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Assessing the effect of implementing a central line care bundle on central line-associated bloodstream infections in a tertiary hospital in Saudi Arabia

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ABSTRACT

Central line-associated bloodstream infections (CLABSIs) are severe bloodstream infections caused by catheter use and are often associated with a longer hospital stay, increased healthcare costs, and a higher mortality rate. However, catheter-related bloodstream infections can be successfully treated. It is essential that healthcare workers are aware of central line (CL) insertion and maintenance bundles to reduce and prevent the incidence of CLABSI. The objective of this study was to assess the impact of implementing CL care bundles on hospital-wide CLABSI incidence rates. This is a prospective study conducted at the King Faisal Specialist Hospital and Research Center in Saudi Arabia from January 2017 to December 2021. The research period was divided into two phases: the pre-intervention phase (January 1, 2017 to December 31, 2018) and the post-intervention phase (January, 2019 to December 31, 2020). During both phases, outcome variables, including CLABSI rate, were assessed. In the present study, the total number of CLABSIs is 439, of which 266 were in the pre-intervention phase and 173 were in the post-intervention phase. The overall CLABSI rate significantly decreased from 1.6±0.05 in the pre-intervention phase to 0.9±0.05 in the post-intervention phase. This decline in CLABSI was significant ($p<0.0001$) across all hospital settings, including critical care and non-critical care units. The implementation of care bundles is essential and has been shown to significantly reduce CLABSI rates in nearly all participating units.

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Introduction

The use of central intravascular lines is crucial in hospital care as a life-saving device.[1] However, one of their significant risks is the transmission of central line-associated bloodstream infections (CLABSIs).[2,3] CLABSI occurs when pathogens migrate up the catheter and into deeper tissue or are introduced into the catheter hub and spread along the lumen.[4] The incidence of CLABSI is around 9% among all health-associated infections.[5] Almost 60% of nosocomial bacteremia arises as a result of vascular access.[6] In addition, the number of CLABSI incidences in a hospital contributes significantly to the length of stay, the unnecessary use of antibiotics, morbidity, and mortality.[7,8] Therefore, several hospitals have focused on the development of safe vascular access procedures and preventive interventions, such as central line (CL) insertion and maintenance bundles to decrease hospital-acquired CLABSIs.[9-11]

Several evidence-based interventions have been developed for preventing CLABSI, including the use of chlorhexidine gluconate for the preparation of the insertion site, the use of sterile barriers when inserting a central venous catheter (CVC), choosing the subclavian vein or internal jugular vein, maintaining good hand hygiene, and removing the CVC as soon as possible.[12-15] The Institute for Healthcare Improvement (IHI) included these interventions in a bundle of care known as the CL bundle.[11]

Care bundles, developed in 2001 by the Voluntary Hospital Association and the IHI as a quality improvement tool, included the initiative of creating a CL bundle to specifically address the reduction of CLABSIs.[16]

CL care bundles are groups of best practices that, when applied together, may lead to significantly better outcomes than when implemented individually, for example, such as reducing or eliminating CLABSIs.[13,17,18] According to several data studies and evidence reviews published, implementing preventive measures such as CL care bundles, nursing knowledge, and compliance with best practices has a direct and effective impact on reducing the incidence of CLABSI.[19-21] Furthermore, such strategies have the potential to reduce device-associated infections by 30% and also result in a reduction in healthcare costs.[22]

As a precautionary measure against infections, the IHI recommends hand hygiene, chlorhexidine skin disinfection, maximal sterile barriers, selection of the best catheter site, and reviewing line necessity on a daily basis with the prompt removal of unnecessary lines to reduce the risk of infections.[23] Despite the availability of guidelines that provide evidence-based interventions, CLABSI remains a serious threat to hospitalized patients.[4,23]

In Saudi Arabia, a Ministry of Health study spanning 12 hospitals from 2013 to 2016 revealed CLABSI rates ranging from 2.2 to 10.5 per 1000 CL-days, with a crude device-associated mortality of 41.9%.[22] Moreover, like many other countries, Saudi Arabia has limited data on the effectiveness of a CL bundle in reducing CLABSI cases in general hospitals.[22,24] Thus, we conducted this retrospective study to identify the CLABSI rates from 2017 to 2021 and to evaluate the impact of a hospital-wide implementation of a CL care bundle in 2019 at the King Faisal Specialist Hospital and Research Center (KFSH&RC) to counter CLABSI. This information is crucial for both patients and those involved in healthcare settings. It allows the relevant health authorities to take immediate action and implement improvement plans for the CL bundle, and based on this data, effectively reduce the number of CLABSI cases.

Materials and Methods

Study setting and subjects

This retrospective cohort study spanned over 5 years, from January 2017 to December 2021 at KFSH&RC, a tertiary referral hospital in Riyadh, Saudi Arabia. This study obatined approval from the local ethics committee and institutional review board at KFSH&RC. The patients in this study were new admissions to KFSH&RC who received CL insertions between January 2017 and December 2021. This included patients from medical units, the emergency department, surgical units, and critical care units. The propensity score matching analysis were conducted for sample size and weight analysis.

Study design

We conducted a review of records for 513 consecutive patients diagnosed with CLABSI across various hospital units. The inclusion criteria were: i) gender and age (categorized into pediatrics and adults); ii) admission in specific wards or clinics, such as surgical units, critical care units, medical units, and the emergency department; iii) admission year; iv) type of catheter, such as peripherally inserted central catheter (PICC), CVC, Hickman, dialysis catheter, implantable port (Port-a-Cath), GamCath, Permacath, Quinton, Cordis, and the right antecubital; v) microorganisms isolated from blood cultures related to CLABSI. In addition, the study included two time periods: the pre-intervention phase before the initiation of the CL bundle (January 1, 2017 - December 31, 2018) and the post-intervention phase, spanning 2 years from the implementation of the CL bundle (January 1, 2019 - December 31, 2020).

Definition and microbial identification of central line-associated bloodstream infections

The surveillance of CLABSIs was conducted by trained infection control practitioners. The diagnosis of CLABSIs was based on the definition set by the National Healthcare Safety Network (NHSN) of the Centers for Disease Control and Prevention (CDC).[25] CLABSIs are defined by the NHSN as laboratory-confirmed bloodstream infections in which the CL was in place for more than two calendar days on the date of the event and the line was in place on the date of the event or the day before.[25,26] Clinical and Laboratory Standards Institute guidelines were used to identify and interpret all positive blood cultures.[27] Additionally, microorganisms were identified and their susceptibility to different antibiotics was assessed using a fully automated system, VITEK 2 (bioMérieux Marcy, l'Etoile, France).

Central line bundle interventions

The CL care bundle in this study comprised the insertion and maintenance bundles. The components of the CL insertion bundle included the following practices: patient identification, patient consent, insertion reason, sterile technique, maximum barrier precaution, type of skin preparation (antiseptic), and clamp lumens. The maintenance bundle included the following elements: hand hygiene, discussion of line requirements, daily maintenance bundle, daily bathing, line access, and dressing changes.[28-30]

Compliance with the care bundles was reported every month by nursing staff in each unit and submitted to the infection control team at KFSH&RC. The insertion and maintenance bundle scoring systems used to report this data are shown in the *Supplementary Tables 1 and 2*. Compliance with the CL bundles was measured according to a CDC guidelines checklist as follows:[31] for each element in the bundle, the scoring was considered as one if there was compliance and zero if not. In addition, compliance was considered to be achieved if all of the elements of a bundle were followed, meaning that even if one component was missing, it was scored zero for compliance.

Statistical analysis

All statistical analyses were performed using GraphPad Prism 8 (San Diego, USA). Categorical variables were represented as counts (n) and percentages (%). Comparisons in CLABSI incidence between the pre-intervention and post-intervention phases were made, and the percent change between the two phases was calculated. Statistical significance was defined as $p<0.05$.

Results

Demographic and clinical characteristics of patients with central line-associated bloodstream infections over a 5-year period (2017-2021)

Among the female population, the breakdown is as follows: 13 (5.12%) infants, 50(19.69%) children, 22 (8.66%) adolescents, 61(24.02%) adults between 19 and 44 years of age, 52/254 (20.47%) adults between 45 and 64 years of age, 52 (20.47%) adults between 65 and 84 years of age, and 4 (36.36%) adults aged >85 years. For the males, the data includes 19 (7.34%) infants, 65 (25.10%) children, 22/259 (8.46%) adolescents, 48 (18.53%) adults between 19 and 44 years of age, 62 (23.94%) adults between 45 and 64 years of age, 36 (13.90%) adults between 65 and 84 years of age, and 7 (63.64%) adults aged >85 years, as illustrated in Figure 1A and Table 1.

Figure 1B displays the distribution of CLABSIs across the various wards and clinics, categorized by pediatric and adult age groups. The results for pediatric patients (n=191) reveal the following breakdown: medical unit 58.11%, critical care unit 24.6%, surgical unit 16.75%, and the emergency emergency department 0%. Among the adult patients (n=322), the distribution is as follows: medical unit 44.72%, critical care unit 33.8%, surgical unit 20.80%, and the emergency department 0.31%. In both categories, the incidence of CLABSIs was highest in the medical unit, followed by the critical care unit compared to other units.

During the study period, different types of catheters

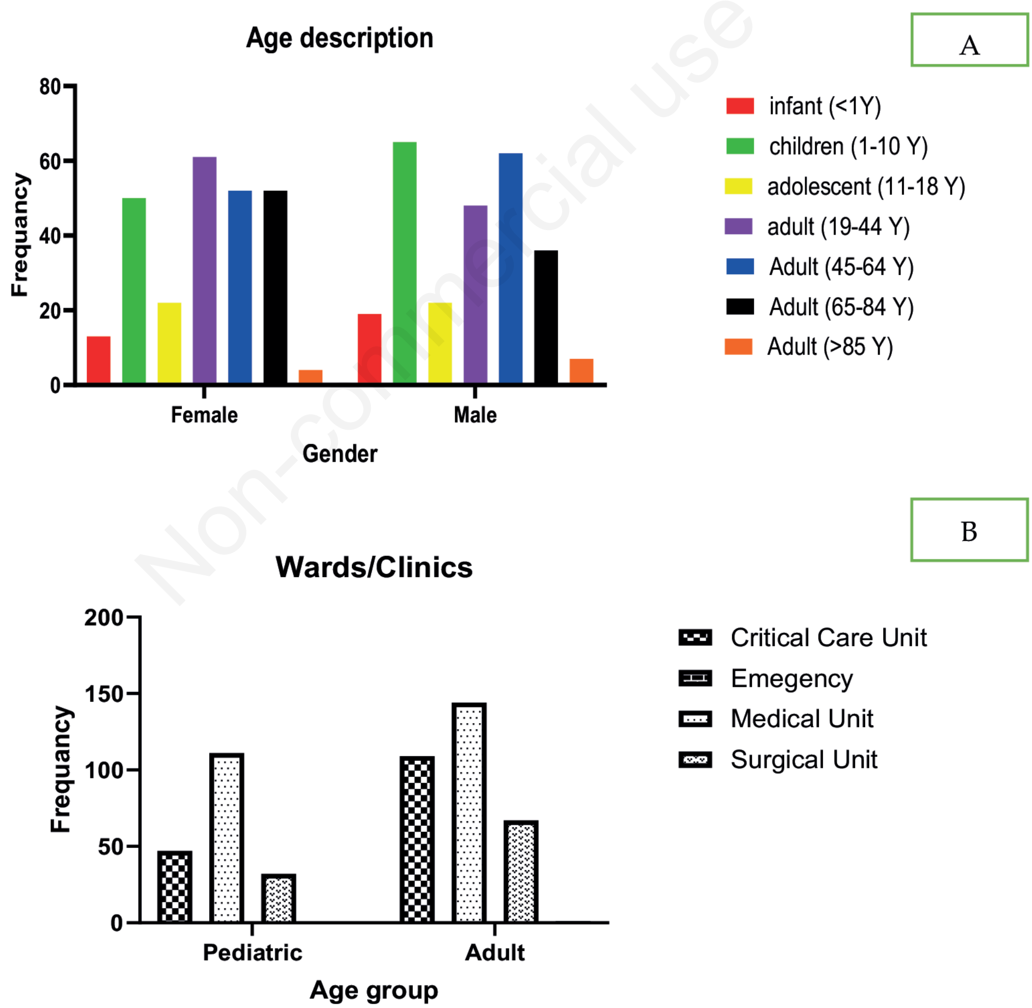

Figure 1. Demographic and clinical characteristics of patients with central line-associated bloodstream infections (CLABSIs) over a 5-year period (2017-2021). A) Age distribution for male and female CLABSI patients; B) ward/clinic description for pediatric and adult CLABSI patients.

were used, with PICC being the most common (Table 1). Furthermore, several different microorganisms were isolated from blood cultures, with some patients having more than one organism within blood cultures.

The microorganism profile is shown in Table 1. Predominantly, Gram-negative rods (GNR) were identified, followed by Gram-positive cocci (GPC) and yeasts, with infection rates varying across different patient groups. Additionally, a total of 18 multidrug-resistant (MDR) pathogens were identified during the study period.

The propensity score matching approach is used to examine the impact of participation in CLABSI. According to propensity score matching analysis for the total sample size 513 with the covariablilities like age, gender, and catheter selection calculation found with the odd ratio 0.699. There are no significant differences (p<0.09) identified according to covariablilities.

Incidence of central line-associated bloodstream infections during the pre-intervention (2017-2018) and post-intervention phases (2019-2020)

The CLABSI incidence rate was assessed before and after the intervention phase for critical and non-critical care units. The total number of CLABSI during the pre-intervention phase is 266 and the number of the post-intervention phase is 173 (p<0.0009). The overall CLABSI rate was significantly (p<0.0001) decreased from the pre-intervention phase (1.6±0.05) to the post-intervention phase (0.9±0.05). Similarly, the CLABSI rate changed significantly for the non-critical care unit [pre-intervention phase (1.5±0.04) to post-intervention phase (0.9±0.03) p<0.0001] and critical care unit [pre-intervention phase (1.8±0.06) to post-intervention phase (0.8±0.04) p<0.0001] (Table 2).

Table 1. Comparison of demographic and clinical characteristics of patients with central line-associated bloodstream infections (n=513) over a 5-year period (2017-2021).

Characteristics	Gender	
	Females (n=254)	Males (n=259)
Age group, n (%)		
Pediatric (<18 years)	85 (33.46)	106 (40.93)
Adult (>19 years)	169 (66.54)	153 (59.07)
Type of catheter, n (%)		
Hickman	30 (11.81)	23 (8.88)
CVC	29 (11.42)	50 (19.31)
Port-A	34 (13.39)	34 (13.13)
Dialysis catheter	19 (7.48)	21 (8.11)
PICC	125 (49.21)	114 (44.36)
Permacath	7 (2.76)	12 (4.63)
Quinton	5 (1.97)	5 (1.93)
Cordis	2 (0.79)	0 (0.00)
GamCath	2 (0.79)	0 (0.00)
Right antecubital	1 (0.39)	-
*Isolated microorganisms (n=525), n (%)		
Gram-negative rod	139 (54.72)	130 (50.19)
Gram-positive cocci	85 (33.46)	98 (37.84)
Yeast	24 (9.45)	32 (12.36)
Gram positive rod	7 (2.76)	5 (1.93)
Gram negative cocci	3(1.18)	1 (0.38)
Mold	1 (0.39)	0 (0.00)
Antibiotic susceptibility, n (%)		
MDR bacteria	11 (2.10)	7 (1.33)

CVC, central venous catheter; PICC, peripherally inserted central catheter; MDR, multidrug resistant. *The total number of isolated organisms is 525 as some patients presented with more than one organism.

Table 2. Changes in central line-associated bloodstream infection rate between the pre-intervention phase (2017-2018) and the post-intervention phase (2019-2020) across various units and categories.

	Total number of CLABSIs (n=439)		
	Pre-intervention phase	Post-intervention phase	p
No. of CLABSIs	266	173	*0.0009
CLABSI rate			
Total	1.6±0.05	0.9±0.05	*<0.0001
Non-critical unit	1.5±0.04	0.9±0.03	*<0.0001
Critical care unit	1.8±0.06	0.8±0.04	*<0.0001
No. of microorganisms isolated (n=467)	282	185	*<0.0001
MDR pathogens	17	1	<0.0001

CLABSIs, central line-associated bloodstream infections; MDR, multidrug resistant. *The changes in the CLABSI rate between the pre and post-intervention phases were assessed by using a paired t-test. The two-tailed p-value is less than 0.05. This difference is considered to be extremely statistically significant.

With regards to the pathogens responsible for CLABSIs before and after the CL bundle was implemented (Table 2), the number of identified microorganisms significantly decreased in the post-intervention phase (p=0.0001). Additionally, while 17 pathogens were identified as MDR in the pre-intervention phase, only 1 pathogen was identified as MDR in the post-intervention phase (p=0.0001).

Discussion

The CL insertion and maintenance bundles play a critical role in implementing evidence-based measures to prevent CLABSIs. However, it is unclear how these bundles affect CLABSI cases across various units in a general hospital. This study was conducted with the aim of assessing the effect of implementing the CL bundle on hospital-wide CLABSI incidences.

In the current study, we conducted a 5-year analysis from 2017 to 2021, involving 513 CLABSI cases, with 254 females and 259 male patients studied. No significant differences were observed in the demographic and clinical characteristics of CLABSI patients, such as gender and age. However, the majority of CLABSI cases were found in children (1-10 years old) and adults aged between 45 and 64 years. Several other studies have outlined significant risk factors associated with CLABSI in children.[32-34] Non-modifiable risk factors include the type of central venous line used, which can be tunneled, non-tunneled, peripherally inserted, or completely implantable.[34,35] Several studies have suggested that younger patients are more vulnerable to CLABSI.[36,37] Furthermore, CLABSIs are more likely to occur in young patients with underlying illnesses such as cancer.[32,33,37,38] On the other hand, De Jonge *et al.* found that older children and adults are at a similar risk for CLABSI.[39]

Our study reveals that PICCs were the most commonly used in hospitalized patients across various medical care units, owing to the numerous advantages afforded by these devices. Several studies have demonstrated that PICC catheters are less likely to cause CLABSIs compared to other catheters.[40-42] Additionally, using a PICC catheter helps avoid many of the mechanical complications associated with traditional CVC placement.[41,42]

A major finding in this study was a noteworthy decrease (p≤0.0001) in CLABSI rates after implementing the care bundle in 2019. The CLABSI incidence rate was higher within the pre-intervention phase, demonstrating the CL bundle was not implemented within the years 2017 and 2018. After the implementation of the CL bundle within the post-intervention stage (2019), the diminished CLABSI rate essentially demonstrated the adequacy of using the CL bundle. This finding aligns with other studies conducted in Saudi Arabia and other countries.[27,43-47] However, most of these studies primarily focused on CLABSI events in intensive care units (ICUs) in terms of surveillance and intervention. Interestingly, it was found that the CLABSI events occurring in medical units were higher than those observed in critical care units. This could be explained by the fact that the number of ICU patients admitted was lower than the number of non-ICU patients. Furthermore, one of the main reasons for the increased use of CL is that non-ICU patients may have catheters in place for a longer period of time, particularly for dialysis patients, the elderly, and the critically ill.[48] Few studies have examined the incidence of CLABSIs in admission wards other than ICUs.[49,50] The findings emphasize that implementing the CL bundle or any other preventive measures for CLABSI reduction must be applied to both critical care units and other hospital units. In the post-intervention phase, CLABSI cases decreased significantly in medical units (p=0.0050), while in other units, it decreased slightly but not significantly (p>0.05). Similarly, a previous study by Han *et al.* showed that the CLABSI rates in non-ICUs were similar to those in ICUs.[49] Consequently, non-ICUs should not be overlooked when implementing preventive interventions aimed at reducing CLABSI occurance.[48,49]

Monitoring local pathogens and drug susceptibility is essential for better-guiding antibiotic therapy.[49] In this study, it was found that the primary pathogens causing CLABSI in KFSH&RC were GNR, GPC, and yeast. Han *et al.* conducted a study in a teaching hospital in China between 2017 and 2018 to assess the effect of the CL bundle on CLABSI reduction and identified that the most common microorganisms were Gram-negative bacteria (mainly *Acinetobacter* spp.), followed by Gram-positive bacteria (mainly *Staphylococcus* spp.), and yeast (mainly *Candida* spp.)[49].

During the post-intervention phase, the number of pathogens causing CLABSI decreased significantly (p=0.0247), likely attributable to the reduction in CLABSI cases, as mentioned previously. A total of 17 MDR bacteria were identified in the pre-intervention phase, whereas only one was identified in the post-intervention phase. This data aligns with the findings of Han *et al.*[49]

Study limitations

Studying the effectiveness of a specific CL bundle intervention cannot be definitively determined as it is challenging. However, several unique interventions in the CLABSI prevention program contributed directly to its success. Descriptions of the included patients' comorbidities, severity of illness scoring, Charlson-comorbidity index, immunosuppressive medications, and steroids, which could all affect the incidence of CLABSI, are recommended. Additionally, recent years' data will be collected to re-evaluate the effectiveness of CL insertion and maintenance bundles. Addressing this particular limitation in future studies could involve conducting specific investigations for each element in the CL insertion and maintenance bundles. Additionally, it is worth noting that since the study was conducted in a tertiary care hospital, the results may be influenced by a high proportion of patients with severe illnesses, thus introducing a potential bias.

Conclusions

This work carries important implications for hospital policy and patient safety. Our findings underscore the significance of implementing CL care bundles on a hospital-wide scale. The effectiveness of both insertion and maintenance bundles in reducing hospital-wide CLABSI is evident, and applicable to patients with central intravascular lines, both in ICU and in non-ICU settings. Therefore, the incorporation of care bundles into routine hospital protocols is crucial in striving to minimize CLABSI cases in hospitals.

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Online supplementary material:

Supplementary Table 1. Summary of central line-associated bloodstream infection insertion care bundle scoring system.

Supplementary Table 2. Summary of central line-associated bloodstream infection maintenance care bundle scoring system.