Supportive Care in Cancer (2022) 30:1673–1679
https://doi.org/10.1007/s00520-021-06339-x

ORIGINAL ARTICLE

A prospective study of the use of central venous catheters in patients newly diagnosed with acute myeloid leukemia treated with induction chemotherapy

Christi McKeown[1] · Asha Ricciuti[1] · Mounzer Agha[1] · Anastasios Raptis[1] · Jing-Zhou Hou[1] · Rafic Farah[1] · Robert L. Redner[1] · Annie Im[1] · Kathleen A. Dorritie[1] · Alison Sehgal[1] · James Rossetti[1] · Konstantinos Lontos[1] · Dana H. Bovbjerg[1] · Daniel Normolle[1] · Michael Boyiadzis[1]

Received: 7 April 2021 / Accepted: 2 June 2021 / Published online: 25 September 2021

Abstract

Purpose Central venous catheters (CVCs) are widely used in acute myeloid leukemia (AML) patients. Complications associated with CVCs are frequently encountered and contribute to morbidity and mortality. Prospective studies investigating and comparing complications of different types of CVCs in AML patients and their effects on the quality of life are limited.

Methods We conducted a prospective observational study and evaluated the complications associated with the use of CVCs in adult AML patients during induction chemotherapy and evaluated quality of life outcomes as reported by the patients during and after their hospitalization.

Results Fifty newly diagnosed patients with AML (median age, 59 years) who received intensive induction chemotherapy were enrolled in the study. Twenty-nine patients (58%) had a peripherally inserted central catheters (PICCs) placed and 21 (42%) patients received a Hickmann tunneled central catheter (TCC). Three percent of cases developed catheter-related thrombosis in PICCs and no thrombosis in TCCs. Catheter-related bloodstream infection was diagnosed in 8% of patients. CVC occlusion occurred in 44 patients (88%). The total number of occlusion events was 128; 97% of patients with PICCs and 76% of patients with TCCs ($p = 0.003$). All patients reported that the use of CVC simplified their course of treatment. Most patients reported similar restrictions in activity associated with TCCs and PICCs.

Conclusion The present study demonstrates that thrombosis and catheter-related bloodstream infections remain important complications of CVCs in AML patients. Occlusion rates were higher with the use of PICCs and the use of CVCs impacted the quality of life.

Keywords AML · Induction chemotherapy · Central venous catheters · Complications · Quality of life

Introduction

Access to the venous system for the administration of chemotherapy, blood products, and fluids, and for obtaining blood for laboratory testing is essential for the treatment of patients with acute myeloid leukemia (AML). For these purposes, two different types of central venous catheters (CVCs) for AML therapy are in common clinical use; tunneled central catheters (TCCs) and peripherally inserted central catheters (PICCs) [1].

Each type of access has its own risks, advantages, and disadvantages [2]. The risk of extravasation with the use of CVCs is markedly reduced, which is particularly relevant for the administration of vesicant or irritating chemotherapeutic agents. PICCs are placed into small caliber veins in the midarm or antecubital fossa, whereas TCCs are inserted into large central veins in the chest, which may result in more bleeding and hemothorax. One advantage of PICCs is that, in most cases, they can be easily and safely inserted and removed at the beside by the IV team, whereas TCC insertion and removal are commonly performed by a surgeon or interventional radiologist to reduce the risk of vascular injury. Both CVC types are associated with risks of line

✉ Michael Boyiadzis
boyiadzism@upmc.edu

[1] Division of Hematology-Oncology, University of Pittsburgh School of Medicine, UPMC Hillman Cancer Center, 5150 Center Ave, Suite 564, Pittsburgh, PA 15232, USA

occlusion, venous thrombosis, line migration, and central line-associated bloodstream infections (CLABSIs) [3–5].

Most CVCs in AML patients are placed in the hospital at the time of AML diagnosis for use during initial induction chemotherapy. They also typically continue to be used in the outpatient setting after patients are discharged following initial induction chemotherapy. During this period, patients typically return to the hospital for blood work and continued leukemia treatment.

Patients' experiences with CVCs, including impact on quality of life and daily activities in the hospital and at home following discharge, have received little research attention. Furthermore, studies investigating the complications among different catheter types in AML patients are also limited and most have been retrospective [6–13].

In the current study, we prospectively evaluated complications associated with the use of CVCs in adult AML patients during induction chemotherapy and evaluated quality of life outcomes as reported by the patients during and after their hospitalization.

Methods

Study design

We conducted a prospective observational study involving newly diagnosed AML patients who received intensive induction chemotherapy via CVCs. Inclusion criteria included age > 18 years, new diagnosis of AML according to the World Health Organization [14], and placement of a PICC or TCC. The type of CVC placed, PICC, or TCC, was based on the attendings' and patients' preferences. Patients with a diagnosis of acute promyelocytic leukemia were excluded from the study. Patients were followed up for 90 days after discharge from the hospital. The protocol was reviewed by the University of Pittsburgh Institutional Review Board and approved according to institutional guidelines. Written informed consent was obtained from all participants.

Central venous catheters

All CVCs were inserted according to institutional protocols by interventional radiologists or a specialized IV nursing team using maximal barrier precautions. Prior to the use of CVCs, placement was confirmed by chest radiograph. The National Healthcare Safety Network surveillance definition of CVS central line-associated bloodstream infection (CVS-CLABSI) was used [15]. Exit-site infection was defined as the presence of documented tenderness, erythema, or purulent drainage at the catheter exit site, without concomitant bloodstream infection. Evaluation for exit-site infection was performed daily. CVC occlusion was defined as the use of tissue plasminogen activator (tPA) to restore the patency of the catheter at least once during the course of the study period. Malposition was defined as CVC requiring readjustment or removal and re-insertion to reposition the CVC tip.

Quality of life

A quality of life questionnaire regarding patient-reported experience with CVCs was specifically developed for this study. These questionnaires were given to the patients in the hospital 2 weeks after the CVC was placed and again 90 days after discharge. Questions regarding discomfort, feelings of anxiety, and restrictions in patient activities were included. Patients chose their level of agreement to each question from five options: (1) not at all; (2) a little bit; (3) somewhat; (4) quite a bit; (5) very much. Figure 1 lists the questions included in the questionnaire.

Statistical analysis

Demographic, clinical, and laboratory characteristics and response to induction therapy were collected. Quantitative data were described using mean, median, and range. Categorical data were described by frequencies and percentages. Questionnaire results and differences in CVC complications during the follow-up period were compared by Wilcoxon rank sum tests. Exact (Clopper-Pearson) 95% confidence intervals were determined for estimates of proportions. Wald-type confidence intervals were calculated for estimates of means.

Results

Patient characteristics

A total of 50 consecutive patients newly diagnosed with AML who received intensive induction chemotherapy at our institution were enrolled in the study. Chemotherapy infusions were administered through the CVC in all patients. The median age was 59 years (range 23–72 years). Patient demographics, baseline characteristics, and chemotherapy administered are presented in Table 1. Complete remission (CR) was achieved in 40 patients (80%) after induction chemotherapy (Table 1). The median length of hospitalization during induction therapy was 32 days (range 23–110 days).

CVC in AML patients

Twenty-nine patients (58%) had a PICC inserted, of which 28 were placed by the IV team at the bedside and

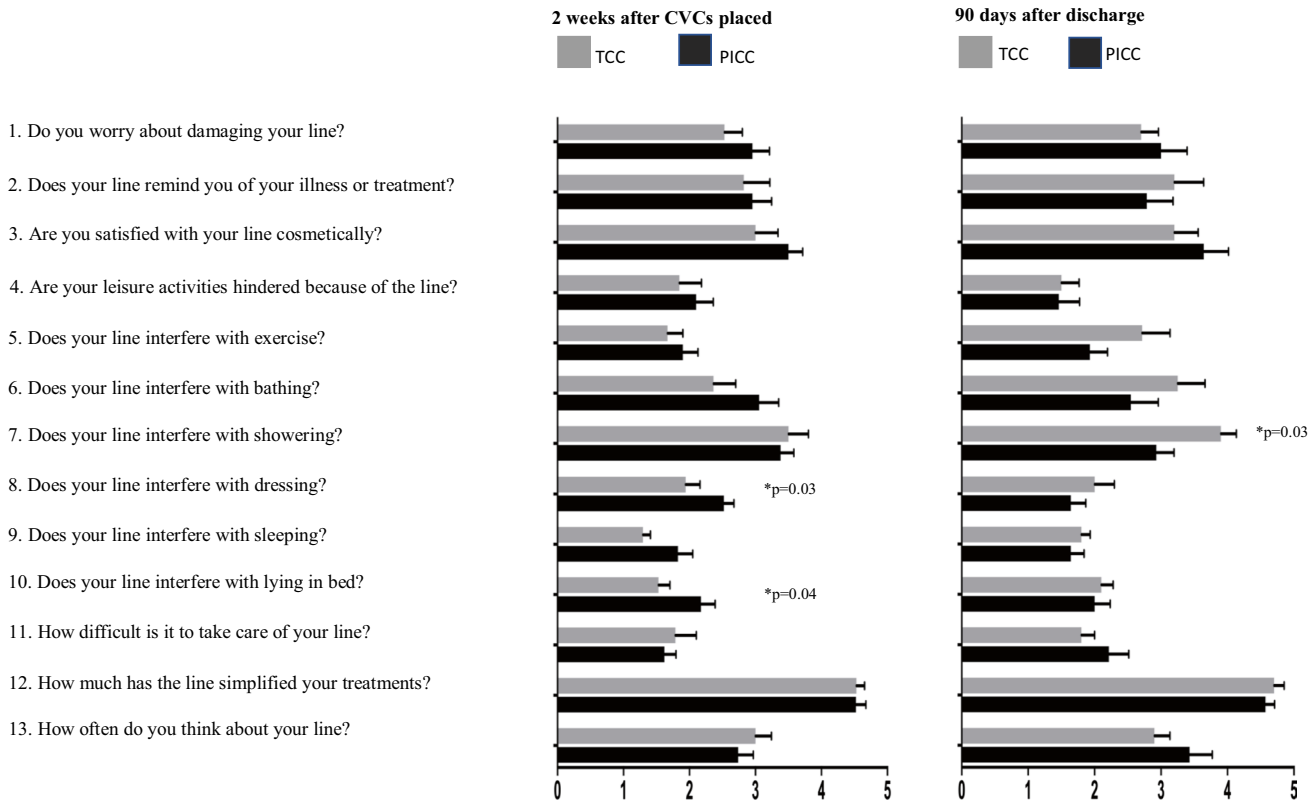

Fig. 1 Patient-reported experience and activity with CVCs. Mean scores of questionnaires given to the patients in the hospital 2 weeks after the CVC was placed and 90 days after discharge. Results were compared with Wilcoxon rank sum tests. *TCC,* tunneled central catheter; *PICC,* peripherally inserted central catheter

one by the interventional radiology team. Twenty of the PICCs were inserted into the left upper extremity (basilic vein, cephalic vein). Twenty-one (42%) patients received a Hickmann TCC, of which all were placed by the interventional radiology team. All TCCs were placed in the right internal jugular vein. The demographic characteristics, WBC counts, platelet counts, blast percentage, and coagulation parameters at AML diagnosis did not statistically differ between the two CVC groups (Table 1). Malposition occurred in two PICC insertion cases and exit site infection occurred in two TCC insertion cases (Table 2). One TCC was removed on day 9 after placement due to the exit site infection and two TCCs were removed due to malfunction 51 and 121 days after placement.

CVC occlusion

CVC occlusion occurred in 44 patients (88%); the total number of occlusion events was 128, median 3 (range 0–10). Twenty-eight patients (97%) with PICCs and 16 patients (76%) with TCCs developed CVC occlusion ($p = 0.003$). Tissue plasminogen activator (tPA) to lyse the occluded CVC was administered 95 times in PICCs and 33 times in TCCs.

CVC-related thrombosis

Catheter-related thrombosis developed in 3 patients (10%) after PICC placement 2 days, 18 days, and 59 days, respectively. All thrombosis events were confirmed by Doppler ultrasonography and were classified as superficial vein thrombophlebitis occurring in the ipsilateral site of insertions. No prophylactic anticoagulation was routinely administered in any of the enrolled patients. Platelet count at the time of thrombosis was 24,000/μL, 47,000/μL, and 52,000/μL in the 3 patients, respectively. No lines were removed due to the superficial vein thrombophlebitis since they remained functioning and no patients were managed with systemic anticoagulation. No pulmonary embolism was diagnosed in these 3 patients. No catheter-related thrombosis was associated with the TCC catheters.

Table 1 Patients' characteristics

Characteristic	PICC $n=29$	TCC $n=21$	All $n=50$
Age	55.4 years (50.2, 60.5)	54.6 years (49.5, 59.8)	55.1 years (51.5, 58.6)
Gender			
Male	15 [0.52 (0.33, 0.71)]	12 [0.57 (0.34, 0.76)]	27 [0.54 (0.39, 0.68)]
Female	14 [0.48 (0.29, 0.67)]	9 [0.43 (0.22, 0.66)]	23 [0.46 (0.32, 0.61)]
Cytogenetic Risk			
Unfavorable	6 [0.17 (0.06, 0.39)]	10 [0.33 (0.15, 0.60)]	16 [0.24 (0.12, 0.41)]
Intermediate	18 [0.62 (0.40, 0.80)]	4 [0.19 (0.06, 0.46)]	22 [0.44 (0.28, 0.61)]
Favorable	5 [0.21 (0.08, 0.43)]	7 [0.48 (0.06, 0.490)]	12 [0.32 (0.19, 0.49)]
WBC count $\times 10^9$/L	37.3 (15.7, 58.8)	29.2 (11.4, 47.0)	33.9 (19.7, 48.0)
% blasts in bone marrow	33.4 (19.9, 46.8)	32.7 (19.9, 45.5)	33.1 (23.9, 42.3)
Platelet count at the time of CVC insertion $\times 10^9$ /L	72.0 (54.4, 89.7)	92.6 (58.1, 127.1)	80.7 (63.4, 97.9)
Creatinine at the time of CVC insertion (mg/dL)	0.87 (0.73, 1.00)	0.79 (0.68, 0.88)	0.83 (0.74, 0.92)
INR at the time of CVC insertion	1.21 (1.14, 1.28)	1.29 (1.19, 1.39)	1.24 (1.19, 1.30)
PT at the time of CVC insertion	15.0 (14.3, 15.7)	15.6 (15.0, 16.1)	15.2 (14.8, 15.7)
Fibrinogen at the time of CVC insertion	372.9 (324.2, 421.6)	401.6 (318.8, 484.4)	384.9 (341.8, 421.6)
CR after induction			
1 course	14	13	27
2 courses	8	2	10
3 courses	1	2	3

PICC, peripherally inserted central catheter; *TCC*, tunneled central catheter; *Pts*, patients; *CR*, complete remission. Means are accompanied by 95% confidence intervals. Counts are printed with proportions and exact binomial or multinomial confidence intervals

Table 2 Complications associated with CVC in AML patients

	PICCs ($n=29$)	TCCs ($n=21$)	All ($n=50$)
Malposition	2 (7%)	0	2 (4%)
Exit site infection	0	2 (10%)	2 (4%)
Catheter occlusion	28 (97%)	16 (76%)	44 (88%)
Catheter-related thrombosis	3 (10%)	0	3 (6%)
Catheter-related bloodstream infection	2 (7%)	2 (10%)	4 (8%)

CVC-related bloodstream infection

Catheter-related bloodstream infections (CR-BSI) occurred in 4 (8%) patients; 2 patients who had a PICC and 2 patients who had a TCC. Pathogens related to the CR-BSI were Staphylococcus haemolyticus, Staphylococcus epidermidis, Staphylococcus aureus, and Streptococcus mitis. Lines were removed due to CR-BSI in 2 cases (50%) due to persistent bacteremia, and the other 2 cases had clearance of blood cultures with antibiotic therapy.

Patient-reported experience and activity with CVCs

All patients reported that the use of CVC simplified their course of treatment. Regardless of the type of CVCs, most patients reported restrictions in activity associated with them as shown in Fig. 1. Overall, there were few statistically significant differences in quality of life issues between the groups of patients with TCCs and PICCs (Fig. 1). The use of PICCs interfered more with dressing ($p=0.03$) and with lying in bed ($p=0.04$) compared with the use of TCCs reported 2 weeks after line placement. At 90 days after discharge, the use of TCCs interfered more with showering ($p=0.03$) compared with the use of PICCs (Fig. 1).

Patient-reported pain and discomfort with CVCs

Pain and discomfort scores (range 1–10) reported by patient groups with TCCs and PICCs did not differ. Forty percent of patients reported pain related with their PICC at 2 weeks and 36% of patients at 90 days after discharge. The mean pain score reported with PICCs at 2 weeks was 1.2 (range 1–7) and 1.4 (range 1–6) at 90 days. Thirty-one percent of patients reported pain related with their TCC at 2 weeks and

33% of patients at 90 days after discharge. The mean pain score reported with TCCs at 2 weeks was 0.8 (range 1–3) and 0.9 (range 1–4) at 90 days.

Fifty-two percent of patients reported discomfort related with their PICC at 2 weeks and 57% of patients at 90 days after discharge. The mean discomfort score reported with PICCs at 2 weeks was 1.7 (range 1–7) and 2 (range 1–6) at 90 days. Fifty percent of patients reported discomfort related with their TCC at 2 weeks and 75% of patients at 90 days after discharge. The mean discomfort score reported with TCCs at 2 weeks was 1.3 (range 1–5) and 1.7 (range 1–4) at 90 days.

Discussion

Placement of a CVC is clinically indicated in most AML patients who receive induction chemotherapy with curative intent. CVCs are used for the intravenous administration of antileukemic chemotherapy, parenteral nutrition, fluid therapy, blood products, medications, and blood sampling without repeated venipuncture. Despite these benefits, CVCs have considerable potential for serious complications. Early complications related to CVC placement include bleeding, cardiac arrhythmia, malposition, air embolism, pneumothorax, and, rarely, injury to vessels or nerves. Late complications include infection, thrombosis, and catheter malfunction [1] [4, 5]. The reported rate of CRBSI in patients with cancer is 1.5 per 1000 CVCs/days [16, 17]. Lower infection rates were seen in patients with implanted catheters versus tunneled catheters and PICCs. The rates of symptomatic CVC-related venous thrombosis have been reported in the range of 4–8% [18].

Various CVC types are currently available; however, there is insufficient evidence to routinely recommend a specific type of CVC [1, 18]. In addition, the decision about what type of CVC to place can depend on the patient's wishes, provider, type of therapy administered, and institutional policies. Studies investigating the differences in complications among the different catheter types in AML patients are limited, most are retrospective, and there is no consensus on the preferred catheter to use.

In the current study, 3% of cases showed catheter-related thrombosis in PICCs and no thrombosis with the use of TCCs. Catheter-related bloodstream infection was diagnosed in 8% of patients. Furthermore, we encountered high rates of catheter occlusion requiring tPA, with PICC use resulting in a higher rate compared to the use of TCCs ($p=0.003$).

Lim et al. conducted a retrospective study of complication rates for Hickman catheters ($n=64$) versus PICCs ($n=84$) in patients with AML undergoing induction chemotherapy, a cohort of patients similar to those in our study [9]. There were no significant differences in the rates of catheter-related thrombosis (3.2% for Hickman vs. 12.9% for PICCs, $p=0.55$) or catheter-related bloodstream infections (4.8% for Hickman vs. 1% for PICCs, $p=0.48$). In that study, PICCs were also associated with a significantly higher rate of catheter occlusion requiring alteplase compared to Hickman catheters (48.2% vs. 3.2%, $p=0.0001$).

Refaei et al. evaluated the incidence of catheter-related thrombosis in 663 patients with acute leukemia; 72% of patients had AML and received PICC or centrally inserted catheters [11]. The number of patients who developed catheter thrombosis with PICC use was higher. When the first catheter insertion was considered, the number of patients who developed thrombosis in PICC was 14.8% and 6.5% when centrally inserted. Khalil et al. evaluated 125 AML patients with PICCs, infusion port, or Hickmans. PICCs were associated with higher rates of thrombosis [8]. There was no significant difference in bloodstream infections across the different catheter types.

Picardi et al. conducted a randomized study of 93 AML patients treated with intensive chemotherapy who received a PICC ($n=46$) or centrally inserted central catheter (CICC, $n=47$) as a frontline intravascular device [19]. Catheter-related venous thrombosis occurred in 4 patients in the PICC group and 12 patients in the CICC group (8.7% vs. 25%; $p=0.03$). Using PICCs, the reduction in bloodstream infections and symptomatic venous thrombosis decreased mortality from catheter-related infection and venous thromboembolism. In contrast, the CICC approach led to early catheter removal, mostly for difficult-to-treat infectious pathogens. The authors believed that these results which differed from the prior retrospective reports could be related to the specific procedures followed by implantation teams, to the trauma intrinsically associated with subclavian catheter insertion creating a more prothrombotic environment, or to a higher incidence of colonized microorganisms in the cervical thoracic area compared to the upper arm.

Johansson et al. reported on 43 adult patients with acute leukemia who were randomized to receive a double-lumen totally implantable subcutaneous port systems (PORT, $n=19$) or a double-lumen central venous catheter (CVC, $n=24$) [20]. An extensive subcutaneous hematoma developed in 5 of 17 patients with a PORT compared with none of the 20 patients with a CVC ($p=0.01$). Following the fifth and last case of severe bleeding in the PORT group, recruitment of patients was stopped. Occlusion of the CVC was noted on 14 occasions in seven patients and of the PORT on three occasions in three patients. There were more positive blood cultures in patients with a CVC than in those with a PORT.

Another aim of the present study was to evaluate the daily impact on life in relation to the use of CVCs. A questionnaire to assess patient impact of the CVC on daily activity was administered 2 weeks after line insertion in

the hospital, and 90 days after discharge. The most positive aspect regarding the use of PICCs or TCCs was avoiding the need for repeated peripheral venipunctures. Overall, a large number of patients reported restriction in everyday activity for both types of line placed. In addition, pain and discomfort related to the line were reported in more than half of the patients. Johansson et al. evaluated the use of double-lumen central venous catheter and double-lumen totally implantable subcutaneous port system (PORT) in acute leukemia patients [21]. More patients in the central venous catheter group stated that they thought having a central venous access device interfered when dressing or taking a shower compared with the PORT group. Thus, in addition to medical complications associated with CVCs, the potential advantages and disadvantages of CVCs from the patient's perspective should also be considered in deciding which CVC should be placed.

A major strength of the present study is that all of the AML patients received induction chemotherapy, thus removing a potential substantial source of variability in outcomes. In addition, all data, including complications and outcomes, were prospectively collected. A limitation of the study was that the decisions for type of line placed, PICC or TCC, were based on the attending's and patients' preferences and were not randomized. PICCs and TCCs were placed by highly trained and experienced interventional radiologists or a specialized IV nursing team. Although the experiences and training of these providers may differ somewhat, which could conceivably have contributed to early complications, such differences reflect the reality of clinical practice in any hospital system. An innovative aspect of the current study was the inclusion of a questionnaire specifically exploring quality of life and line-related effects on the activity of the enrolled patients. The questions related to the use of the CVC need to be validated in a larger cohort but provide some insight on impacts to the quality of life and activity of AML patients.

In conclusion, the present prospective observational study demonstrated that thrombosis and catheter-related bloodstream infections remain important complications of CVCs. While the rate of thrombosis and catheter infection remained relatively low, the rate of occlusion requiring thrombolysis was significantly higher with the use of PICC lines. Importantly, our study assessed the impact of CVCs on the quality of life in AML patients and activities of daily living. Overall, the present study showed similar impacts on quality of life on all but a few measures between the groups of patients with TCCs and PICCs.

Author contribution CM, MB, and DB contributed to the study conception and design. Data collection was performed by CK, MB, and AR. All authors were involved in the provision of study materials and patients and data interpretation. All authors contributed to the writing and critical review of the manuscript.

Data availability Available to review if requested.

Code availability N/A

Declarations

Ethics approval The trial protocol was approved by the University of Pittsburgh Institutional Review Board and approved according to institutional guidelines. Written informed consent was obtained from all participants.

Consent to participate All participants provided written informed consent.

Consent for publication All authors consented to publish this paper.

Competing interests The authors declare no competing interests.

References

1. Sousa B, Furlanetto J, Hutka M, Gouveia P, Wuerstlein R, Mariz JM, Pinto D, Cardoso F, Committee EG (2015) Central venous access in oncology: ESMO Clinical Practice Guidelines. Ann Oncol 26(Suppl 5):v152-168
2. Bishop L, Dougherty L, Bodenham A, Mansi J, Crowe P, Kibbler C, Shannon M, Treleaven J (2007) Guidelines on the insertion and management of central venous access devices in adults. Int J Lab Hematol 29(4):261–278
3. Bell T, O'Grady NP (2017) Prevention of central line-associated bloodstream infections. Infect Dis Clin North Am 31(3):551–559
4. Chopra V, O'Horo JC, Rogers MA, Maki DG, Safdar N (2013) The risk of bloodstream infection associated with peripherally inserted central catheters compared with central venous catheters in adults: a systematic review and meta-analysis. Infect Control Hosp Epidemiol 34(9):908–918
5. Pu YL, Li ZS, Zhi XX, Shi YA, Meng AF, Cheng F, Ali A, Li C, Fang H, Wang C (2019) Complications and costs of peripherally inserted central venous catheters compared with implantable port catheters for cancer patients: a meta-analysis. Cancer Nurs 43(6):455–467
6. Chen MH, Hwang WL, Chang KH, Chiang LCJ, Teng CLJ (2017) Application of peripherally inserted central catheter in acute myeloid leukaemia patients undergoing induction chemotherapy. Eur J Cancer Care (Engl) 26(6):e12627
7. Cortelezzia A, Fracchiolla NS, Maisonneuve P, Moia M, Luchesini C, Ranzi ML, Monni P, Pasquini MC, Lambertenghi-Deliliers G (2003) Central venous catheter-related complications in patients with hematological malignancies: a retrospective analysis of risk factors and prophylactic measures. Leuk Lymphoma 44(9):1495–1501
8. Khalil MO, Pierson N, Maymani H, Holter J, Cherry M (2014) Central venous catheter-related complications in acute myeloid leukemia patients. J Vasc Access 15(6):543
9. Lim MY, Al-Kali A, Ashrani AA, Begna KH, Elliott MA, Hogan WJ, Hook CC, Kaufmann SH, Letendre L, Litzow MR, Patnaik MS, Pardanani A, Tefferi A, Wolanskyj AP, Grill DE, Pruthi RK (2013) Comparison of complication rates of Hickman((R)) catheters versus peripherally inserted central catheters in patients

with acute myeloid leukemia undergoing induction chemotherapy. Leuk Lymphoma 54(6):1263–1267
10. Loh AH, Chui CH (2007) Port-A-Cath insertions in acute leukemia: does thrombocytopenia affect morbidity? J Pediatr Surg 42(7):1180–1184
11. Refaei M, Fernandes B, Brandwein J, Goodyear MD, Pokhrel A, Wu C (2016) Incidence of catheter-related thrombosis in acute leukemia patients: a comparative, retrospective study of the safety of peripherally inserted vs. centrally inserted central venous catheters. Ann Hematol 95(12):2057–2064
12. Skaff ER, Doucette S, McDiarmid S, Huebsch L, Sabloff M (2012) Vascular access devices in leukemia: a retrospective review amongst patients treated at the Ottawa Hospital with induction chemotherapy for acute leukemia. Leuk Lymphoma 53(6):1090–1095
13. Strahilevitz J, Lossos IS, Verstandig A, Sasson T, Kori Y, Gillis S (2001) Vascular access via peripherally inserted central venous catheters (PICCs): experience in 40 patients with acute myeloid leukemia at a single institute. Leuk Lymphoma 40(3–4):365–437
14. Arber DA, Orazi A, Hasserjian R, Thiele J, Borowitz MJ, Le Beau MM, Bloomfield CD, Cazzola M, Vardiman JW (2016) The 2016 revision to the World Health Organization classification of myeloid neoplasms and acute leukemia. Blood 127(20):2391–2405
15. O'Grady NP, Alexander M, Burns LA, Dellinger EP, Garland J, Heard SO, Lipsett PA, Masur H, Mermel LA, Pearson ML, Raad II, Randolph AG, Rupp ME, Saint S, Advisory HICP, C, (2011) Guidelines for the prevention of intravascular catheter-related infections. Clin Infect Dis 52(9):e162-193
16. Centers for Disease C, Prevention, (2011) Vital signs: central line-associated blood stream infections–United States, 2001, 2008, and 2009. MMWR Morb Mortal Wkly Rep 60(8):243–248
17. Raad I, Chaftari AM (2014) Advances in prevention and management of central line-associated bloodstream infections in patients with cancer. Clin Infect Dis 59(Suppl 5):S340-343. https://doi.org/10.1093/cid/ciu670
18. Schiffer CA, Mangu PB, Wade JC, Camp-Sorrell D, Cope DG, El-Rayes BF, Gorman M, Ligibel J, Mansfield P, Levine M (2013) Central venous catheter care for the patient with cancer: American Society of Clinical Oncology clinical practice guideline. J Clin Oncol 31(10):1357–1370
19. Picardi M, Della Pepa R, Cerchione C, Pugliese N, Mortaruolo C, Trastulli F, Giordano C, Grimaldi F, Zacheo I, Raimondo M, Chiurazzi F, Pane F (2019) A frontline approach with peripherally inserted versus centrally inserted central venous catheters for remission induction chemotherapy phase of acute myeloid leukemia: a randomized comparison. Clin Lymphoma Myeloma Leuk 19(4):e184–e194. https://doi.org/10.1016/j.clml.2018.12.008
20. Johansson E, Bjorkholm M, Bjorvell H, Hast R, Takolander R, Olofsson P, Backman L, Weitzberg E, Engervall P (2004) Totally implantable subcutaneous port system versus central venous catheter placed before induction chemotherapy in patients with acute leukaemia-a randomized study. Support Care Cancer 12(2):99–105
21. Johansson E, Engervall P, Bjorvell H, Hast R, Bjorkholm M (2009) Patients' perceptions of having a central venous catheter or a totally implantable subcutaneous port system-results from a randomised study in acute leukaemia. Support Care Cancer 17(2):137–143