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Effectiveness of insertion care bundle to prevent Central-line-associated bloodstream infections at Pediatric ICU

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Abstract

Purpose: Central-line-associated bloodstream infections are the most common healthcare- associated- associated infections in Pediatric intensive care units worldwide. The aim of this survey was to quantify the impact of central-line care bundle insertion to the prevention Central-line-associated bloodstream infections in a Greek Pediatric Intensive Care Unit.

Methods: All patients with non- tunneled central venous catheter admitted to the unit between October 2012 and October 2015 were included in the cohort study. After twenty-six months of surveillance, a Central-line-associated bloodstream infections prevention insertion bundle was introduced. The insertion bundle derived from the Centers for Disease Control and Prevention recommendations.

Results: One hundred fifty one patients were enrolled in the present study. The incidence rates of CLABSIs decreased from 14.0 (pre-intervention period) to 4.8 (post-intervention period) per 1000 central venous catheter-days ($p = 0.041$, 95% Confidence Interval: 0.7023- 17.7), whilst the central-line utilization ratio was increased from 0.51 to 0.59 ($p=<0.002$, 95% Confidence Interval: 0.039-0.1258). The insertion-bundle compliance was 95.3% in the post-intervention period.

Conclusions: According to the results the implementation of insertion bundle has the potential to reduce the incidence of Central-line-associated bloodstream infections. A prevention strategy targeted on the insertion of vascular access can decrease the incidence rates of Central-line-associated bloodstream in pediatric intensive care units.

Keywords: Care bundle; Children; CLABSI; Pediatric Intensive Care Unit; Prevent

1 Introduction

Central Line Associated Bloodstream Infection (CLABSI) remains a severe global health problem, with serious consequences for patients, their families and healthcare systems, despite the major technological advances since the first central line insertion decades ago. CLABSI is the most common healthcare-associated infection in children, related with increased mortality, maintenance costs and duration of hospitalization [1].

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Pediatric population is more vulnerable to develop CLABSI due to additional factors which are related to either endogenous or exogenous causes [2]. Anatomical and physiological differences, underlying diseases, age, clinical condition severity, prematurity and immaturity of the immune system are the main endogenous causes which ~~increases~~ the occurrence of CLABSI among hospitalized children in comparison with adult population [2-3]. Different studies have shown that previous hospitalization, type of Central Line (CL), parenteral nutrition, multiple CLs, reduced or no staff compliance with insertion and maintenance protocols are some of the known exogenous factors that may contribute to vulnerability of pediatric patients for developing CLABSI [4-5].

CLABSI rate in pediatric population varies depending on the patient subpopulation. In 2013, 1.3 CLABSI per 1,000days of catheterization in cardiosurgery Pediatric Intensive Care Units (PICUs), 0.8 CLABSI in pathology PICUs, 0.3 CLABSI in surgery PICUs and 1.2 CLABSI in general PICUs were reported by the National Nosocomial Infection Surveillance System (NHSN) of the Center for Disease Control and Prevention (CDC) [6]. Significant difference has been found between developed and developing countries. For the same time period of the above study, International Nosocomial Infection Control Consortium reported 8.46 CLABSI per 1000 days catheterization in developing countries' PICUs, a CLABSI rate rise which was associated with the lower social-economic status of investigated countries [7]. In 2011-12, the European Centre for Disease Prevention and Control held the first Europe-wide point-prevalence survey of health-maintenance -associated infections in acute maintenance hospitals. Bloodstream infections were the most common type of infection, followed by lower respiratory tract infections, gastrointestinal infections, eye, ear, nose, and throat infections, urinary tract infections, and surgical-site infections. They analyzed data for 17273 children and adolescents from 29 countries and CLABSI were the most common healthcare- associated infections (44.6%) [8].

Preventing CLABSI has a major impact on the quality of care on pediatric patients [9]. Cornerstone of CLABSI prevention is health professional training on the appropriate procedures which must be followed during the CL insertion and maintenance, but also on control measures for hospital infections. There is a great evidence of the effectiveness of such training programs on CLABSI prevention even in developing countries and in those with severe financial recession. Multidisciplinary approach has been also reported as important factor for the reduction of CLABSI in PICUs with great workload. Furthermore, care bundle (CB), a group of evidence-based interventions, has significant better outcome in diseases' prevention [2, 9-11]. The most widely known CLABSI CB has been reported by CDC and includes CL insertion CB and CL maintenance CB [12].

The aim of this study was to investigate the effectiveness of CL insertion CB reported by CDC in reducing CLABSI rate in a PICU. Sub-objective of the study was to record the frequency of occurrence of nosocomial pathogens that are the cause of CLABSI.

2 Material and methods

A prospective intervention study was conducted in a PICU of a Pediatric Hospital in Athens, Greece. All pediatric patients, who were admitted in PICU during research period and had non-tunneled CL recruited for the study, had an age range from 15 days old to 14 years. Paediatric Risk of Mortality III (PRISM III) score was used for the estimation of disease severity [13]. Patients were followed from the day of admission until the day of discharge or death. Patients, who remained less than two days in PICU were excluded from the study.

CLABSI in PICU was surveyed, in the pre-intervention period for 26 months. CLABSI diagnosis was set according to CDC guidelines. Thus, CLABSI was defined as laboratory-confirmed bloodstream infection (LCBI) where CL was in place on the date of event or the day before and an eligible bloodstream infection organism is identified [12]. CL Utilization Ratio (CL- DUR), CLABSI Standardized Infection Ratio (CLABSI SIR) [14] and CL Standardized Utilization Ratio (CL SUR) [15] were calculated pre and post intervention.

CLABSI rate per 1.000 CL days is calculated by dividing the number of CLABSIs by the number of CL days and multiplying the result by 1000, while CL- DUR is the result of dividing the number of CL days by the number of patients' days [12].

CLABSI SIR is an index for healthcare- associated infections surveillance at a national, state, local, or facility level over time. Using negative binominal regression statistical it compares models the actual number of infections with the number of expected infections according CDC reports and taking account various risk factors each time.14 Similar to CLABSI SIR, CL SUR is also an epidemiological index for hospital infections surveillance which track CL use at a national, state, local, or facility level over time [15].

Intervention period lasted 2 months. A training program for CLABSI causes, prevention, surveillance and CL insertion CB was establised by medical and nursing staff. For implementation of CL insertion CB, we used an insertion checklist

(Central Catheter Introduction Control Form), which empowers nurses to end a procedure if there is no compliance with sterile insertion practices.

For the 6 months post-intervention, CLABSI rate per 1.000 CL days, CL-DUR, CLABSI SIR and CL SUR were calculated as mentioned above.

Statistical package SPSS 22.0 (Statistical Package of Social Sciences-IBM) was used for data analysis. Poisson distribution was calculated for CLABSI ratio distribution. Quantitative variables were presented as mean values (± standard deviation) whist qualitative values were presented as relative (%) frequencies. Kolmogorov-Smirnov and Shapiro Wilks control test were applied to estimate the normal distribution of quantitative variables. Chi-squared test and Fischer's exact test were used to investigate the correlation between qualitative variables, while non-parametric statistical test (Mann-Whitney test, Kruskal Wallis test) were used as quantitative variables of present study didn't distribute normally. Sperman's rho test was calculated as well. The value p- value = 0.05 was considered as significance level.

3 Results

A total of 151 patients with non-tunneled CL participated in the study (108 patient's in pre and 43 in post-intervention). Characteristics of patients are summarized in Table 1.

Table 1 Characteristics of the patients who participated in the study

	Before		After		p-value
	N	%	N	%	
Gender					0.089
Male	69	63.9	21	48.8	
Female	39	36.1	22	51.2	
Age					0.111
Infant (0-12 months)	24	22.2	8	18.6	
Children (1-12 years)	73	67.6	25	58.1	
Teenagers (>12 years)	11	10.2	10	23.3	
Transport out of the PICU					0.405
Yes	35	32.4	17	39.5	
No	73	67.6	26	60.5	
Previous hospitalizations					0.121
Yes	70	64.8	21	48.8	
No	38	35.2	22	51.2	
Admission Diagnosis					0.484
Medical	51	47.2	23	53.5	
Sepsis	11	10.2	6	14.0	
Surgical	46	42.6	14	32.5	
Medications					
Total Parenteral nutrition					0,775*
Yes	11	10.2	5	11.6	
No	97	89.8	38	88.4	
Inotropes					0.59
Yes	35	32.4	12	27.9	

No	73	67.6	31	72.1	
Immunosuppressive treatment					0.162
Yes	13	12.0	9	20.9	
No	95	88.0	34	79.1	
Transfusion					0.022
Yes	60	55.6	15	34.9	
No	48	44.4	28	65.1	
Surgeries and Procedures					
Surgery					0.529
Yes	30	27.8	10	23.3	
No	76	70.3	33	76.7	
Gastrostomy					0.764*
Yes	10	9.3	5	11.6	
No	98	90.7	38	88.4	
Arterial catheter					0.405
Yes	73	67.6	26	60.5	
No	35	32.4	17	39.5	
Mechanical ventilation					0.573
Yes	73	67.6	27	62.8	
No	35	32.4	16	37.2	
Urinary catheter					0.134
Yes	81	75.0	27	62.8	
No	27	25.0	16	37.2	
	M	SD	M	SD	p-value
	95% CI		95% CI		
Age (months)	65.51	56.37	93.28	62.22	0.021
	54.76-76.26		74.13-112.43		
	52.0**		120**		
	(14.25, 118.0)**		(15.0, 144.0)**		
Length of stay (days)	11.11	14.76	7.77	6.04	0.998
	8.30-13.93		5.91-9.63		
	5.0**		5.0**		
	(4.0, 9.75)**		(4.0, 9.0)**		
PRISM III score	12.58	6.40	12.72	7.09	0.920
	11.36-13.80		10.54-14.90		
	11.5**		12.0**		
	(8.0, 16.0)**		(7.0, 18.0)**		

*Fischer's exact test; **Median and quartiles (25%, 75%)

2638 hospitalization days and 1415 non-tunneled CL days were investigated. In pre-intervention period, CLABSI was recorded in 14 out of 108 patients (12.96%) with CL and 14 CLABSI per 1000 CL days were recorded, whilst in post-intervention period, CLABSI was recorded in 2 out of 43 patients (4.6%) with CL and 4.8 CLABSI per 1000 CL days were recorded. In post-intervention period, there was a 66% decrease of CLABSI (p=0.041). CL- DUR increased from 0.514 (before intervention) to 0.5970 (after the intervention) (p <0.002, 95% Confidence interval of the difference 0.039-0.1258).

Pre-intervention, CLABSI SIR was 8.398 in contrast with post-intervention analyses where CLABSI SIR couldn't be evaluated as the denominator was <1. Additionally, CL SUR increased by 0.166 (pre: 1.038, post: 1.204, p<0.001). Regarding hospitalization days and CL days, statistically significant differences were~~n't~~ not found pre and post intervention (p=0.997 and p=0.829 respectively). Crude death rate increased from 6.5% in pre-intervention period (7/108 patients) to 14.28% in post-intervention period (6/43 patients), while Case Fatality Rate due to CLABSI reduced from 14,28% (2/14patients) to 0 (0/2patients). Both differences though, were not statistically significant (p=0.196 and p=1 respectively) (Table 2).

Table 2 Outcome indicators before and after the intervention

Indicator	**Before**	**After**	**p**
Crude death rate	7/108=0.065	6/43=0,1395	0.196***
Case Fatality Rate	2/14=0.1428	0/2=0	1.0***
H~~h~~ospitalization days (days)	11.11	7.77	0.998
	5.0*	5.0*	
	(4.0, 9.75)**	(4.0, 9.0)**	
Central Lines days (days)	10.85	7.42	0.829
	5.0*	5.0*	
	(4.0, 9.75)**	(4.0, 9.0)**	

*median; **quartiles (25%, 75%); ***Fischer's exact test

Moreover, statistical analysis revealed that CLABSI ratio was correlated with hospitalization days (z= -4, 16, p=0.00) and CL days (z= -4, 19, p=0.00) before intervention, with no statistically significant after intervention (z= -1.07, p=0.35 and z= -1, 10, p=0.29, respectively). In addition, the patient's age and the frequency of CLABSI was not statistically significant before (z = -0.19 and p = 0.86) and after (z= -0, 49 και p=0.65) intervention.

Furthermore, no statistically significant difference was observed between the PRISM III score and CLABSIs, both before (z = -1.52, p = 0.13, 95% confidence interval: 0.12-0.14) and after the intervention (z = -0.46, p = 0.68, 95% Confidence interval: 0.67-0.69). Additionally, staff compliance in CL insertion CB was in average 95.3% (Table 3).

Table 3 Staff compliance in Central Line insertion Care Bundle

Care Bundle	**N**	**Compliance %**
Hand Hygiene	43	100
Maximal barrier precautions	41	95.3
Use mask	42	97.7
Use cap	42	97.7
Use sterile gloves	43	100
Use sterile gown	43	100
Use of large sterile field	43	100
Skin Antiseptic	43	100
Allow to dry in the air	43	100
Total compliance	41	95.3

Finally, the most common type of germ isolated before the intervention was Gram (-) bacteria by 85.7%, followed by Gram (+) bacteria isolated in 7.15% and fungi in the remaining 7.15% of cases. After the intervention, 50% of the pathogens belonged to Gram (-) bacteria and the other 50% to Gram (+) bacteria (table 4).

Table 4 Pathogens isolated before and after the intervention

Pathogens isolated	**Before**		**After**	
	N=14	**%**	**N**	**%**
Klebsiella pneumoniae	3	21.5	0	0
Enterobacter cloacae	5	35.7	0	0
Enterococcus faecalis	1	7.15	0	0
Pseudomonas aeruginosa	1	7.15	0	0
Acinetobacter baumannii	2	14.2	1	50
Candida spp. parapsilosis	1	7.15	0	0
Escherichia coli	1	7.15	0	0
Methicillin-resistant Staphylococcus aureus (*MRSA*)	0	0	1	50

4 Discussion

CLABSI prevention is a priority for patient safety and quality of care [15]. Our study aimed to investigate the effect of CDC's non-tunneled CL insertion CB on reduction of CLABSI in PICU. Our main finding was that there was a significant reduction of CLABSI incidence in post-intervention period. CLABSI in our PICU remained a severe health issue despite high staff compliance (95.3%). Baseline CLABSI incidence rate was higher than in NHSN report (14 CLABSI/1000 CL days vs 1.2 CLABSI/1000 CL days) [6], but also higher than those in previous studies in USA and Europe [16-17] However, similar findings were reported in **S**outh American and Asian studies and in Greek studies as well [18-20].

The statistically significant reduction of CLABSI is a crucial finding of the study, with Bion et al highlighting the difficulty of reducing CLABSI in PICUs. Bion et al applied in 215 ICUs (196 Adult ICUs and 19 Pediatric ICUs) in England applying an insertion CB that included maximal barrier precautions; skin antiseptic with chlorhexidine; hand hygiene; implementation of a checklist during admission and daily evaluation of central catheter need to reduce CLABSI in children from 5.65 to 2.89 ($p = 0.625$). In this study, the researchers achieved a statistically significant reduction of 60% in adult ICUs, while in Pediatric ICUs, although they achieved a 48% reduction, the reduction was not found to be statistically significant [21]. Espiua et al achieved a corresponding reduction of CLABSI after the implementation of a central catheter insertion CB in PICUs from 5.5 CLABSI to 3.8 ($P = 0.49$) per 1000 catheter days [22].

Hospitalization and CL days were correlated with CLABSI ratio in line with similar findings [23-24] but also with CDC guidelines according to which CL must be removed as soon as possible [25]. In our study, before the intervention, a statistically significant relationship was found between CLABSI and the days of hospitalization (increased frequency of CLABSI as the patient is hospitalized) and the days with CL (increased incidence of CLABSI the more days CL remains). Several studies agree with the above where the duration of catheterization was found to be a significant risk factor for the development of CLABSI [23-24,27]. A similar study showed that prolonged hospitalization increases the risk of developing CLABSI [26].

In the current study, the age may not be correlated with CLABSI, a finding that is against to other studies that estimated that patients under one year of age were more likely to develop CLABSI than older patients [23,26]. However, a study by Ciofi degli Atti et al found the group 6-11 ages at a higher risk of developing CLABSI, but they believe that this may reflect the fact that this age group is more likely to suffer from serious chronic conditions in their hospital [27].

Furthermore, CL-DUR increased after CL insertion CB implementation (0.51 before and 0.59 after), while CLABSI rate decreased, both values though are higher than those NHSN Report [11].

In addition, CLABSI SIR post-intervention was estimated at 8,398, indicating that more CLABSIs were observed than expected, while after the intervention it was not calculated as the number of expected infections was below <1. At the same time, the SUR is a measure intended to accompany the SIR for the respective department, hospital or health service. The SUR is an indicator of the duration of use of device and does not measure the proper handling of the device. The Central Line SUR before and after the intervention was calculated at 1,037 and 1,204 respectively, which shows that more device days were observed than predicted before and after the intervention based on the national data of the CDC for 2015. It is noted that the numerical value of SUR for a health service that is above 1 does not mean that the SUR for that health service is worse than the national data of the CDC [14,15].

In present study, staff compliance after implementation of CL insertion CB was calculated at 95.3%. In up to date literature review, staff compliance to CB ranges from 20.1% [28] to 94% [29].

Our study highlights the importance of multidisciplinary team to CLABSI prevention. The introduction of the checklist "Central Catheter Introduction Control Form" in our PICU which systematizes, organizes and record the insertion process was used both by nurses and doctors. Checklists remind staff of the basic steps and procedures they should take when importing and managing catheters and they are suggested by guidelines [2]. In addition, checklists utility in high-intense environments such as PICU contribute to medical errors and omissions prevention [30]. Numerous studies have incorporated checklists into CB procedure [11,21,28] but also highlighted the necessity for multidisciplinary team for CLABSI reduction[29] and the effective nurse role in CL insertion [11,16].

A systematic review and meta-analysis showed~~s~~ that in both developed and developing countries systematic implementation of CB leads to CLABSI reduction [10]. Present study, which was conducted in a country which still suffers from severe financial recession, found that implementation of simple and low-cost measures (staff training, checklists, monthly staff knowledge feedback, CLABSI rate recording) can lead to significant reduction of CLABSI.

Finally, before intervention, Gram (-) bacteria (85.7%) were most often isolated, followed by Gram (+) organisms (7.15%) and fungi (7.15%), with Enterobacter cloacae is the most common cause of CLABSI in 35.7% while after the intervention Gram (-) bacteria were isolated in 50% and Gram (+) organisms in the remaining 50%. A study by Venturini et al in Italy agrees with our study of Gram (-) bacteria being the most common pathogens responsible for CLABSI [31]. In contrast, a study by Wylie et al at a pediatric hospital in Boston, Gram (+) organisms were the most common cause of CLABSI in 68% of patients, with coagulase-negative staphylococci causing 49% of all infections [23] Gram (+) bacteria were more common in a study by Rey et al in pediatric ICUs in Spain [32].

Limitations

Our study had some methological limitations. Initially, sample derived from one PICU which limits the generalization of the results in population. In addition, as CB included a group of interventions, it couldn't be calculated which of each item was most effective in CLABSI reduction and further evaluation by controlled clinical trials is required. Another limitation of our study is CL maintenance CB wasn't implemented and pre-intervention staff compliance wasn't assessed. Furthermore, it was not possible to perform statistical control of the CL SUR with statistical tests proposed by CDC as the NHSN statistical program was under construction.

5 Conclusion

As CLABSI is currently a severe clinical problem in ICU, any successful attempt to limit it is of clinical importance. This study was the first systematic record of the incidence of CLABSI, CL- DUR, CLABSI SIR and CL SUR in a Greek PICU. The main finding was that the implementation of a simple and low-cost CL insertion CB can significantly reduce the CLABSI rate in PICU. The study also highlighted the important role nurses play in CLABSI prevention. Critical care nurses need to be continuing educated in regarding the indications for intravascular catheter use, proper procedures for the insertion and maintenance of intravascular catheters, and appropriate infection-control measures to prevent intravascular catheter-related infections. Active surveillance of CLABSI and insertion CB and CL checklist can achieve improvement of patient safety by reducing CLABSIs. Finally, CLABSI rate and responsible pathogens surveillance can contribute to strategy development and decision-making regarding CLABSI prevention.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare that there is no conflict of interests regarding the publication of this paper.

Statement of ethical approval

The study was conducted under the rules laid down by National and Kapodistrian University of Athens, Greece. Our research was approved by hospital's ("P & A Kyriakou") Scientific and Ethics Committee (Ethics approval number: 20808/11-13-2012).

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

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