $P < .05$.

savings from decreased premature removals. The catheter and radiography costs for the 27 PICCs removed prematurely in cohort 1 utilizing the 2011 Medicare B hospital fee reimbursement schedule was at least \$9,717, making the additional radiology and imaging cost \$27,641.74 for cohort 1 versus \$17,863.32 for cohort 2. This exceeded the secondary desired outcome of a 25% decrease in radiology costs due to reduced premature PICC removals.

For the purposes of this study, specific costs related to decreased rates of infection and complications, as well as length of stay, were not calculated. Given an attributable cost estimate of up to \$45,000 per CVC-associated bloodstream infection and the higher incidence of CLABSI in the baseline group (5 PICCs), there are greater implications for cost savings than those calculated for this study.¹

Table 4
Peripherally inserted central catheter (PICC) removal

	Baseline group	Intervention group	P value
Total PICCs	200	200	
Total removals	89 (44.5)	48 (24)	<.0001
Total premature removals	32 (16)	5 (2.5)	<.0001
Reason for removals			
Completion of therapy	39 (19.5)	34 (17)	
Early discontinuation	11 (5.5)	0 (0)	.003
Infection:			
Suspected	4 (2)	0 (0)	
Secondary	5 (2.5)	5 (2.5)	1.0
Confirmed central line-associated bloodstream infection	5 (2.5)	0 (0)	.06*
Deep vein thrombosis			
Confirmed	4 (2)	1 (0.5)	
Patient self-removal	4 (2)	5 (2.5)	
Exchange by PICC team	4 (2)	3 (1.5)	
PICC insertion delay			
Yes	0 (0.0)	0 (0.0)	
No	200 (100.0)	200 (100.0)	
Average catheter days	18.2	13.2	

NOTE. Values are presented as n or n (%). Bold values are statistically significant $P < .05$.

*Fisher exact test used; failed to meet the assumptions χ^2 analysis.

Table 5
Peripherally inserted central catheter (PICC) complications

	Baseline group	Intervention group	P value
Total PICCs	200	200	
Total number of complications	91 (45.5)	68 (34)	.02
Multiple complications	23 (11.5)	16 (8)	.62
Types of complications			
Infection			
Suspected	64 (32)	45 (22.5)	.03
Confirmed	10 (5)	5 (2.5)	.06
Deep vein thrombosis			
Suspected	18 (9)	19 (9.5)	.86
Confirmed	11 (5.5)	10 (5)	.82
Malposition + suspected infection	7 (3.5)	2 (1)	
Suspected infection + deep vein thrombosis	4 (2)	4 (2)	
Malposition + central line-associated bloodstream infection	1 (0.5)	0 (0)	
Malposition + deep vein thrombosis	1 (0.5)	1 (0.5)	
Infection + deep vein thrombosis	1 (0.5)	0 (0)	
Infection + suspected deep vein thrombosis	1 (0.5)	1 (0.5)	
Other	4 (2)	6 (3)	
Multiple	3 (1.5)	2 (1)	

NOTE. Values are presented as n or n (%). Bold values are statistically significant $P < .05$.

Table 6
Peripherally inserted central catheter (PICC) imaging

	Baseline group	Intervention group	P value
Total PICCs	200	200	
Chest radiograph only	168 (84)	168 (84)	
Interventional radiology referral	12 (6)	12 (6)	1.0
Fluoroscopy	6 (3)	6 (3)	
Chest radiograph + fluoroscopy	3 (1.5)	3 (1.5)	
Chest radiograph + fluoroscopy + venogram	2 (1)	2 (1)	
Multiple interventions	8 (4)	8 (4)	
Other	2 (1)	2 (1)	

NOTE. Values are presented as n or n (%).

Cohort 1 had a CLABSI rate of 2.5% (5 PICCs) versus 0% for cohort 2. The attributable cost would amount up to \$225,000 for the intervention period, if this model were used. Adding in \$9,717 in cost savings from decreased PICC removals, the total amount saved during the 5-month intervention period (amount of time required to collect data for 200 consecutive PICCs during the intervention period) could exceed \$234,717 with the inclusion of length of stay. The average catheter duration was 18.16 days for cohort 1 and 13.15 days for cohort 2.

DISCUSSION

In this historical cohort study, there was a significant decrease in adult inpatient premature PICC removals, PICC complications, and costs following the institution of a multidimensional intervention utilizing a MECT compared with baseline with no PICC assessment and removal communication and evaluation requirement. This decrease in premature PICC removals, complications, and costs has been sustained to date. The decrease in premature PICC removals

Leveraging MECT

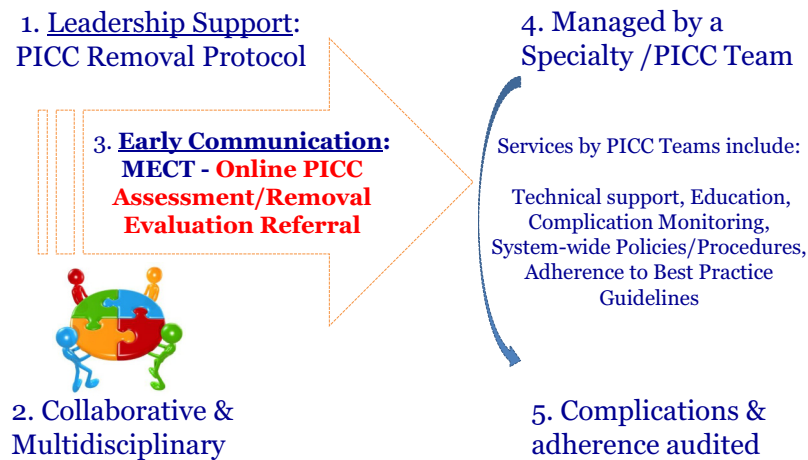


Fig 2. Leveraging the mandatory electronic communication tool (MECT). PICC, peripherally inserted central catheter.

MECT Continuum

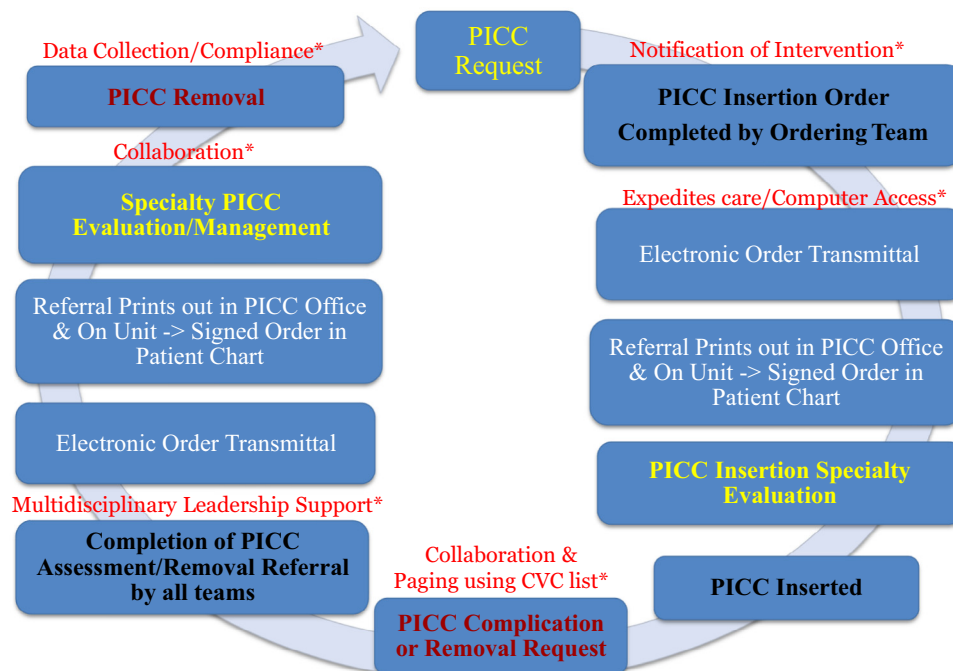


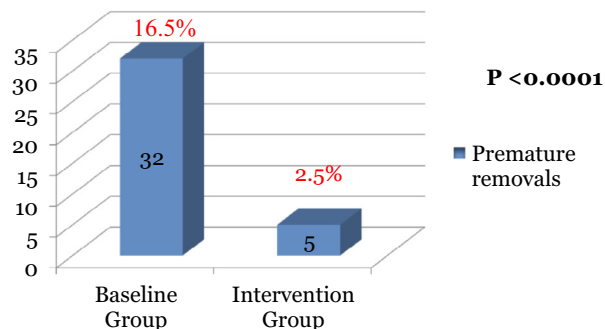
Fig 3. Mandatory electronic communication tool continuum. CVC, central venous catheter; PICC, peripherally inserted central catheter.

Aim 1: 50% decrease in Premature PICC Removal rates

Outcome 1: 85% decrease in premature PICC removal rates, ZERO provider led removals

n = 200 per group

Premature PICC Removals

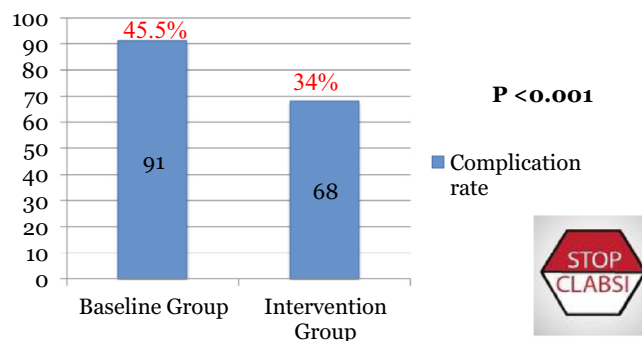


Aim 2: 25% decrease in PICC Complication rates

Outcome 2: 25.3% decrease in PICC complication rates, ZERO CLABSI

n = 200 per group

PICC Complication Rates



Aim 3: 25% decrease in Radiology Costs resulting from decreased Premature PICC Removals

Outcome 3: 35.4% decrease in radiology costs

n = 200 per group

PICC Radiology Costs	Baseline Group	Intervention Group	p value
Total PICCs	200	200	
Chest x-ray only	168 (84%)	178 (89%)	
IR Referral	12 (6%)	12 (6%)	
Total imaging costs	\$17,924.64	\$17,863.32	
Premature removal additional costs	\$9,717	\$0	
Total radiology costs	\$27,641.74	\$17,863	1.0

Fig 4. Study outcomes. CLABSI, central line-associated bloodstream infection; IR, interventional radiology; PICC, peripherally inserted central catheter.

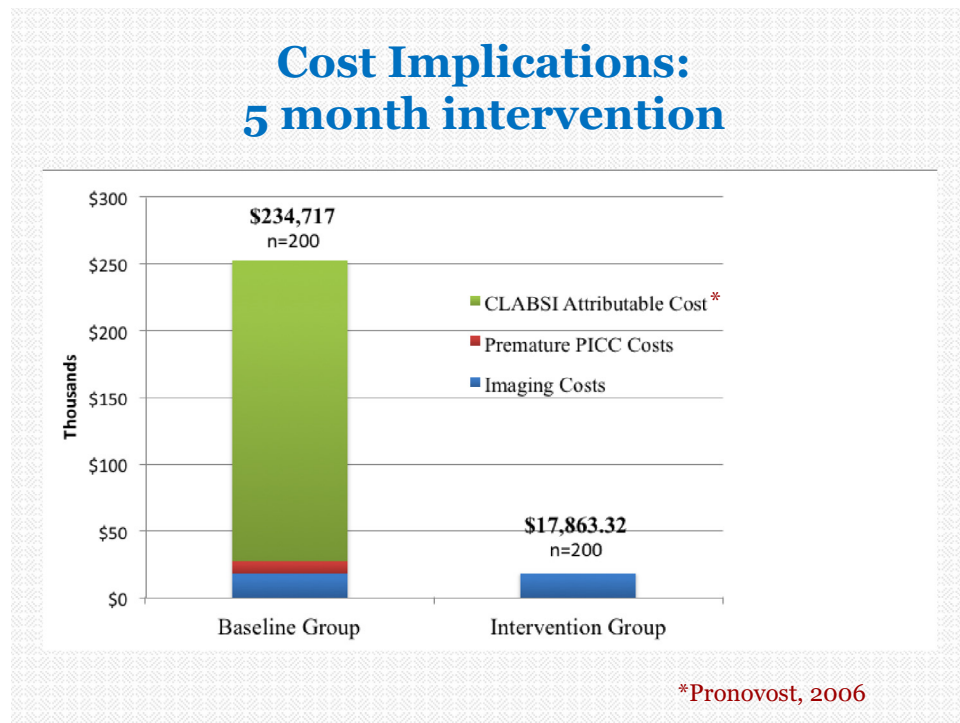


Fig 5. Cost data. CLABSI, central line-associated bloodstream infection; PICC, peripherally inserted central catheter.

and PICC complications are presumably related to the ability of an interdisciplinary team to communicate early and collaboratively with a specialty team to assess and manage PICC complications leading to PICC removal, following clinical practice guidelines. High compliance was achieved through strong leadership support at the executive level.

This study adds to the developing body of knowledge associating early communication and specialty evaluation with reductions in premature PICC removals, PICC complications, and CLABSI. Our study is the first study focused primarily on a mandatory intervention to decrease premature PICC removals and unique in using innovative technology, such as an MECT and paging system, for reducing CVC-related complications and costs. Historically, the focus has always been on reducing CLABSI rates through removing unnecessary catheters as soon as possible, with less focus on methods in determining catheter necessity, such as the use of a specialty team in that decision-making process.

This study was part of an institutional drive to reduce CLABSI rates across the health system due to an increase in CLABSIs during 2011. An executive leadership-sanctioned multidisciplinary CLABSI task force was formed and 3 groups developed focusing on CVC insertion, maintenance, and removal. A health system consensus guideline for the insertion, management, and removal of CVCs was also developed. These synergistic efforts contributed to the enthusiastic buy-in of key interdisciplinary stakeholders, including members of the pulmonology/critical care and infection control and epidemiology staff. There was an increased focus on appropriate use of PICCs, starting from determining the appropriateness and timing of PICC insertions through the careful and cautious management of PICC complications and removals. Confounders for decreased CLABSI rates could have included chlorhexidine bathing for all patients with CVCs, which started in November 2012, and a change to standardized central line kits in January 2013. It is important to note that infection rates had been 0 since the start of study during late September 2012, before these changes.

A statistically significant change in the PICC device from the Xcela (Navilyst Medical Inc, Glen Falls, NY) to the PowerPICC FT catheter (Bard Access Systems Inc, Salt Lake City, UT) ($P < .001$) was apparent due to a change in the health system PICC purchasing contract during summer 2012. The catheter was changed from Xcela to PowerPICC FT due to certain custom kit requirements by the PICC team; however, the catheters were comparable and had similar characteristics. Both were nonvalved, power-injectable for contrast studies, and consisted of a polyurethane material. Before use of Navilyst catheters in 2010, the majority of catheters placed were nonvalved, nonpower injectable Arrow (Teleflex Medical Inc, Research Triangle Park, NC) and nonvalved, power injectable Bard (power-injectable) catheters. Other catheters had also been trialed, including power injectable Arrow and AngioDynamics Morpheus (AngioDynamics Inc, Queensbury, NY) catheters before the change to Bard PowerPICC FT PICCs. No anecdotal differences in PICC complications and removal related to manufacturer was noted at any time; however, in 2010, the PICC team elected to use all power-injectable catheters for increased utility, consistent with the practice of many other university-affiliated health care systems.

A statistical difference in PICC indication ($P = .03$) and comorbidities, such as coinfection ($P = .02$), miscellaneous patient c-morbidities ($P < .0001$), and CKD ($P < .01$) was noted between the 2 cohorts. These differences were presumably related to greater scrutiny by the interdisciplinary team for appropriate insertion of PICCs for intermediate- to long-term access, such as with long-term chemotherapy and total parenteral nutrition. There was also increased collaboration with nephrology for vessel preservation in CKD patients possibly needing future upper extremity dialysis access. Coinfection refers to any possible source of secondary infection, such as a urinary tract infection, pneumonia, decubitus ulcer, and abscess. Due to the higher vigilance by members of the infection prevention team, if there was active fever, increasing leukocytosis, or suspicion of a bloodstream infection PICC placement was deferred and a peripheral intravenous line placed (including

ultrasound-guided peripheral intravenous lines for those with difficult access). Miscellaneous patient comorbidities referred to any miscellaneous comorbidities affecting PICC placement and management not listed in the other comorbidity categories, such as if the patient had upper arm contractures making PICC placement difficult, had dementia or impaired cognitive function leading to premature PICC removal, was homeless or uninsured leading to premature PICC removal due to inability to continue long-term antibiotics, had a history of stroke with limited mobility in an extremity increasing DVT risk, and atrial fibrillation increasing risk for anticoagulant use and a change in DVT rates. Specialty evaluation from insertion through removal decreased unnecessary or inappropriate insertions leading to premature insertion and removal. The historical placement of PICCs for intravenously administered outpatient therapy also decreased. Outpatient agencies are now expected to place peripheral lines for the majority of short-term outpatient intravenous access use instead of relying primarily on PICCs as in the past.

A statistically significant difference was also noted in outcomes between the 2 cohorts for the type of vein used for PICC placement ($P = .001$), malposition ($P < .001$), and reposition ($P = .001$). These changes were possibly related to decreases in premature PICC removal rates ($P < .0001$), as well as a change in providers (staffing changes for rotating IR nurse practitioners usually occur every 3 months) with differences in vein preference used for PICC placement (brachial veins are associated with higher risk of complications). Although no significant changes were noted between cohorts for a history of central venous access devices ($P = .53$), current central venous access device ($P = .12$), and reinsertion rates ($P = 1.0$), historically these factors also contribute to changes in malposition and reposition rates.

LIMITATIONS

The limitation of this quality improvement study is that is not of a randomized, double-blind controlled design and thus cannot fully exclude confounding variables. The interdisciplinary team was advised to submit a MECT for all PICC assessment and removal requests; however, some chose to use the paging system for early communication and specialty evaluation rather than the MECT, and had to be reminded to also complete the MECT for interdisciplinary auditing purposes by infection control and the PICC team. Any bias on the interpretation of premature PICC removal and CLABSI was minimized due to an interdisciplinary, collaborative review by study investigators, infection control and epidemiology department members, the PICC team, and the study unit. CLABSI rates were publicly reported to the NHSN and California Department of Health during the study timeframe.

CONCLUSIONS

At many institutions, the decision to remove PICCs is often clinical. Strict adherence to clinical practice guidelines for PICC removal may be challenging because the management of these catheters across its lifespan involves multiple medical and nursing teams with limited communication with one another. Strong leadership is also critical for teams focused on programs for the prevention of CLABSI.

Our historical cohort study demonstrates that the facilitation of early interdisciplinary communication and specialty evaluation, through innovative methods such as MECT and paging, can increase clinical quality and result in zero provider-led premature PICC removals and zero CLABSI. As other intervention studies have also demonstrated in the past, removing PICCs judiciously and not reactively, can decrease complications, reduce associated health care costs, and improve clinical quality. (Figs 1–5)

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