Rabie *et al.*
Egyptian Pediatric Association Gazette (2022) 70:16
https://doi.org/10.1186/s43054-022-00108-z

Egyptian Pediatric Association Gazette

RESEARCH Open Access

Central line-associated bloodstream infection (CLABSI) with three different vascular access in neonatal intensive care unit

Dina Rabie[1], Mohammed F. Mostafa[1], Rania M. Abdel Halim[2] and Ola Ahmad Ezzat[3*]

Abstract

Background: Central venous catheters (CVCs) are a mandatory aspect in the neonatal intensive care units. Unfortunately, bloodstream infection is a frequent complication of CVCs. A needleless connector is attached to the end of CVC to allow infusion of fluids. We aimed to assess the effect of needleless connectors on central line-associated blood stream infection, and to assess rate of occurrence of bloodstream infection with the use of three different types of venous access in neonates.

Methods: This study is a prospective, randomized, comparative study which was held at the Neonatal Intensive Care, Faculty of Medicine, Ain Shams University. The study recruited 120 neonates who were categorized into three groups according to the type of inserted CVC: group A with umbilical venous catheter, group B with peripherally inserted central catheter, and group C with non-tunneled central venous catheter, and each group was further subdivided into two groups according to the use of needleless connector. Criteria of central line-associated bloodstream infection (CLABSI) and central line-related bloodstream infection (CLRBSI) were applied.

Results: The study included 120 neonates, a multivariable logistic regression analysis was held for two predictors (type of CVC and use of needleless connector) of CLABSI/CLRBSI, it revealed that the use of needleless connector was associated with significant lower incidence of CLABSI/CLRBSI (P value < 0.05, adjusted odds ratio [aOR] = 0.303), the use of peripheral inserted central catheter (PICC) was also associated with the lowest incidence of CLABSI/CLRBSI (P value = 0.015, aOR = 0.284). Another multivariable logistic regression analysis was done for four predictors (type of CVC, use of needleless connector, gestational age, and catheter dwell time) which revealed that the gestational age (P value = 0.001, aOR = 0.691) and catheter dwell time (P value = 0.004, aOR = 1.313) were the only independent predictors for the occurrence of CLABSI/CLRBSI.

Conclusion: The use of needleless connector can lower the incidence of CLABSI/CLRBSI, PICC line was associated with the lowest incidence of CLABSI/CLRBSI among the three types of CVCs. Low gestational age and long catheter dwell time were found to be the main risk factors for increasing the incidence of CLABSI/CLRBSI.

Keywords: Needleless connector, CLABSI, CLRBSI, Central catheter, Bloodstream infection, Neonates

Background

Central venous catheters (CVCs) are a mandatory aspect of neonatal care in neonatal intensive care units (NICUs) because they allow the delivery of intravenous fluids and medications. The main used types of CVCs in NICUs are umbilical venous catheters (UVCs), peripheral inserted central catheters (PICCs) and tunneled or non-tunneled

*Correspondence: ola.aez.88@gmail.com

[3] Obstetric and Gynecology Hospital, Faculty of Medicine, Ain Shams University, Cairo, Egypt
Full list of author information is available at the end of the article

central venous catheters [1]. Unfortunately, using of these CVCs is linked to several complications, bloodstream infection is one of the most frequent and fatal complication that can be encountered [2]. Neonatal population are specifically at higher risk of fatal bloodstream infection because of many reasons such as the difference in the nature of their immunological system response such as changes in neutrophils function due to gestational age or relative deficiency in immunoglobulin or complements level especially in premature neonates, also their immature skin barrier can add up to this risk [3].

A needleless connector is a piece attached to the end of central vascular catheters to allow infusion and aspiration of fluid and medications into the catheter [4]. It has a protective split septum that opens the fluid pathway only when a male luer has been inserted and then automatically seals when disconnected. Before the introduction of needleless connector, 3-way stopcocks were used as a traditional way [4]. This prospective study assesses the effect of needleless connectors on the central line-associated blood stream infection and the rate of occurrence of bloodstream infection with the use of three different types of venous access in neonates.

Methods

Study design

This study is a prospective, randomized, comparative study held at Neonatal Intensive Care Unit, Faculty of Medicine, Ain Shams University over 2 years from September 2019 to August 2021. This study has been approved by the Research Ethics Committee of Faculty of Medicine, Ain Shams University (approval number: MS292/2019). A written informed consent was taken from all parents or the legal guardians of the enrolled neonates after full explanation of the aim and plan of the work.

Study population and setting

The study recruited 120 neonates with inserted CVC who were categorized into three groups according to the type of inserted CVC (umbilical venous catheter, peripheral inserted central catheter, non-tunneled central venous catheter); each group was subdivided into two groups according to the use of the needleless connector.

Inclusion criteria

Neonates with umbilical venous catheter or peripheral inserted central catheter or non-tunneled central venous catheter.

Exclusion criteria

Neonates who had more than one type of central venous catheters, neonates who had the central venous catheter placed for less than 24 h, neonates with congenital anomalies and karyotyping abnormalities, neonates with laboratory confirmed sepsis before insertion of the catheter. All included 120 neonates were categorized into 3 groups according to the type of inserted CVC; group A: 40 neonates (40) with umbilical venous catheter, then subdivided into 2 groups: group A1 20 neonates (20) with umbilical venous catheter and needleless connector and group A2 20 neonates (20) with umbilical venous catheter but without needleless connector. Group B: 40 neonates (40) with peripherally inserted central catheter, furthermore, subdivided into 2 groups; group B1 20 neonates (20) with peripherally inserted central catheter and needleless connector and group B2 20 neonates (20) with peripherally inserted central catheter but without needleless connector. Group C included 40 neonates (40) with non-tunneled central venous catheter, additionally subdivided into two subgroups; group C1 included 21 neonates (21) with non-tunneled central venous catheter and needleless connector and group C2: included 19 neonates (19) with non-tunneled central venous catheter but without needleless connector.

All neonates were subjected to recording of the date of central line insertion, the date of central line removal, determination of the catheter dwell time, gestational age, and assessment of the Hematological Scoring System (HSS) [5]. On the day of catheter removal, full general examination and laboratory investigations were done (catheter tip colonization, blood culture, and complete blood count).

Microbiological techniques

Blood culture

A sterile syringe was used to collect blood samples (3 ml) from a peripheral puncture under complete aseptic condition to be inoculated on BD BACTEC™ Peds Plus™ media then positive cultures were further sub-cultured in blood agar plates.

Catheter tip culture

Catheters were removed when no longer required or with HSS > 2 due to possibility of sepsis [6]. Catheters were removed using a sterile scissor, and 5 cm of the distal tip of the catheter was cut off and transferred in sterile transport container to the microbiology laboratory. A semi-quantitative culture was carried out by using blood agar plate and it was incubated aerobically at 35 °C. It was considered positive when > 15 CFU/ml.

The following definitions were applied according to the results of cultures. Central line-related blood stream infection (CLRBSI) was defined as one positive blood culture confirmed by a positive semi quantitative catheter tip culture (> 15 CFU/catheter segment) of the same

organism (species and antibiogram) isolated from the blood culture [7]. Central line-associated blood stream infection (CLABSI) was defined as bacteremia confirmed by positive blood culture associated with clinical signs of sepsis according to CDC criteria with absence of any other source of infection except the catheter but without laboratory confirmation of CVC tip colonization [8]. Catheter tip colonization was defined as absence of infection signs at the catheter insertion site and positive semi quantitative culture of catheter tip (> 15 CFU/catheter segment of the catheters tip) with negative blood culture [8].

Statistical analysis

Sample size

To assess the incidence of bloodstream infection of the three types of central venous catheter: using PASS program, setting alpha error at 5%, and power of study 80%. Result from previous study results showed that the colonization in group A, group B, and group C was 39%, 23.8%, and 8.3% respectively [9]. Based on this, the needed sample was 40 cases per group (total 120). To assess the impact of needleless connectors on CLABSI, result from previous study, sample size of 60 patients in each group (total 120 patients) achieves 80% power to detect difference rate in infection rate of 25% assuming infection rate in control is 35% and in intervention group 10%. The targeted significance level is 0.05 [10]

Statistical analysis of results

Data were analyzed using IBM© SPSS© Statistics version 26 (IBM© Corp., Armonk, NY). Categorical variables were presented as counts and percentages and between-group differences were compared using the Pearson chi-squared test or Fisher's exact test. Ordinal data are compared with the chi-squared test for trend. Multivariable binary logistic regression analysis was used to examine predictors of CLABSI/CLRBSI. *P* values < 0.05 were considered statistically significant.

Results

The study was carried out on 120 neonates (54 males and 66 females with a male to female ratio of 1:1.2) with a mean ± SD gestational age of 35 ± 3 weeks, birth weight of 2.5 ± 0.81 kg, catheter dwell time of 9 ± 4 days and postnatal age at catheter removal day of 13 ± 6 days as shown in Table 1.

The demographic data of neonates recruited in the study as well as variables of our population are shown in Tables 1 and 2.

The most common organism isolated by blood culture was coagulase negative staphylococci (15.0%) followed by Staphylococcus aureus (8.3%) as shown in Table 2.

There was a trend for a higher incidence of blood stream infection caused by catheter insertion regardless of whether it was CLABSI or CLRBSI in association with the use of non-tunneled CVCs (47.5%) and a lower incidence in association with umbilical venous catheter (35.0%). The lowest incidence was observed in association with PICC (22.5%). However, these differences among the three CVCs type did not attain statistical significance (p value = 0.064). The types of CVCs were then stratified by needleless connector, and the differences among the three CVCs types showed a similar trend that did not reach a statistical significant level.

The use of needleless connector is associated with a statistically significant lower incidence of CLABSI/CLRBSI (odds ratio = 0.330, 95% CI = 0.150 to 0.724, Z = 2.767, P value = 0.006). When stratified by type of CVCs, use of needleless connector with only non-tunneled central venous catheter was associated with a statistically significant lower incidence of CLABSI/CLRBSI (odds ratio = 0.185, 95% CI = 0.048 to 0.715, Z = 2.446, P value = 0.014). However, the effect of using needleless connector for umbilical venous catheter (odds ratio = 0.407, 95% CI

Table 1 Characteristics of the study population: categorical variables

Variable					Percentile		
	Mean	SD	Minimum	Maximum	25th	50th	75th
Gestational age at delivery (weeks)	35	3	29	41	33	35	37
Postnatal age at catheter removal day (days)	13	6	2	27	9	13	18
Weight (kg)	2.50	0.81	0.85	4.50	2.00	2.60	3.00
Duration of catheter insertion (days)	9	4	2	20	6	9	11
TLC (cells/µl)	11,450	6955	2000	25,000	5000	9500	18,000
IT ratio	0.14	0.03	0.11	0.24	0.12	0.13	0.16
Platelets (cells/µl)	115,208	47,022	21,000	196,000	89,500	109,000	15,6000

TLC total leucocytes count, *IT ratio* immature neutrophil count to total neutrophil count

Table 2 Characteristics of the study population: categorical variables

Variable			Count	%
Type of CVC		Central (non-tunneled)	40	33.3%
		Umbilical	40	33.3%
		PICC	40	33.3%
Needleless connector		Without needleless (regular)	59	49.2%
		With needleless	61	50.8%
Sex		M	54	45.0%
		F	66	55.0%
Clinical assessment at catheter removal day	**Temperature**	Hypothermic < 36.5 °C	6	5.0%
		Normal	102	85.0%
		Hyperthermic > 37.5 °C	12	10.0%
	Respiratory rate	Bradypnea	0	0.0%
		Normal	94	78.3%
		Tachypnea	26	21.7%
	Heart rate	Bradycardia	6	5.0%
		Normal	97	80.8%
		Tachycardia	17	14.2%
	Mental status	Lethargic	25	20.8%
		Alert	91	75.8%
		Agitated	4	3.3%
Localized signs of infection at catheter insertion site		Purulent drainage	1	0.8%
		Pustules	2	1.7%
		Vesicles	1	0.8%
		Boils	1	0.8%
		Local swelling	15	12.5%
		Erythema	39	32.5%
		Hotness	9	7.5%
Blood culture		CoNS (confirmed)	18	15.0%
		Staphylococcus aureus	10	8.3%
		Klebsiella	9	7.5%
		Acinetobacter	4	3.3%
		Pseudomonas	1	0.8%
Catheter tip culture		CoNS	21	17.5%
		Staphylococcus aureus	12	10.0%
		Klebsiella	7	5.8%
		Acinetobacter	1	0.8%
		E. coli	10	8.3%
		Candida	1	0.8%
Final diagnosis		No growth	52	43.3%
		Catheter colonization	26	21.7%
		CLABSI	19	15.8%
		CLRBSI	23	19.2%
CLABSI/CLRBSI		No growth/catheter colonization	78	65.0%
		CLABSI / CLRBSI	42	35.0%

M male, *F* female, *CVC* central venous catheter, *PICC* peripheral inserted central catheter, *CoNS* coagulase negative staphylococci, *CLABSI* central line-associated bloodstream infection, *CLRBSI* central line-related bloodstream infectio

$= 0.107$ to 1.559, $Z = 1.312$, P value $= 0.190$) or for PICC (odds ratio $= 0.412$, 95% CI $= 0.087$ to 1.952, $Z = 1.118$, P value $= 0.264$) is not statistically significant.

In a multivariable binary logistic regression analysis for predictors (type of CVCs and using of needleless connector) of CLABSI/CLRBSI, we found that the use

of PICC (aOR = 0.284, 95% CI = 0.103 to 0.783, *p* value = 0.015) and the use of a needleless connector (aOR = 0.303, 95% CI = 0.134 to 0.685, *p* value = 0.004) were associated with statistically significant lower incidence of CLABSI/CLRBSI as illustrated in Table 3

In another multivariable binary logistic regression analysis for predictors (type of CVC, use of needleless connector, gestational age, catheter dwell time) of CLABSI/CLRBSI, gestational age (aOR = 0.691, 95% CI = 0.554 to 0.861, *p* value = 0.001) and duration of catheter insertion (aOR = 1.313, 95% CI = 1.089 to 1.582, *p* value = 0.004) were the only independent predictors for the occurrence of CLABSI/CLRBSI, for each week decrease in gestational age, there was an observed increase in the risk of CLABSI/CLRBSI occurrence by 0.69. On the other hand, an increase in the catheter dwell time was associated with an increased the risk of CLABSI/CLRBSI occurrence by 0.31, neither the type of catheter nor the use of needleless connector was a determinant of CLABSI/CLRBSI (*p* values > 0.05) as shown in Table 4

Discussion

In this study, assessment of the relation between type of catheters and occurrence of bloodstream infection was scrutinized, a trend for a higher incidence of CLABSI/CLRBSI in association with the use of non-tunneled CVCs was found, a lower incidence with umbilical venous catheters, whereas the lowest incidence of CLABSI/CLRBSI was observed in association with PICC. However, these differences among the three CVCs type did not reach statistical significance level in the univariable analysis (*p* value = 0.064); however, when corrected for two variables (type of CVCs and use of needleless connector), it showed that the use of PICC was associated with the lowest incidence of CLABSI/CLRBSI. Our result goes along with previous studies which stated that PICC line had a significant lower incidence of blood stream infection than UVC [11, 12]. In contrast to Ferreira et al. who compared the rate of blood stream infection caused by CVC between PICC and umbilical catheter, they found that use of PICC was associated with a significantly higher rate of blood stream infection;

Table 3 Multivariable binary logistic regression analysis for predictors of CLABSI/CLRBSI

Variable	Coefficient	Std. error	Wald	*p* value	aOR	95% CI
Type of catheter						
Non tunneled CVC[a]					1.000	
Umbilical	− 0.596	0.480	1.543	0.214	0.551	0.215 to 1.411
PICC	− 1.257	0.516	5.927	0.015	0.284	0.103 to 0.783
Connector						
Without NC[a]					1.000	
With NC	− 1.194	0.416	8.245	0.004	0.303	0.134 to 0.685
Constant	0.519	0.394	1.740	0.187		

NC needleless connector, *aOR* adjusted odds ratio, *CI* confidence interval, *Std. error* standard error

[a] Odds ratio is set to 1.000 because it is the reference group

Table 4 Multivariable binary logistic regression analysis for predictors of CLABSI/CLRBSI with adjustment for gestational age at delivery and duration of catheter insertion

Variable	Coefficient	Std. error	Wald	*p* value	aOR	95% CI
GA (weeks)	− 0.370	0.112	10.842	0.001	0.691	0.554 to 0.861
CDT (day)	0.272	0.095	8.146	0.004	1.313	1.089 to 1.582
Type of catheter						
Non tunneled CVC[a]					1.000	
Umbilical	0.339	0.738	0.211	0.646	1.403	0.331 to 5.958
PICC	− 0.686	0.601	1.305	0.253	0.503	0.155 to 1.634
connector						
Without NC[a]					1.000	
With NC	− 0.655	0.486	1.821	0.177	0.519	0.201 to 1.345
Constant	9.947	4.092	5.909	0.015		

GA gestational age, *CDT* catheter dwell time, *NC* needleless connector, *aOR* adjusted odds ratio, *CI* confidence interval, *Std. error* standard error

[a] Odds ratio is set to 1.000 because it is the reference group

this finding was due to PICC's longer dwell time than the umbilical catheter [13]. Also, Chein et al. reported higher incidence of blood stream infection in PICC (21.9%) than umbilical venous catheter (8.6%) with p value < 0.05, and this finding is most likely due to the study population which included neonates with low gestational age and low birth weight, lower Apgar score, and small for gestational age neonates; this population criteria is different from our population criteria [14].

To find the relation between the needleless connectors and central line-associated/related blood stream infection, this study showed that the use of needleless connector is associated with statistically significant lower incidence of CLABSI/CLRBSI (P value < 0.05, unadjusted odds ratio = 0.33, CI = 0.150 to 0.724). When stratified by type of CVC, the needleless connector with non-tunneled central venous catheter was associated with a statistically significant lower incidence of CLABSI/CLRBSI (unadjusted odds ratio = 0.185 CI = 0.048 to 0.715). However, the effect of using the needleless connector for umbilical venous catheter and PICC was not statistically significant (P value > 0.05), it was so close to be significant but may be the sample size was insufficient to get the effect. When adjusted for the type of CVC and use of needleless connector, this study proved that the use of needleless connector was a protective factor (adjusted odds ratio = 0.303 CI = 0.134 to 0.685). It goes in agreement with previous study that reported a significant decrease in bloodstream infection after implementation of the needleless connectors [4]. On the contrary, Sengul et al. conducted a randomized experimental study which included neonates with CVC and peripheral catheters with needleless connector and three-way stopcock, and they reported that there was no significant difference between needleless connectors and three-way stopcocks, as far as the author mentioned in the methods, and they did not disinfect the needleless connectors by 70% isopropyl alcohol before application, which should be applied [15]. Conversely, Maki DG reported that needleless connector increases the incidence of bloodstream infection [16].

In our study, another analysis involving four predictors of CLABSI/CLRBSI (type of CVCs, use of needleless connector, gestational age, and catheter dwell time). After comparing the effectiveness of these four variables, we found that the gestational age and catheter dwell time were the only independent predictors for the occurrence of CLABSI/CLRBSI as follows: for each week decrease in gestational age, there was an observed increase in the risk of CLABSI/CLRBSI occurrence by 0.69, and for each day increase in catheter dwell time, there was an associated increase in the risk of CLABSI/CLRBSI occurrence by 0.31. Neither the type of catheter nor use of needleless connector was a determinant of CLABSI/CLRBSI (p values > 0.05). This is consistent with the results by Stoll et al. who found a risk of 3.8 (95% CI 2.2–6.6) for bloodstream infection with catheter dwell time being increased from 8 to 14 days [17]. Meanwhile, Njere et al. reported a risk of 3.1 (95% CI 1.64–5.87) when catheter dwell time lasted 9 days or more [18]. It also goes in concordance with Bierlaire et al. where both low gestational age and long catheter dwell time were proved as risk factors for bloodstream infection caused by catheter [2]. A study done by Konstantinidi et al. reported that only long catheter dwell time was the sole risk factor for bloodstream infection [12]. Also, Filippi et al. outlined that low gestational age was the only risk factor related to bloodstream infection caused by catheter [19]. In contrast, a study was done by Gracia et al. found that long catheter dwell time was not an independent significant risk factor for bloodstream infection. A doable reason for this disagreement might be due to the inclusion criteria of the studied population, which included neonates who had several underlying diseases, birth anomalies, and comorbidities. So, the extrapolation based on this studied population may be inaccurate [20].

Conclusion

Type of CVCs and use of needleless connector can affect the CLABSI/CLRBSI incidence if they were used in a population with the same gestational age and with equal catheter dwell, and the use of PICC line had a significant lower incidence of bloodstream infection; also, the use of needleless connector can be considered as a protective factor for bloodstream infection caused by catheter. But with different gestational age population and different catheter dwell time, both low gestational age and long catheter dwell time were the main risk factors for increasing the incidence of bloodstream infection caused by any catheter.

Abbreviations

aOR: Adjusted odds ratio; CDT: Catheter dwell time; CFU: Colony forming unit; CI: Confidence interval; CLABSI: Central line-associated bloodstream infection; CLRBSI: Central line-related bloodstream infection; CoNS: Coagulase negative staphylococci; CVC: Central venous catheters; GA: Gestational age; HSS: Hematological Scoring System; IT ratio: Immature neutrophil count to total neutrophil; NC: Needleless connector; NICU: Neonatal intensive care units; PICC: Peripheral inserted central catheter; Std. error: Standard error; TLC: Total leucocytes count; UVC: Umbilical venous catheter.

Acknowledgements

Not applicable

Authors' contributions

DR put the design of the work, wrote and revised methodology, wrote and revised the article, and supervised the study. MF supervised the study and revised the article. RM shared in analysis and interpretation of the data, wrote and revised methodology, revised the article, and supervised the study. OA

collected data, wrote the methodology, and wrote the article. All authors have read and approved the manuscript in its final form.
The authors certify that the manuscript is original and has not been published before, has been seen and approved by all authors involved, and is neither being published in any other peer-reviewed journal nor being considered for publication elsewhere. The article contains nothing that is unlawful, libelous, or which would, if published, constitute a breach of contract or of confidence or of commitment given to secrecy. The authors are responsible for all parts of the work. All statements contained in the article are true and any formula or instruction contained in the article will not, if followed accurately, cause any injury, illness, or damage to the user.

Funding
No funding sources or any financial support were offered in this manuscript.

Availability of data and materials
The datasets analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
This study has been approved by the Research Ethics Committee of Faculty of Medicine, Ain Shams University (approval number: MS292/2019). A written or oral informed consent was taken from all parents or the legal guardians of the enrolled neonates after full explanation of the aim and plan of the work.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests

Author details
[1]Department of Pediatrics, Faculty of Medicine, Ain Shams University, Cairo, Egypt. [2]Department of Clinical Pathology, Faculty of Medicine, Ain Shams University, Cairo, Egypt. [3]Obstetric and Gynecology Hospital, Faculty of Medicine, Ain Shams University, Cairo, Egypt.

Received: 20 April 2022 Accepted: 2 June 2022
Published online: 14 June 2022

References

1. Khieosanuk K, Fupinwong S, Tosilakul A, Sricharoen N, Sudjaritruk T (2022) Incidence rate and risk factors of central line-associated bloodstream infections among neonates and children admitted to a tertiary care university hospital. Am J Infect Control 50(1):105–107
2. Bierlaire S, Danhaive O, Carkeek K, Piersigilli F (2021) How to minimize central line–associated bloodstream infections in a neonatal intensive care unit: a quality improvement intervention based on a retrospective analysis and the adoption of an evidence-based bundle. Eur J Pediatr 180(2):449–460
3. Payne V, Hall M, Prieto J, Johnson M (2018) Care bundles to reduce central line-associated bloodstream infections in the neonatal unit: a systematic review and meta-analysis. Arch Dis Child Fetal Neonatal 103:F422–F429
4. Rosenthal VD (2020) Impact of needle-free connectors compared with 3-way stopcocks on catheter-related bloodstream infection rates: a meta-analysis. Am J Infect Control. 48(3):281–284
5. Arya S, Shukla G, Goyal P, Channa U (2022) Comparative assessment of umbilical cord blood with peripheral venous blood using hematological scoring system as an early predictive screening method for the detection of early-onset neonatal sepsis in the tertiary care center of Central India. Asian J Med Sci 13(1):118–122
6. Makkar M, Gupta C, Pathak R, Garg S, Mahajan NC (2013) Performance evaluation of hematologic scoring system in early diagnosis of neonatal sepsis. J Clin Neonatol 2(1):25
7. Centers for Disease Control and Prevention (CDC) (2011) Guidelines for the prevention of intravascular catheter-related infections. Avalible via https://www.cdc.gov/infectioncontrol/pdf/guidelines/bsi-guidelines-H.pdf . Accessed Oct 2017
8. Centers for Disease Control and Prevention (CDC), National Healthcare Safety Network (NHSN) (2022), patient safety component manual. .Available via https://www.cdc.gov/nhsn/pdfs/pscmanual/pcsmanual_current.pdf Accessed Jan 2022
9. De Brito CS, de Brito DV, Abdallah VO, Filho G (2010) Occurrence of bloodstream infection with different types of central vascular catheter in critically neonates. J Infect 60(2):128–132
10. Clavier T, Ferguen M, Gouin P, Gillibert A, Dusenne M, Merle V, Veber B (2019) Impact of MaxZero™ needle-free connector on the incidence of central venous catheter-related infections in surgical intensive care unit. Aust Crit Care 32(2):107–111
11. Dubbink-Verheij GH, Bekker V, Pelsma I, van Zwet EW, Smits-Wintjens VE, Steggerda SJ, Te Pas AB, Lopriore E (2017) Bloodstream infection incidence of different central venous catheters in neonates: a descriptive cohort study. Front Pediatr 5:142
12. Konstantinidi A, Sokou R, Panagiotounakou P, Lampridou M, Parastatidou S, Tsantila K, Gounari E, Gounaris AK (2019) Umbilical venous catheters and peripherally inserted central catheters: are they equally safe in VLBW infants? A non-randomized single center study. Medicina 55(8):442
13. Ferreira J, Camargos PAM, Rosado V, Mourão PHO, Romanelli RMC (2020) Risk factors for central venous catheter related bloodstream infection in neonates. Am J Infect Control 48(9):1102
14. Chien LY, Macnab Y, Aziz K, Andrews W, Mcmillan DD, Lee SK (2002) Canadian Neonatal Network. Variations in central venous catheter-related infection risks among Canadian neonatal intensive care units. Pediatr Infect Dis J 21(6):505–511
15. Sengul T, Guven B, Ocakci AF, Kaya N (2020) Connectors as a risk factor for blood-associated infections (3-way stopcock and needleless connector): A randomized-experimental study. Am J Infect Control 48(3):275–280
16. Maki DG (2010) In vitro studies of a novel antimicrobial luer-activated needleless connector for prevention of catheter-related bloodstream infection. Clin Infect Dis 50:1580–1587
17. Stoll BJ, Hansen N, Fanaroff AA, Wright LL, Carlo WA, Ehrenkranz RA, Lemons JA, Donovan EF, Stark AR, Tyson JE, Oh W (2002) Late-onset sepsis in very low birth weight neonates: the experience of the National Institute of Child Health and Human Development Neonatal Research Network. J Pediatr 110(2 Pt 1):285–291
18. Njere I, Islam S, Parish D, Kuna J, Keshtgar AS (2011) Outcome of peripherally inserted central venous catheters in surgical and medical neonates. J Pediatr Surg 46(5):946–950
19. Filippi L, Pezzati M, Di Amario S, Poggi C, Pecile P (2007) Fusidic acid and heparin lock solution for the prevention of catheter related bloodstream infections in critically ill neonates: a retrospective study and a prospective, randomized trial. Pediatr Crit Care Med 8:556–562
20. García H, Romano-Carro B, Miranda-Novales G, González-Cabello HJ, Núñez-Enríquez JC (2019) Risk factors for central line-associated bloodstream infection in critically ill neonates. Indian J Pediatr 86(4):340–346

Publisher's Note