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ORIGINAL ARTICLE

Central venous catheter-associated bloodstream infections in pediatric hematology–oncology patients and effectiveness of antimicrobial lock therapy

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KEYWORDS
antimicrobial lock therapy;
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Background: Central line-associated bloodstream infection (CLABSI) is a serious complication in hematology–oncology patients. This study aimed to analyze the prevalence of CLABSI and the effectiveness of antimicrobial lock therapy (ALT) in pediatric patients.
Methods: BSIs of all pediatric hematology–oncology patients admitted to a children's hospital between January 2009 and December 2013 were reviewed. The United States National Healthcare Safety Network and Infectious Diseases Society of America guidelines were used to define CLABSI and catheter-related BSI (CRBSI). The incidence, laboratory and microbiology characteristics, poor outcome, and effectiveness of ALT were analyzed.
Results: There were 246 cases of CLABSI in 146 patients (mean age, 10.0 years), including 66 (26.8%) cases of CRBSI. The incidence of CLABSI was 4.49/1000 catheter-days, and the

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infection was responsible for 32.9% of the complications these patients developed and 9.3% of contributable mortality. Patients with acute myeloid leukemia had the highest infection density (5.36/1000 patient-days). Enterobacteriaceae (40.2%) and coagulase-negative staphylococci (CoNS; 20.7%) were the predominant pathogens. In multivariate analysis, older age, male sex, elevated C-reactive protein, acute lymphoblastic leukemia, and candidemia were associated with poor outcome. The success rate of ALT was 58.6% (17/29) for the treatment of CoNS and 78.3% (29/37) for Enterobacteriaceae infections. Patients with candidemia ($n = 18$) had the highest mortality (33.4%) and catheter removal rate (66.7%). Chlorhexidine as the disinfectant decreased the 1-year CLABSI rate from 13.7/1000 to 8.4/1000 catheter-days ($p = 0.02$).

Conclusion: CoNS and Enterobacteriaceae are the predominant pathogens in CLABSI among pediatric hematology—oncology patients. ALT is effective and showed no significant side effect. New disinfection practice and infection control measures can decrease CLABSI.

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Introduction

In pediatric hematology—oncology patients, the central venous catheter, especially totally implantable venous access ports (Port-A), is important for the administration of antineoplastic chemotherapy, blood component therapy, and parenteral nutrition. It is also useful for blood sampling. The most common and serious complication is central line-associated bloodstream infection (CLABSI) or catheter-related BSI (CRBSI). The most commonly involved organisms are coagulase-negative staphylococci (CoNS), *Staphylococcus aureus*, *Enterococcus* spp., *Escherichia coli*, *Klebsiella* spp., other enteric Gram-negative bacteria, and *Candida* spp.,[1] with infection rates varying widely in different patient groups.

In adults, 5.6—8.0% of patients with Port-A catheter experience a related infection, with the incidence rate ranging from 0.15 to 0.39/1000 catheter-days.[1—4] However, there is a lack of similar data in the pediatric group. An estimated 0.2 episodes/1000 catheter-days in children with sickle cell disease and 11 episodes/1000 catheter-days in infants with intestinal insufficiency have been reported.[5,6]

The diagnosis of CRBSI is based on the culture of the removed catheter tips or on quantitative blood cultures drawn from the catheter and from peripheral veins. The incidence of CRBSI is difficult to evaluate because of the need to obtain blood samples in pairs in the pediatric group. Antimicrobial lock therapy (ALT), also called anti-infective lock therapy or antibiotic lock therapy involves instilling an antibiotic or antiseptic into the catheter lumen to permit high concentration at the site of infection, is a novel way of treating CLABSI while attempting to salvage the catheter.[1,7] Performing ALT early to save the catheter or avoid unnecessary systemic treatment is valuable, especially in the pediatric group. The Infectious Diseases Society of America treatment guidelines for CRBSI recommend the routine use of adjunctive ALT for adults and children.[8] This retrospective study analyzed the incidence, laboratory and microbiology characteristics, risk factors, and outcomes in CLABSI/CRBSI episodes, and the effectiveness of ALT in pediatric hematology—oncology patients.

Methods

Patients and setting

This study was conducted in a university-teaching pediatric hospital in Taipei, Taiwan, with 292 beds. Pediatric hematology—oncology in-patients, aged 0—18 years, with central venous catheter who had a BSI from January 2009 to December 2013 in the oncology department were enrolled. Patients with BSI with other identified infectious foci were excluded. The data retrieved from the medical records included sex, age at the infection day, hematological—oncological diseases, date of central venous catheter implantation and removal, white blood cell count, neutropenia (absolute neutrophil count $< 500/mm^3$), level of C-reactive protein (CRP), microbiology results of all clinical specimens, use of systemic antimicrobial therapy, and the duration and regimen of ALT for documented infections.

Disinfection methods

For central line entry-site care, topical skin disinfection with povidone—iodine swabs and dry gauze dressing were used weekly or whenever the dressing is soiled or loose. Since June 2012, 2% chlorhexidine (in 70% alcohol) was used as the disinfectant as recommended by the U.S. Centers for Disease Control and Prevention guideline.[9]

Patient management and follow up

In the hematology—oncology departments, the primary physicians were encouraged to obtain blood samples (at least 1 mL) for culture from the central line catheter and peripheral veins in pairs when the patients had clinical symptoms or signs of infection, fever $> 38.3^{\circ}C$, or unstable vital signs (e.g., hypotension, tachypnea, tachycardia/bradycardia, or consciousness change). Samples from other potential infection foci were also cultured to determine the origin of infection. Empirical antibiotics were administered after obtaining blood cultures and their doses were adjusted based on the culture results. When CRBSI or a

central venous catheter infection was documented, ALT was initiated under the supervision of an infectious diseases specialist. Patients with uncertain episodes of CRBSI (i.e., no confirmed diagnosis of CRBSI was made) or central venous catheter infection who received ALT were excluded from the analysis.

The ALT technique involved instilling a concentrated antibiotic solution (5—10 mL) diluted with sterile normal saline and heparin (50 U) into the catheter lumen for at least 12 hours daily for 10—14 days. The antibiotic solution was withdrawn before the administration of other intravenous therapies. The most frequently used antibiotics for ALT are listed in Table 1.[8,10—13] Serial follow-up blood culture was obtained 24, 48, 72, and 120 hours, and 2 days after ALT from both peripheral veins and central catheters. If the catheter was removed, its tip was sent for culture. The primary physician determined whether to remove the central catheter based on clinical severity, the identified pathogen, and responses to antibiotic treatment. Data from the personal medical record and hospital infection control center were reviewed. Data on catheter-day were electronically recorded and available since 2011.

Definitions

CLABSI[14] was defined as one of the following in a patient with central line catheter: (1) at least one set of positive blood culture of recognized pathogens, including Enterobacteriaceae or other Gram-negative bacilli, *S. aureus*, and fungi, without other identifiable infectious foci; or (2) at least two sets of positive blood cultures of bacteria that were potential skin contaminants, including CoNS, *Viridans streptococci*, *Propionibacterium* spp., *Bacillus* spp., or micrococci, together with clinical signs (i.e., fever $>$ 38°C, chills, or hypotension). Repeated positive blood cultures with the same pathogen were considered a single episode of CLABSI if the two sets of blood cultures were obtained within 1 week (for bacterial pathogens) or within 2 weeks (for fungal pathogens).

Patients with CRBSI[8] were defined as those with clinical signs of infection and the same microorganism grown from at least one percutaneous blood culture and from a culture of the catheter tip (>15 colony-forming units), or a growth of microbes from blood sample drawn from a catheter hub at least 2 hours before microbial growth was detected in a blood sample obtained from a peripheral vein. If the culture was positive only from the central venous catheter sample, it was defined as *central catheter infection*.

Table 1 Frequently used antimicrobials and their concentrations used in antimicrobial lock therapy in pediatric hematology—oncology patients

Vancomycin: 5 mg/mL	Teicoplanin: 10 mg/mL
Amikacin: 2 mg/mL	Gentamicin: 10 mg/mL
Minocycline: 1 mg/mL	Erythromycin: 5 mg/mL
Ciprofloxacin: 1 mg/mL	Amphotericin B: 2.5 mg/mL
Ampicillin: 2 mg/mL	
Cefazolin: 5 mg/mL	
Ceftazidime: 5 mg/mL	

The data presented are modified from references 8,10—13.

Table 2 Clinical characteristics of patients with central line-associated bloodstream infection

Characteristic	Values
Age, *y*, median (IQR)	10 (4.8—14)
Male, *n* (%)	151 (M:F = 1.58:1)
WBC cells/mm^3, median (IQR)	360 (100—2210)
CRP level, mg/L, median (IQR)	3.50 (1.04—7.97)
Neutropenia, *n* (%)	184 (74.8%)
Paired blood culture, *n* (%)	219 (89%)
Polymicrobial infection, *n* (%)	28 (11.3%)
CRBSI	66 (26.8%)
Catheter type	
Port-A	214
Temporary nontunneled CVC	30
Hickman	2
Duration from catheter insertion day to DOI[a], median (IQR)	134 (25—310.3)
Poor outcome, *n* (%)	81 (32.9)
Contributable mortality, *n* (%)	23 (9.3)
Catheter removal, *n* (%)	66 (26.8)
Successful ALT in CRBSI/catheter infection	58/81 (71.6)

[a] DOI is defined as the 1st day of clinical suspicion of infection (i.e., day of infection).
N = 246 episodes.
ALT = antimicrobial lock therapy; CRBSI = catheter-related bloodstream infection; CRP = C-reactive protein; CVC = central venous catheter; IQR = interquartile range; WBC = white blood cell.

The infection density was estimated as number of episodes/1000 patient-days and number of episodes/1000 catheter-days. The CLABSI and CRBSI density data were available in the health information system of the hospital from 2009 to 2013 and from 2011 to 2013, respectively.

The success of ALT was defined as "no positive culture" of the same pathogen after 72 hours of therapy. Relapse was defined as the culture of the same pathogen in blood

Table 3 Underlying diagnosis in pediatric hematology—oncology patients with central line-associated bloodstream infection

Underlying diagnosis	Number/ percentage	Infection density[a](0/00)
Acute lymphoblastic leukemia	90 (36.6)	3.63
Acute myeloid leukemia	66 (26.8)	5.36
Neuroblastoma	23 (9.3)	2.31
Lymphoma	10 (4.0)	1.05
Germ cell tumor	8 (3.3)	1.76
Rhabdomyosarcoma	6 (2.4)	1.64
Osteosarcoma	6 (2.4)	1.12
Severe aplastic anemia	9 (3.6)	2.67
Langerhan histiocytosis	4 (1.6)	3.61
Medulloblastoma	7 (2.8)	3.97
Other malignancies	17 (6.7)	NA

[a] Infection density: episodes/1000 patient-day of specified diagnosis.

Table 4 Factors significantly associated with poor outcome in pediatric hematology—oncology patients with central line-associated bloodstream infection

	Unadjusted OR (95% CI)	*p*	Adjusted OR (95% CI)	*p*
Older age	4.24 (2.40—7.51)	<0.001	1.10 (1.04—1.16)	0.001
Male sex	2.13 (1.19—3.79)	0.010	2.11 (1.06—4.22)	0.034
Neutropenia	3.49 (1.62—7.53)	0.001	2.18 (0.88—5.39)	0.091
Elevated CRP	1.07 (1.04—1.11)	<0.001	1.06 (1.02—1.11)	0.001
ALL	2.18 (1.26—3.77)	0.005	2.51 (1.30—4.86)	0.006
Candidemia	12.27 (3.44—43.80)	<0.001	7.75 (2.02—29.78)	0.002

ALL = acute lymphoblastic leukemia; CI = confidence interval; CRP = C-reactive protein; OR = odds ratio.

sample within 3 months. Patients with poor outcome were those with shock, sepsis[15] [defined as suspected or proven infectious etiology with systemic inflammatory response syndrome, involving 2 of the following 4 items: fever or hypothermia (>38.5 or <36°C), tachycardia, tachypnea, and elevated leukocyte count or depressed for age or >10% immature neutrophils], hematogenous complications (i.e., infective endocarditis, septic arthritis, or vertebral osteomyelitis), septic thrombophlebitis, respiratory failure, and intensive care unit transfer. Attributable mortality was confirmed from the death certificate, which was applied by the clinician following the death of the patient.

Statistical analysis

Descriptive statistics included frequencies and percentages for categorical variables, and medians and interquartile ranges (IQRs) for continuous variables. Potential risk factors associated with poor outcome were analyzed by univariate analysis. Multivariate analysis was conducted using a stepwise logistic regression model to identify the set of independent risk factors. Statistical significance was set at $p < 0.05$. Statistical analysis was performed using the SPSS software package version 20.0 (SPSS Inc., Chicago, IL, USA).

Results

Patient characteristics

There were 279 BSI episodes in 157 pediatric hematology—oncology patients between January 2009 and December 2013. Among these, 246 (88.18%) CLABSI episodes were documented and 66 (26.8%) were classified as CRBSI. Other excluded episodes were secondary to urinary tract infection ($n = 6$), soft-tissue infection ($n = 7$), intra-abdominal infection ($n = 3$), pneumonia ($n = 5$), mastoiditis ($n = 1$), and bacteremia or fungemia without central venous catheter and other obvious foci ($n = 11$). The characteristics of CLABSI episodes are summarized in Table 2. The median patient age was 10.0 years (IQR, 4.8—14 years) and the male-to-female ratio was 1.6:1.

There were 214 Port-A-related episodes, two Hickman-related episodes, and 30 temporary nontunneled central venous catheter-related episodes. Paired blood cultures were obtained from both peripheral veins and central venous catheter in 89% (219/246) of CLABSI episodes. The median CRP was 3.50 mg/dL (IQR, 1.04—7.97). Neutropenia occurred in 184 (74.8%) episodes. Polymicrobial pathogen accounted for 11.3% (28/246) of these episodes. Acute leukemia (63.4%, 156/246) was the leading underlying disease, followed by neuroblastoma (9.3%, 23/246) and lymphoma (4.0%, 10/246). Patients with acute myeloid leukemia (AML) had the highest infection density (5.36 episodes/1000 patient-days; Table 3). In multivariate analysis, older age, male sex, acute lymphoblastic leukemia (ALL), elevated CRP, and candidemia were associated with poor outcome (Table 4). Meanwhile, white blood cell count, diagnosis other than ALL, and receiving bone marrow transplant and ALT were not associated with poor outcome.

The median duration from catheter insertion to the day of infection (DOI) was 134 days (IQR, 25—310.3 days; $n = 232$, missing data 14). Of the CLABSI episodes, 29% occurred within 30 days after the catheter implantation (Figure 1).

Microbiological data and clinical management

The microbiological data are summarized in Table 5. The predominant pathogens were Enterobacteriaceae (40.2%) and CoNS (20.7%). Most infections were monomicrobial (88.6%). Methicillin resistance was noted in 94.1% (48/51) of CoNS cases and in 20% (2/10) of *S. aureus* cases.

The average period from the DOI to initiating ALT is 1.96 days. The success rate of ALT as a catheter salvage management was 58.6% (17/29) in cases with CoNS infections, 78.0% (29/37) in Enterobacteriaceae, and 66.7% (2/3) in *S. aureus*, and none in *Candida* spp. The percentage of central catheter removal was highest in *Candida* cases (66.7%; 12/

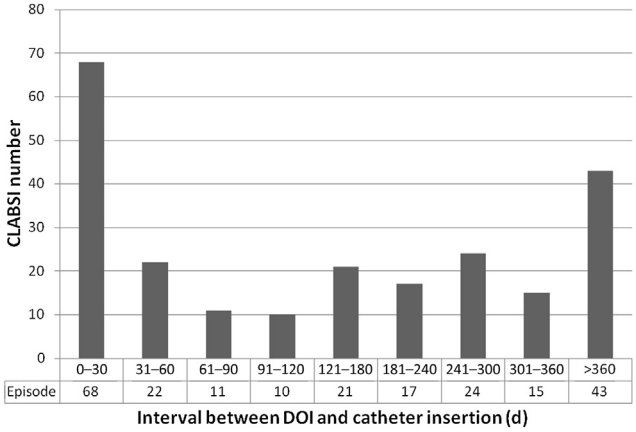

Figure 1. Distribution of central line-associated bloodstream infection (CLABSI) according to interval between date of infection (DOI) and catheter insertion.

Table 5 Analysis of microbiological data in the 246 central line-associated bloodstream infection episodes in pediatric hematology—oncology patients

	Number (%)	Removal catheter (%)	Contributory mortality (%)	CRBSI (ALT number)	Catheter infection (ALT number)	Number of successful ALT (%)	Relapse rate in 3 mo (%)
Coagulase-negative staphylococci, *n* (%)	51 (20.7)	25 (49.0)	4 (7.8)	30 (16)	17 (13)	17 (58.6)	3 (17.6)
Viridans streptococci, *n* (%)	18 (7.3)	1 (5.6)	0 (0)	3 (3)	0 (0)	2 (66.7)	0 (0)
Staphylococcus aureus, *n* (%)	10 (4.1)	5 (50)	1 (10)	3 (3)	3 (0)	2 (66.7)	0 (0)
Enterococcus spp., *n* (%)	15 (6.1)	3 (20)	2 (13.3)	1 (0)	5 (3)	1 (33.3)	1 (100)
Bacillus spp., *n* (%)	3 (1.2)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Other GPC, *n* (%)	5 (2.0)	1 (20)	2	0 (0)	0 (0)	0 (0)	0 (0)
Enterobacteriaceae, *n* (%)	99 (40.2)	13 (13.1%)	7 (7)	20 (17)	21 (20)	29 (78.0)	2 (6.9)
Escherichia coli	47	6	3	10 (7)	10 (8)	13	1
Klebsiella spp.	41	8	4	8 (7)	9 (7)	11	1
Proteus mirabilis	1	0	1	0 (0)	0 (0)	0 (0)	0 (0)
Enterobacter cloacae	7	1	1	3 (3)	0 (0)	2	0 (0)
Serratia	3	1	0 (0)	0 (0)	2 (2)	1	0 (0)
Morganella morganii	1	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Citrobacter freundii	1	0 (0)	0 (0)	0 (0)	1 (1)	1	0 (0)
Salmonella spp.	6	0 (0)	0 (0)	2 (2)	0 (0)	2	0 (0)
Pseudomonas aeruginosa	10	1	2	0 (0)	0 (0)	0 (0)	0 (0)
Stenotrophomonas maltophilia	5	1	2	1 (1)	1 (1)	1	0 (0)
Burkholderia cepacia	1	1	0 (0)	1 (1)	0 (0)	1	0 (0)
Sphigomonas spp.	2	2	0 (0)	1 (1)	0 (0)	0 (0)	0 (0)
Acinetobacter spp.[a]	11 (4.5)	3 (27.3)	0 (0)	6 (5)	3 (1)	6 (100)	0 (0)
Other GNB	9 (3.7)	1 (11.1)	0 (0)	0 (0)	3 (3)	2 (66.7)	0 (0)
Candida spp., *n* (%)	18 (7.3)	12 (66.7)	6 (33.4)	5 (2)	4 (0)	0 (0)	0 (0)
C. albicans	3	1	2	5	0 (0)	0 (0)	0 (0)
C. tropicalis	12	9	3	0 (0)	4 (2)	0 (0)	0 (0)
C. parapsilosis	2	1	0	0 (0)	0	0 (0)	0 (0)
C. krusei	1	1	1	0 (0)	0	0 (0)	0 (0)
Other fungi	2 (0.8)	1 (50)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

[a] *Acinetobacter baumannii* and *Acinetobacter lwoffii*.
ALT = antimicrobial lock therapy; CRBSI = catheter-related bloodstream infection.
Other GNB: *Aeromona* spp. ($n = 3$), *Moraxella* spp. ($n = 1$), *Haemophilus parainfluenzae* ($n = 1$), *Alcaligenes faecalis* ($n = 1$), *Rhizobium radiobacter* ($n = 1$), *Achromobacter xylosoxidans* ($n = 1$), and *Capnocytophaga* species ($n = 1$).
Other fungi: *Fusarium* species ($n = 1$) and *Trichosporon asahii* ($n = 1$).
Other GPC: *Rothia mucilaginosa* ($n = 1$), *Gordonia* spp. ($n = 1$), *Granulicatella adiacens* ($n = 1$), *Corynebacterium jeikeium* ($n = 1$), and *Leuconostoc species* ($n = 1$).

18), followed by *S. aureus* (50%; 5/10) and CoNS (49%; 25/51). The mortality rates were higher among cases with *Candida* infections (33.4%), but modest in cases with CoNS and Enterobacteriaceae infections (7.8% and 7.0%, respectively).

The overall incidence of CLABSI and CRBSI was 4.49 and 1.08/1000 catheter-day, respectively. In terms of the annual distribution of various pathogens in CLABSI (Figure 2), the percentage of CoNS peaked in 2010 (Figure 3), resulting from an outbreak in mid-2010 to early 2011. As a result of timely infection control intervention and the use of chlorhexidine as a disinfectant since June 2012, the incidence of CLABSI decreased gradually, especially in the CoNS group (Figures 3 and 4). The 1-year CLABSI rates decreased significantly after chlorhexidine use (from 13.7/1000 to 8.4/1000 catheter-days; $p = 0.02$).

Discussion

In this study, the CLABSI mortality and catheter removal rates were 9.3% and 26.8%, respectively, in pediatric hematology—oncology patients in Taiwan, which are similar to an earlier report from Turkey.[16] Patients with AML have the highest infection density (5.36 episodes/1000 patient-days). Rinke et al reported that a diagnosis of AML is significantly associated with ambulatory CLABSI in the pediatric oncology group.[17] More intensive chemotherapy regimen and prolonged periods of neutropenia accompanying AML may be the underlying causes.

The predominant pathogens found in our study were CoNS and Enterobacteriaceae, similar to that of the adult patient group.[2] In the CRBSI group, CoNS accounts for 45.5% of infections (30/66). Intraluminal colonization of the

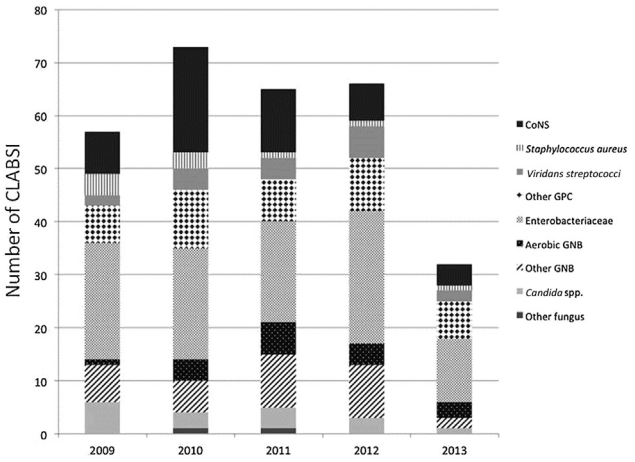

Figure 2. Microbiologic distribution for central line-associated bloodstream infection (CLABSI) in pediatric hematology—oncology patients in 2009—2013. Enterobacteriaceae and coagulase-negative staphylococci (CoNS) were the predominant pathogens. GNB = Gram-negative bacilli; GPC = Gram-positive coccus.

common skin flora from repeated puncture through the septum may account for the high percentage of CoNS.[8] In this study, the prevalence of CoNS in CLABSI has decreased gradually in 2012—2013. The use of chlorhexidine as a disinfectant and the promotion of central venous catheter bundle care may have contributed to this decrease.[18] Kao et al also reported that topical skin disinfection with chlorhexidine may prevent Port-A-related BSI caused by Gram-positive bacteria in adult patients with solid cancers.[19]

The median duration from catheter insertion to the date of catheter infection is 134 days, with IQR of 25—310.3 days. Of all the CLABSI episodes, 29.6% (68/230) occurred within 30 days of central venous catheter insertion (Figure 1). Another study also showed that episodes of Port-A BSI mostly take place during the first 6 months in children with acute leukemia,[20] which may be related to the more profound immune suppression at this stage due to intensive chemotherapy. In addition, unfamiliarity of the patients or

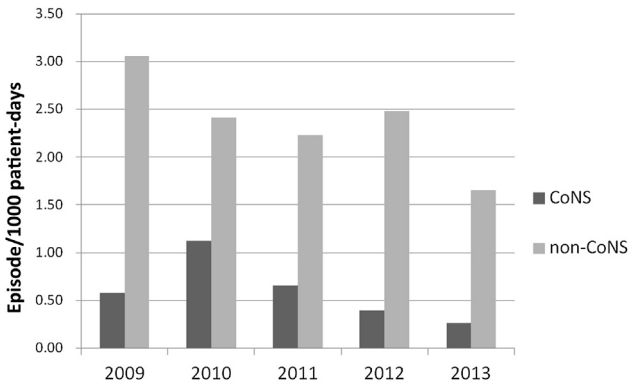

Figure 3. Central line-associated bloodstream infection (CLABSI) episodes/1000 patient-days of the coagulase-negative staphylococci (CoNS) group and the non-CoNS group in 2009—2013.

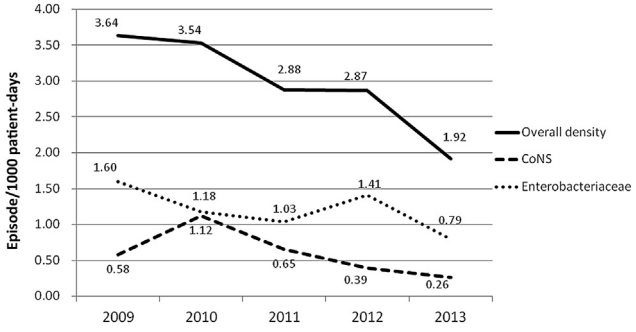

Figure 4. Central line-associated bloodstream infection (CLABSI) density decreased gradually in the period 2009—2013. CoNS = coagulase-negative staphylococci.

caregivers with catheter care during the early periods of central venous catheter insertion may also contribute to high infection rates. Thus, to reduce the CLABSI rate, comprehensive education on catheter care and self-hygiene for the patients and their caregivers before and right after catheter insertion is extremely important.

All BSIs in patients with a central venous catheter but without evidence of other infectious foci are considered as CLABSI. Data from pediatric oncology patients showed that only about one third of CLABSI episodes are related to infections from other sites,[1,21] suggesting that two thirds of CLABSI episodes may be related to central catheters. However, such a clinical surveillance definition may lead to overestimation of infections truly associated with central venous catheters. In this study, only 28.7% of CLABSI episodes were confirmed as CRBSI. The CRBSI rate in this study was 1.08/1000 catheter-days, which is comparable to previous studies in the pediatric group (0.5—6.75/1000 catheter-days).[20,22—28] To diagnose CRBSI, obtaining blood samples simultaneously from peripheral veins and the central catheter is crucial.

The Infectious Diseases Society of America treatment guidelines for CLABSI recommend the use of adjunctive ALT for adults and children. In a systemic review and meta-analysis in 2011, O'Horo et al[7] reported that the combination of systemic antibiotics and culture-guided lock therapy is superior to systemic antibiotics alone, with 10% of locked patients requiring replacement compared with 33% of patients without lock. However, the use of ALT is not consistent in the pediatric group, which may be related to the paucity of pediatric safety data, the potential for heparin overdose, and the limited range of studied antibiotics.[1] De Sio et al successfully used an antibiotic lock technique with vancomycin in combination with urokinase in 10 pediatric cancer patients with Gram-positive catheter-related bacteremia after treatment with appropriate intravenous antibiotics was found to be ineffective.[29] Our results show there were no severe side effects after ALT was widely used in 2009. The overall success rate was 71.6%. Therefore, ALT could be considered as a routine therapy for pediatric hematology—oncology patients with CRBSI.

Factors associated with poor ALT response were also identified in this study. CLABSI patients with older age, elevated CRP, ALL, or candidemia have poor outcome. Although very few patients with candidemia received ALT in this study, the high mortality and failure rates of ALT in

these patients were compatible with data mentioned in the current guidelines.[8,30]

Although the total CLABSI rate decreased during the study period, longer follow up is still warranted. Future strategies must be focused on decreasing CRBSI. Chlorhexidine-impregnated sponge dressing or antimicrobial/antiseptic-impregnated catheters may be a choice for the pediatric group.[9,31]

In conclusion, CLABSI is a serious complication in pediatric hematology—oncology patients with central line catheter, and was responsible for 9.3% of the patient deaths in this study. CoNS and Enterobacteriaceae are the predominant pathogens. Current disinfection practice and infection control measures may decrease CLABSI. Besides, routine ALT based on culture results is a safe and effective option for catheter salvage therapy in pediatric hematology—oncology patients.

Conflicts of interest

All contributing authors declare no conflicts of interest.

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