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Abstract

Background

Whether peripherally inserted central catheters (PICCs) are appropriate as safe and durable venous access devices (VADs) is still controversial. The aim of this 7-year, prospective cohort study was to compare the incidence rate differences of catheter-related complications (CRCs) among 4 types of central VADs in cancer patients receiving home parenteral nutrition (HPN).

Methods

We enrolled all adult cancer outpatients who were candidates for HPN and who had a central VAD inserted during the study period, focusing on the incidence rate of CRCs.

Results

We evaluated 854 central VADs (401 PICCs, 137 nontunneled centrally inserted central catheters [CICCs], 118 tunneled-cuffed CICCs, and 198 ports) in 761 patients, for a total of 169,116 catheter-days. Overall, the rate of total CRCs was 1.08/1000 catheter-days. The incidence of catheter-related bloodstream infections was low (0.29/1000), particularly for PICCs (0.08/1000; $P < .001$ vs tunneled-cuffed CICCs) and for ports (0.21/1000; $P < .019$ vs tunneled-cuffed CICCs). The rates of mechanical complications (0.58/1000) and of catheter-related symptomatic thrombosis (0.09/1000) were low and similar for PICCs, tunneled-cuffed CICCs, and ports. In terms of duration and removal rate due to complications, PICCs were like tunneled-cuffed CICCs and ports. Altogether, PICCs had fewer total complications than tunneled-cuffed CICCs ($P < .001$), there was no difference in total complications between PICCs and ports.

Conclusion

PICCs had significantly better outcomes than tunneled-cuffed CICCs and were safe and durable as ports. Our extensive, long-term study suggests that PICCs can be successfully used as safe and long-lasting VADs for HPN in cancer patients.

Clinical Relevancy Statement

Central venous access devices (VADs) are particularly needed now in the care of cancer patients since the emphasis has shifted to the outpatients' scenario. All healthcare professionals involved in the choice, insertion, or management of VADs should know the pros and cons of the different central VADs. This study demonstrates that peripherally inserted central catheters (PICCs) can be safely used for home parenteral nutrition (HPN) in cancer outpatients, as they are associated with a low incidence of catheter-related bloodstream infections, catheter-related thrombosis, and mechanical complications (overall complications: 0.69/1000 catheter-days). The main finding of this study is that PICCs have significantly better outcomes than tunneled-cuffed centrally inserted central catheters in regard to being safe and durable as ports. These findings are clinically relevant for guiding providers in the proper choice of a safe and long-lasting central VAD in the adult cancer patient eligible for HPN.

Introduction

A safe and reliable central venous access device (VAD) is essential for the management of the oncology patient, both in the initial phases (surgery, radiotherapy, and chemotherapy) and in the advanced stage (home parenteral nutrition [HPN]1, 2 or palliative care3). At present, the choice of the type of VAD for HPN in cancer patients mostly depends on the expected duration of the intravenous treatment, on the clinical experience of the operator,4 and—to a lesser degree—on the preference of the patient.

VADs are often classified as short-term, medium-term, and long-term devices. However, there is not a worldwide consensus on the interpretation of these terms. Peripherally inserted central catheters (PICCs) have never been clearly classified as short-term, medium-term, or long-term VADs.5 Initially, because of lack of clinical data, PICCs were recommended for dwell times of weeks or months. In the 2009 guidelines of the European Society for Clinical Nutrition and Metabolism, PICCs were considered medium-term VADs, appropriate for HPN of ≤3 months.6 On the other hand, the 2008 guidelines of the Australasian Society for Parenteral and Enteral Nutrition considered that PICCs were also appropriate for longer periods of HPN, ≤12–18 months.7 Indeed, the Infusion Nurses Society (INS) suggests that the absolute PICC dwell time is hard to define and that a PICC may stay in place as long as there are no complications requiring its removal.8 In the 2011 Standards of Practice, INS stated the following: "Do not routinely replace PICCs to prevent catheter-related infections."9

Though they have been available since the mid-1970s, a significant clinical experience with PICCs started in North America about 20 years ago. Several clinical studies demonstrated the safety and effectiveness of PICCs in home-care patients10, 11; in particular, PICCs were considered appropriate as tunneled-cuffed centrally inserted central catheters (CICCs) and ports for the delivery of HPN.12 Nonetheless, several reports about HPN in Europe,13, 14 Australia,15 and the US16 published at the beginning of this century have failed to mention PICCs.

In our hospital, PICCs were not considered appropriate for HPN until 2008. From June 2008 on, we started to suggest to patients, oncologists, and VAD providers the placement of PICCs in cancer patients who were candidates for HPN, independently from the anticipated need of VAD duration. In a previous study, we investigated the incidence of catheter-related complications (CRCs) in cancer patients receiving HPN and the relationship between CRCs and the most significant risk factors.17 The aim of this prospective cohort study was to describe, more closely, the incidence of CRCs in cancer patients receiving HPN, comparing 4 different types of central VADs used for this purpose.

Methods

In this prospective cohort study, we consecutively enrolled all adult cancer outpatients who were candidates for HPN and who had a central VAD inserted during the study period. The study was carried out for 7 years—from June 1, 2008, through May 31, 2015—in a 1200-bed university hospital. All patients were followed up from the time of VAD insertion until VAD removal or until death; the follow-up study was concluded when the last VAD inserted during the study period was removed. The ethics committee approved the study protocol, and written informed consent was obtained from each patient for VAD insertion, for HPN, and for participation in the study.

During the study period, 4 different types of central VADs were inserted: (1) nontunneled, noncuffed PICCs (4F single-lumen silicone catheters with distal valve [Groshong PICC, Bard Access Systems, Salt Lake City, UT], 4 and 5F single-lumen polyurethane catheters [Vascu-PICC, MedComp, Harleysville, PA], and 4 and 5F single-lumen polyurethane power-injectable catheters [Pro-PICC, MedComp; Synergy, HealthLine, San Francisco, CA]); (2) nontunneled CICC (5F single-lumen silicone catheters [Hohn, Bard Access Systems]); (3) tunneled-cuffed CICC (8F single-lumen silicone catheters with distal valve [Cuffed Groshong, Bard Access Systems]); and (4) totally implanted, centrally inserted ports (standard- and low-profile reservoirs, connected to silicone or polyurethane catheters of different calibers [5.5–8F] [Celsite, BBraun, Melsungen, Germany; BardPort, Bard Access Systems]).

The choice of the type of VAD for each patient was primarily based on the preference of the operator, though the preference of the patient, of the caregiver, or of the other healthcare professionals was also considered. PICCs were inserted by specifically trained nurses or surgeons; the other VADs were inserted by anesthesiologists and surgeons. The technique of insertion consistently includes maximal barrier precautions and skin antisepsis with 2% chlorhexidine in alcohol. The appropriate central position of the catheter tip (close to the cavoatrial junction) was consistently verified, either intraprocedurally by intracavitary electrocardiography18 or fluoroscopy or postprocedurally by chest x-ray. According to guidelines,19 routine anticoagulation for prevention of catheter-related thrombosis (CRT) was not adopted. In patients receiving both HPN and chemotherapy, the VAD was used for both treatments but never at the same time. The VADs were also used for blood sampling.

Definitions and diagnosis of local infection and catheter-related bloodstream infections (CRBSIs) were established according to the guidelines.9, 20 Management of CRBSIs (by removal and/or ≥10–14 days of systemic antibiotic treatment plus antibiotic lock therapy, when recommended) closely followed

the guidelines, too.20 CRT was diagnosed and treated according to guidelines6, 19; only symptomatic CRT was considered (local pain, edema, and signs suggesting venous thrombosis, later confirmed by ultrasound examination with or without color Doppler). Mechanical complications were managed according to guidelines.6, 8

Causes of VAD removal due to CRCs included infection of the exit site or of the tunnel; CRBSI with indication for VAD removal because of failure of or contraindication to conservative treatment9; CRT associated with catheter malfunction19; rupture of the external segment of the catheter, if impossible to repair; complete or partial (>4 cm) dislocation of nontunneled VADs; dislocation of tunneled-cuffed CICC due to expulsion of the cuff from the tunnel; and lumen occlusion resistant to disobstruction.

Our criteria for accepting patients in the HPN program followed the guideline recommendations for eligibility2 and included proven and prolonged failure to meet nutrition requirements by oral or enteral route (no food for >1 week or <60% of requirement for >1–2 weeks), with potential risk of early death due to malnutrition rather than to cancer progression; life expectancy >2 months; Karnofsky Performance Status (KPS) ≥ 50; adequate control of pain and other severe symptoms (dyspnea, vomiting); absence of severe organ dysfunctions; written informed consent confirming that the patient accepted this modality of nutrition support; having a central VAD; approval by the physician responsible for HPN, as well as the oncologist and the general practitioner; presence of environmental conditions compatible with HPN; availability of an in-home caregiver; and availability of a specifically trained nursing team dedicated to the patient's home care, as provided by the Public Health Service. Exclusion criteria for HPN were capability to meet the nutrition requirements by oral or enteral route, KPS < 50, uncontrolled symptoms, severe organ dysfunctions (heart, respiratory, liver, and renal), lack of an in-home caregiver, and HPN refusal by the patient. After starting HPN, all patients were closely monitored by the physician responsible for HPN (first author) via regularly scheduled and structured telephone interviews (at least every 15 days) and by the nursing team and general practitioner via scheduled home visits (initially, daily for 2–3 weeks, and then at least every week). Home caregivers administered HPN only after adequate training. Telephone assistance was available for each patient, as well as for the caregivers and the healthcare providers. In 98.4% of patients, HPN was delivered using standard nutrition bags that were commercially manufactured and contained amino acids, electrolytes, glucose, and lipids; nutrition was delivered for 10–14 h/d (preferentially, overnight). According to guidelines,2 HPN was prescribed to provide 25–30 kcal/kg/d and an amino acid supply of 1–1.5 g/kg/d. Depending on the daily activity of the patient, the HPN regimen was individually adjusted to meet protein, energy, and fluid requirements. Every 30 days from HPN start (±5 days), an in-hospital re-evaluation by the HPN physician and by the dietitian, including a 24-hour food recall, was performed. HPN was withdrawn in cases of worsening clinical state (onset of severe organ dysfunction or uncontrolled symptoms, downgrading of performance status, estimated life expectancy of hours to days, or patient's request) and in cases of recovery of an adequate nutrition intake by the oral route.

Statistical Analysis

In a previous study,17 we found a nearly 40% reduction (16.9% vs 28.9%) in total complications in the PICC group compared with the tunneled-cuffed CICC group. Similarly, we found a 33% reduction (19.4% vs 28.9%) in total complications in the port group compared with the tunneled-cuffed CICC group. We expected a 4:1 and 2:1 PICC allocation ratio vs tunneled-cuffed CICCs and ports,

respectively. Assuming a 2-sided significance level of 0.05 and a power of 80% ($\alpha = 0.05$; $\beta = 0.2$), the minimal sample size was calculated as 423 VADs.

Qualitative variables were described in terms of frequency and percentage, whereas quantitative variables were reported as median (interquartile range). The rates of complications were expressed per 1000 catheter-days (incidence rate) and/or as a percentage of total VADs. Our unit coordinated the data collection and the computation of the incidence of CRCs. Complications rates were compared using Fisher exact or $\chi 2$ tests, adjusted for catheter-days. Incidence rate difference (IRD) and 95% CI referred to the incidence rate in the PICC group minus that in the tunneled or port groups. The duration of each VAD was calculated as the number of days between the date of VAD insertion and the date of VAD removal or patient death from any cause. The duration of each VAD was expressed as median (range) and was compared using the Kruskal-Wallis test, followed by the Dunn posttest. The level of significance was defined as a P-value < .05. All analyses were carried out using SPSS 17.0 (SPSS, Inc, an IBM Company, Chicago, IL).

Results

We enrolled 761 consecutive cancer outpatients receiving HPN. Table 1 shows the main characteristics of the patient population. During the study period, 475 patients (62%) received anticancer treatments, and 616 patients (81%) received HPN for >90% of the lifespan of the VAD. We evaluated 854 central VADs (401 PICCs, 137 nontunneled CICCs, 118 tunneled-cuffed CICCs, and 198 ports), for a total of 169,116 catheter-days (Table 2). No patient was lost at follow-up. Figure 1 depicts the trends in use from 2008 to 2015 for the types of VADs.

Table 2 shows the complications associated with the 4 types of VADs. The incidence of CRBSIs was low (0.29/1000 catheter-days for all VADs), particularly for PICCs (0.08/1000; P < .001 vs nontunneled and tunneled CICCs) and for ports (0.21/1000; P < .001 vs nontunneled and P < .019 vs tunneled CICCs). Because of CRBSIs, 8 patients required hospitalization and 1 of them died. The total days of hospitalization because of CRBSIs were 121, corresponding to 0.71 days/1000 catheter-days. Symptomatic CRT was rare (0.09/1000) and similar for PICCs, tunneled-cuffed CICCs, and ports. Mechanical complications were uncommon (0.58/1000 for all VADs), particularly for PICCs (0.45/1000) and ports (0.34/1000) (P < .001 vs nontunneled CICCs). Overall, the rate of total CRCs was 1.08/1000 (Table 3).

The overall median duration of the VAD was nearly 6 months; nontunneled CICCs had shorter dwell time than ports or PICCs (P < .001) and tunneled CICCs (P < .005) (Table 3). Overall, VADs were removed because of complications only in 11% of cases. Nontunneled CICCs had a higher incidence of CRCs and also had higher rate of removal due to complications, if compared with other VADs (P < .001). The removal rate due to complications was similar for PICCs, tunneled-cuffed CICCs, and ports (Table 3). Table 4 shows the incidence of complications of PICCs compared with tunneled-cuffed CICCs and ports. Altogether, PICCs had fewer CRBSIs and fewer total complications, if compared with tunneled-cuffed CICCs (P < .001); PICCs and ports had similar rates of complications (CRBSI, CRT, and mechanical and total complications).

Discussion

Because of the reported complication rates in earlier PICC experiences, some physicians are still concerned about the risks potentially associated with the use of PICCs in patients requiring PN.5 Indeed, since the 1990s, several studies have suggested that the use of PICCs is appropriate for PN because of their low rates of infections and CRT, with no significant difference in the rate of these complications when comparing PICCs and CICCs.21-23 Moureau et al, in a 2002 analysis of a database with 50,470 outpatients receiving home infusion for a total of 2.83 million catheter-days, reported that PICCs—51% of all VADs studied—had a lower incidence of CRBSIs than ports and tunneled-cuffed catheters (0.11 vs 0.16 and 0.34/1000 catheter-days, respectively).10 A systematic review of 200 prospective studies published between 1966 and 2005 by Maki et al showed that PICCs had a lower rate of CRBSIs (1/1000 catheter-days) than tunneled-cuffed CICCs (1.6/1000 catheter-days) in outpatients.11 In a meta-analysis of 23 studies on ≈57,000 patients with VADs, PICCs were less likely to be associated with central line–associated bloodstream infection (CLABSI) than other VADs.24 A recent meta-analysis of comparative studies showed that PICCs were associated with a significantly lower rate of CRBSIs in HPN patients, if compared with tunneled-cuffed catheters; however, analysis of single-arm studies showed that the rate of CRBSIs was comparable.25 Moreover, meta-analyses showed a lower or equivalent rate of CRT with PICC use.25, 26

In the last decade, many technological innovations have significantly increased the safety of PICCs (ultrasound-guided venipuncture, new biomaterials, sutureless devices for securement, and dedicated vascular teams), whereas new strategies have successfully minimized the risk of infection (standardized bundles of evidence-based interventions, strict policies of hand washing, education of healthcare operators, use of appropriate skin antisepsis, and use of antimicrobial lock therapy).4, 6, 27-31 Nowadays, the incidence rate of PICC-related complications has changed: CRBSIs, CRT, and mechanical complications are lower than those reported in the last 20 years. However, no randomized clinical trial (RCT) has ever compared PICCs with tunneled-cuffed CICCs or ports in HPN patients. In a community-based medical center (adopting a multimodality bundle for infection prevention), Harnage has reported for PICCs a CLABSI incidence of 0 episodes per 1000 catheter-days for 7 years.30 Almost half of patients in the National Patient Registry for Nutrition Care of the American Society for Parenteral and Enteral Nutrition (ASPEN) were using PICCs, reporting less CLABSIs than those with ports.32 The percentage use of PICCs is similar in the Canadian Registry of HPN patients, where PICCs increased from 21.6% (2005–2008) to 52.9% (2011–2014).33

In recent years, the clinical experience with PICCs increased also in Europe. Two prospective studies showed that PICCs were associated with a significantly reduced risk of CRBSIs and similar duration compared with tunneled-cuffed CICCs17 or ports34 in cancer patients receiving HPN. Tourè et al reported lower catheter infection rates for PICCs, if compared with silicone tunneled-cuffed CICCs (Broviac catheters) in a prospective study of French HPN patients.35 Bech et al36 and Christensen et al37 retrospectively analyzed the same data set of Danish HPN patients and found higher CLABSI rates for PICCs, if compared with tunneled-cuffed CICCs (Hickman catheters). However, PICCs were usually inserted when the patient was not able to care for the VAD or when affected by an acute condition. Conversely, 1 prospective study and a meta-analysis showed that patients using ports for HPN had a significant increase in CRBSIs compared with PICCs, whereas no difference between PICCs and tunneled-cuffed catheters was found.38, 39

Nowadays, whether the PICC is an appropriate VAD for long-term treatment is still a controversial issue. The ASPEN guidelines have stated that the maximum dwell time of PICCs is unknown and that they are suitable for medium-term PN.40 Since the PICC has its exit site on the upper arm, 1 hand may be considered as inoperative and—as a consequence self-management of the VAD—may present some difficulties that require the assistance of a caregiver.7 As a matter of fact, all cancer patients receiving HPN in our study had ≥1 caregiver. A systematic review of the risk factors for CRBSIs in patients receiving HPN has showed that a family caregiver or a nurse aid is not associated to an increase of infection risk, if compared with complete autonomy; on the contrary, self-management of the VAD is associated with an increased risk of CRBSIs compared with management by family caregiver or nurse.41 Kang et al reported that the limitation of the upper extremity activity was absent or minimal in 94% of cancer patients with PICCs.42 Molloy et al found that most cancer patients held favorable views toward having a PICC and could adapt well to PICCs with minimal changes of daily living activities, so they would recommend a PICC to other patients.43

One of the differences of HPN in patients with benign underlying disease vs cancer patients is the duration of HPN, which will be notably shorter (months vs years) in the latter. Therefore, the notion of "long-term HPN" in cancer patients may be slightly different and may include PICCs as a safe and effective VAD. Indeed, during the last 2 decades, PICCs have been increasingly used for cancer patients, both for chemotherapy and/or HPN.3, 29, 43-47 Neoplastic disease, HPN, and chemotherapy are recognized risk factors for the development of infection and venous thrombosis in patients with a central VAD.4, 13, 17, 31, 48 Nonetheless, the results of this study confirmed that, if accurately managed, HPN can be safely provided in cancer patients, even in an advanced stage, recording a low incidence of CRCs.

We think that several key elements played a pivotal role to reduce the occurrence of overall HPN-related complications in our study: (1) the choice of the proper VAD, resulting from a cooperative process among patient and caregivers, nurses, and physicians involved in the care of the patient; (2) the availability of a knowledgeable and experienced venous access team; (3) a proper training of patients and caregivers, along with close monitoring by trained nurses at home; and (4) a well-established experience and collaboration in HPN prescription, management, and follow-up of the nutrition support team.

Likewise, the expected duration of a PICC depends on several factors: the ratio between catheter diameter and vein diameter (1:3 ratio), the technique of insertion (use of ultrasound guidance), the consistent intraprocedural control of the position of the tip (cavoatrial junction), the choice of location of the exit site (middle third of the upper arm), the technique of securing the catheter to the skin (use of sutureless devices), the patient's compliance, and, most importantly, the competence of caregiver and nurse in the maintenance policies.

Limitations of the Study

First, this was a single-center study carried out by clinical units with a well-established experience both in HPN and PICC placement. Also, in our study, we enrolled exclusively cancer outpatients who are always assisted at home by a trained caregiver and nurses; therefore, our results may not be generalizable to other patient populations. Second, the choice of the type of VAD in each patient was

mainly based on the preference of the operator and/or of the patient; therefore, there was no randomization of patients to the different VAD groups, although no significant difference in terms of patients' characteristics potentially associated with an increased risk of CRCs was found. An RCT is needed before we can recommend PICCs as the preferred long-term VAD in cancer patients receiving HPN. Third, this study did not include a multivariate analysis investigating the most significant risk factors in each catheter complication. However, this type of analysis has already been carried out in our previous study.17 Finally, it is difficult to evaluate whether the complication rates seen in this study were more attributable to the nature of the VADs used or more so due to the wise and judicious choice of type of VAD for each patient.

Conclusions

To the best of our knowledge, this is the largest prospective clinical study (761 cancer outpatients, using 854 central VADs for HPN for a total of >169,000 catheter-days) comparing the rate of CRCs associated with the use of different VADs. In summary, our data suggest that (1) PICCs have lower rates of CRBSIs and total complications than tunneled-cuffed CICCs, whereas no significant IRDs of complications vs port were found; (2) PICCs have similar rates of symptomatic CRT, if compared with tunneled-cuffed CICCs and ports; (3) PICCs have similar dwell time, if compared with tunneled-cuffed CICCs and ports; and (4) PICCs have a removal rate due to complications similar to tunneled-cuffed CICCs and ports.

Previous meta-analyses, using data based on older practices, stated that PICCs have a higher risk of CRT and shorter dwell time than CICCs, leading VAD providers to limit their choice of catheters. On the contrary, our extensive, long-term study suggests that PICCs can be successfully used as safe and durable VADs for HPN in cancer patients, without expecting a clinically relevant incidence of complications or failures.

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Statement of Authorship

P. Cotogni and M. Pittiruti equally contributed to the conception and design of the research; A. De Francesco, B. Mussa, and C. Degiorgis contributed to the design of the research; P. Cotogni, B. Mussa, and C. Degiorgis contributed to the acquisition and analysis of the data; P. Cotogni, M. Pittiruti, and A. De Francesco contributed to the interpretation of the data; and P. Cotogni drafted the manuscript. All authors critically revised the manuscript, agree to be fully accountable for ensuring the integrity and accuracy of the work, and read and approved the final manuscript.

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Table 1. Characteristics of Study Population.

No. of patients	761
Female sex, no. (%)	380 (50)
Age, median (IQR), y	64 (57–70)
Age categories, no. (%)	
<70	555 (73)
≥70	206 (27)
Actual body weight, median (IQR), kg	57.3 (50.4–65)
BMI, median (IQR)	21 (18.7–23.4)
Weight loss,[a] median (IQR), (%)	13.8 (9.3–19.1)
Weight loss categories,[a] no. (%)	
≤10%	233 (30.6)
10.1%–15%	187 (24.6)
15.1%–20%	181 (23.8)
>20%	160 (21.0)
PG-SGA	
B[b]	242 (32)
C[c]	519 (68)
Tumor site, no. (%)	
Gastrointestinal	564 (74)
Ovary	47 (6)
Others	150 (20)
Stage, no. (%)	
II/III	220 (29)
IV	541 (71)
Karnofsky Performance Status, no. (%)	
50	102 (13)
60	222 (29)
70	387 (51)
80–90	50 (7)
Chemotherapy/radiation therapy, no. (%)	
No	286 (38)
Yes	475 (62)
HPN duration, median (IQR), d	203 (101–296)
Reason for ending HPN, no. (%)	
Clinical worsening	267 (35)
Death	298 (39)
Recovery of oral nutrition	196 (26)

BMI, body mass index; HPN, home parenteral nutrition; IQR, interquartile range; PG-SGA, Patient-Generated Subjective Global Assessment.
[a]In the last 3 months before HPN.
[b]Moderately malnourished or suspected malnutrition.
[c]Severely malnourished.

Table 2. Complications of Central Venous Access Devices (VADs).

	PICC	Nontunneled	Tunneled	Port	Total
VAD, no.	401 (47.0)	137 (16.0)	118 (13.8)	198 (23.2)	854 (100)
Catheter-days	82,516	25,023	22,840	38,737	169,116
Local infection, no.	6	3	5	7	21
No./1000 catheter-days	0.07	0.12	0.22	0.18	0.12
CRBSI, no.	7[a,b]	21	13	8[a,c]	49
No./1000 catheter-days	0.08	0.84	0.57	0.21	0.29
Venous thrombosis, no. (%)	7 (1.7)	4 (2.9)	2 (1.7)	2 (1.0)	15 (1.8)
No./1000 catheter-days	0.08	0.16	0.09	0.05	0.09
Mechanical complications					
Catheter dislocation, no. (%)	19 (4.7)	21 (15.3)	5 (4.2)	0	45 (5.3)
Rupture of external tract, no. (%)	4 (1.0)	3 (2.2)	6 (5.1)	NA	13 (1.5)
Lumen occlusion, no. (%)	14 (3.5)	9 (6.6)	4 (3.4)	13 (6.6)	40 (4.7)
Total	37[a] (9.2)	33 (24.1)	15[d] (12.7)	13[a] (6.6)	98 (11.5)
No./1000 catheter-days	0.45	1.32	0.66	0.34	0.58

CICC, centrally inserted central catheters; CRBSI, catheter-related bloodstream infection; NA, not applicable; PICC, peripherally inserted central catheter.
[a]$P < .001$ vs nontunneled CICC.
[b]$P < .001$ vs tunneled-cuffed CICC.
[c]P .019 vs tunneled-cuffed CICC.
[d]P .022 vs nontunneled CICC.

Table 3. Outcomes of Central Venous Access Devices (VADs).

	PICC	Nontunneled	Tunneled	Port	Total
VAD, no.	401 (47.0)	137 (16.0)	118 (13.8)	198 (23.2)	854 (100)
Complications, no. (%)					
Infectious	13 (3.2)	24 (17.5)	18 (15.3)	15 (7.6)	70 (8.2)
Noninfectious	44 (11.0)	37 (27.0)	17 (14.4)	15 (7.6)	113 (13.2)
Total	57[a] (14.2)	61 (44.5)	35[b] (29.7)	30[c,d] (15.2)	183 (21.4)
No./1000 catheter-days	0.69	2.44	1.53	0.77	1.08
Duration, median, d (Range)	194[c] (15–1154)	128(7–445)	169[c] (9–711)	186[c] (31–1706)	177(7–1706)
Causes of removal, no. (%)					
VAD complications	19 (5)	53 (39)	14 (12)	8 (4)	94 (11)
End of IV therapy	126 (31)	10 (7)	22 (19)	38 (19)	196 (23)
Death	256 (64)	74 (54)	82 (69)	152 (77)	564 (66)
Removal ratio[e], no. (%)	19/57[c] (33)	53/61(87)	14/35[c] (40)	8/30[c] (27)	94/183 (51)

CICC, centrally inserted central catheters; IV, intravenous; PICC, peripherally inserted central catheter.
[a] $P < .001$ vs nontunneled CICC and tunneled-cuffed CICC.
[b] P .027 vs nontunneled CICC.
[c] $P < .001$ vs nontunneled CICC.
[d] P .005 vs tunneled-cuffed CICC.
[e] Ratio between number of removals because of VAD complications and number of total complications.

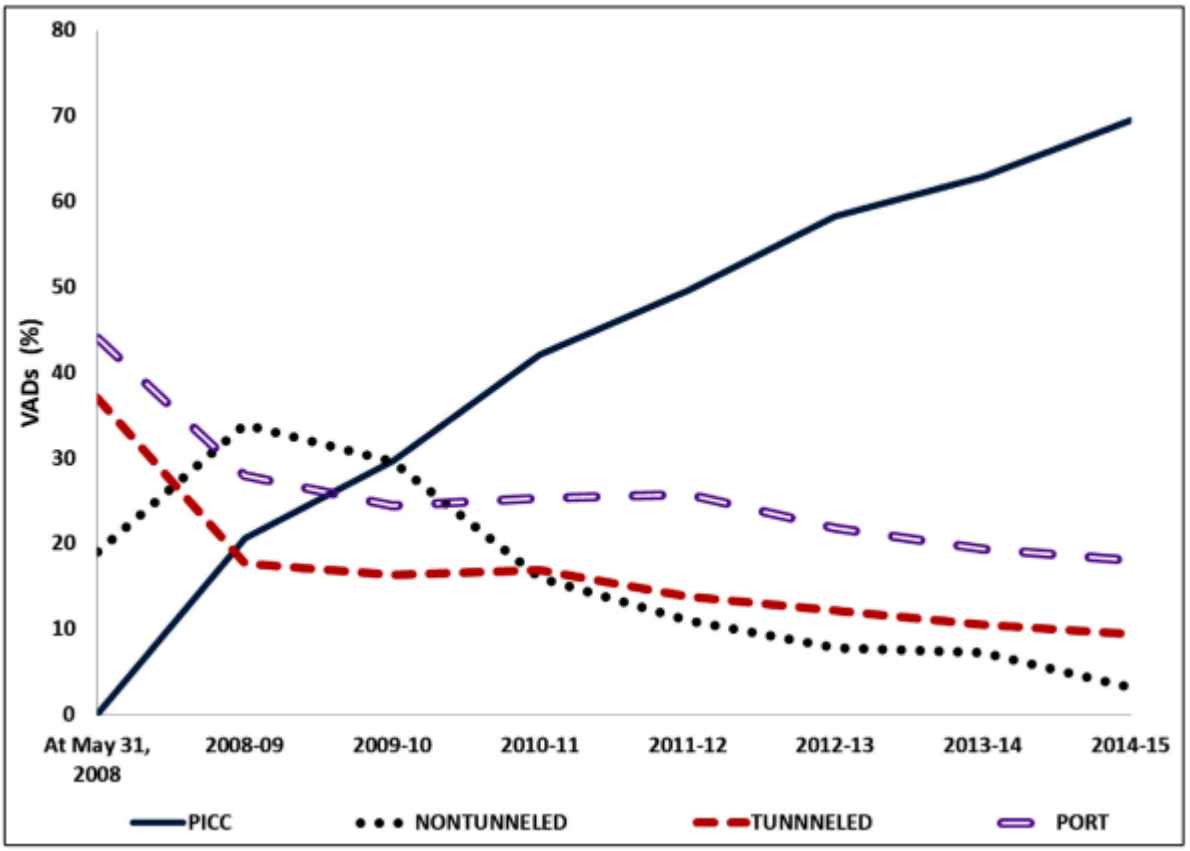

Figure 1. Venous access devices (VADs): trends in use from June 1, 2008, to May 31, 2015. The figure shows a dramatic increase in PICC (peripherally inserted central catheter) use

Table 4. Complications: PICC vs Tunneled-Cuffed CICC and PICC vs Port.

	PICC	95% CI	Tunneled	95% CI	IRD[a] (95% CI)	Port	95% CI	IRD[b] (95% CI)
VAD, no.	401		118			198		
Catheter-days	82,516		22,840			38,737		
Local infection	0.07	0.05–0.14	0.22	0.10–0.45	−0.15 (−0.30, 0.00)	0.18	0.09–0.34	−0.11(−0.23, 0.02)
CRBSI	0.08[c]	0.04-0.16	0.57	0.34–0.92	−0.48(−0.69, −0.28)	0.21	0.11–0.37	−0.12(−0.26, 0.01)
Venous thrombosis	0.08	0.04–0.16	0.09	0.03–0.24	0.00(−0.14, 0.15)	0.05	0.02–0.14	0.03 (−0.07, 0.14)
Mechanical complications	0.45	0.33-0.60	0.66	0.40–1.03	−0.21 (−0.53, 0.12)	0.34	0.20–0.54	0.11 (−0.13, 0.36)
Total complications[d]	0.69[c]	0.53-0.88	1.53	1.10–2.08	−0.84(−1.27, −0.41)	0.77	0.54–1.08	−0.08(−0.41, 0.24)

The rates of complications were expressed per 1000 catheter-days (incidence rate). IRD and 95% CIs were referred to the IR in the PICC group minus that in the tunneled-cuffed CICC or port groups.

CICC, centrally inserted central catheter; CRBSI, catheter-related bloodstream infection; IRD, incidence rate difference; PICC, peripherally inserted central catheter; VAD, venous access device.

[a] PICC vs tunneled-cuffed CICC.

[b] PICC vs Port.

[c] $P < .001$ vs tunneled-cuffed CICC.

[d] Infectious and noninfectious.