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Major Article

Impact of central line bundle for prevention of umbilical catheter–related bloodstream infections in a neonatal intensive care unit: A pre–post intervention study

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Key Words:
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Background: Central line–associated bloodstream infection is the most common infection associated with healthcare in preterm infants. The purpose of this 18-month cross-sectional study was to evaluate the effectiveness of bundle applications in the prevention of umbilical venous catheter (UVC)–associated bloodstream infections.

Methods: This study included patients in whom UVCs were inserted and who were diagnosed with central line–associated bloodstream infection between July 1, 2016, and December 31, 2017, according to the Centers for Disease Control and Prevention criteria. During the second 9-month period of the study (April 1, 2017, to December 31, 2017), bundles were implemented.

Results: In the prebundle period, 589 patients were admitted to the neonatal intensive care unit, and 6,769 hospitalization days and 485 UVC days were recorded. Similarly, during the bundle period, 508 patients were admitted to the neonatal intensive care unit, and 7,789 hospitalization days and 508 UVC days were recorded. The UVC-associated bloodstream infection rate was 12.4 per 1,000 catheter days in the prebundle period and decreased to 3.9 per 1,000 catheter days in the bundle period. Thus, after introducing bundle applications, the rate of infection decreased by 68% ($P < .01$).

Conclusions: This study showed that bundle application effectively reduced UVC-associated bloodstream infection.

Central venous catheters are used for a wide spectrum of indications, including infusion of various drugs and fluids and total parenteral nutrition, and they are essential for the care of critically ill neonates and when long-term vascular access is needed and peripheral vascular access is not an option.[1] The most common central venous access points in neonates are the umbilical vein, umbilical artery, and central veins.[2]

Central line–associated blood stream infection (CLABSI) is defined as a bloodstream infection (BSI) that begins within 48 hours after the insertion of a central catheter, with no other infection focus, and is confirmed by laboratory tests.[3] The Centers for Disease Control and Prevention reported in 2014 that 30,100 CLABSI cases continue to be observed each year in intensive care units despite a 46% decrease in the incidence of CLABSI.[3] CLABSI rates vary with infant birth weight. The average CLABSI rate among infants with birth weights ≤750 g is 3.3 per 1,000 catheter days, and among infants with birth weights >750 g, it is 1.4 per 1,000 catheter days.[4] Among infants with extremely low birth weights (<1,000 g), CLABSI rates exceed 20 per 1,000 catheter days.[4] CLABSI is a serious infection that prolongs hospitalization and increases costs and mortality risk.[3]

To prevent CLABSI, the use of central catheters should be reduced, and antiseptic measures should be taken during catheter insertion and maintenance. Because of the use of bundle applications related to catheter insertion and maintenance, CLABSI rates have decreased in various clinical settings, including pediatric intensive care units and hematology-oncology clinics.[5-8] Although the use of central line bundles has been demonstrated to reduce CLABSI development in adults and neonatal intensive care units (NICUs),[9-11] little evidence is available regarding the effectiveness of bundle application use in NICUs, especially among neonates weighing <1,500 g.

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The aim of this study was to evaluate the effectiveness of bundle applications in the prevention of umbilical venous catheter (UVC)-associated BSI.

METHODS

Dr. Behçet Uz Child Disease and Pediatric Surgery Training and Research Hospital is a 400-bed pediatric referral and tertiary care hospital in Izmir, Turkey. The hospital has an active pediatric surgery clinic and pediatric congenital heart surgery program. During the pre- and postoperative periods, many patients are followed up by the NICU. The NICU of Dr. Behçet Uz Children's Hospital is a 50-bed tertiary care referral center where annual admission is approximately 1,600 patients per year.

Umbilical venous catheterization is performed by a neonatologist and a trained physician. Based on service policy, UVCs are generally inserted in patients with extremely low birth weight (<1,000 g), hemodynamic instability, asphyxia, and the need for parenteral nutrition.

The study period was divided into two 9-month periods: the prebundle (July 1, 2016 to March 31, 2017) and the bundle (April 1, 2017, to December 31, 2017). Neonatologists inserted Ombilicaths (Prodimed, Le Plessis Bouchard, France) in the NICU. Central catheters were inserted under maximum sterile barriers and NICU service conditions. Each umbilical catheter was protected with a semi-permeable Tegaderm cover (3M Healthcare Ltd, Loughborough, United Kingdom). All patients with umbilical lines were included in this study. The criteria defined by the Centers for Disease Control and Prevention were used for the diagnosis of CLABSI. During the study, 2 blood culture samples were taken from each patient thought to be infected, with 1 being taken from the central venous catheter and the other from a peripheral vein. Each blood culture bottle was placed in the BacT/ALERT automated system (bioMérieux, Inc, Marcy-l'Étoile, France) and incubated for 7 days or until a positive test result was obtained.[12] Samples taken from positive blood cultures were added to chocolate, eosin methylene blue lactose sucrose, and blood agar plates according to national laboratory guidelines and incubated at 37.8°C in 5% CO_2 for 48 hours. Microorganisms were detected by the VITEK 2 system (bioMérieux, Inc), and antibiotic susceptibility tests (eg, measuring minimum inhibitory concentration levels, extended-spectrum beta-lactamase presence, and carbapenem resistance) were, in a similar manner, conducted for each isolate according to the criteria of the Clinical and Laboratory Standards Institute and instructions of the manufacturer.[6] The identification of gram-positive bacteria was made and antibiotic susceptibility tests conducted, according to the instructions of the manufacturer, using the automated VITEK 2 system with a gram-positive AST-P592 identity card, a subsidiary e-test (bioMérieux, Inc), and a disk diffusion test. This system was also used to detect gram-negative bacteria using the AST-N325, AST-N326, and AST-N327 identification cards and by conducting antibiotic susceptibility tests.

The study consisted of 4 main components, including determination elements of bundle implementation, education, surveillance, and feedback. Education sessions were provided to all healthcare workers in the NICU regarding the earlier described bundle implementations for CLABSI prevention. The education sessions were provided monthly by the bundle team (ie, an infection control nurse, a pediatric infectious disease specialist, and a neonatology specialist). During the study period, prospective, active, and cohort surveillance, as well as monitoring of compliance with bundle components, was performed by the bundle team weekly and monthly, respectively. The healthcare workers in the NICU received feedback on rates of compliance with bundle components.

The prebundle period was the 9-month period before bundle application (July 1, 2016, to March 31, 2017). During this period, 3-way stopcocks were used, and flushing was performed using 1-2 mL of 0.9% NaCl, which was manually prepared from polyvinyl chloride bags.

Bundle period

During the second 9-month period of the study, a bundle comprising the following elements was implemented in the NICU: education−training−assignment, evaluation of daily catheter indications, hand hygiene and aseptic technique, maximal sterile barrier precautions during catheter insertion, closure of the catheter area with transparent dressing, use of BD Q-Syte needleless connectors (BD, Franklin Lakes, NJ) instead of 3-way stopcocks, and regular flushing of catheter lumens with single-use prefilled (SUF) BD PosiFlush SP saline syringes (BD). Employees were informed about bundle applications, and feedback on bundle adjustment and CLABSI rates was considered. The ethics committee of Dr. Behçet Uz Child Disease and Pediatric Surgery Training and Research Hospital approved this study.

Statistical analysis

The data were analyzed using SPSS Statistics 17.0 (International Business Machines Corp, Armonk, NY). The Kolmogorov-Smirnov test was used to determine whether the distribution of continuous variables was approximately normal, and the Levene test was used to determine whether the assumption of homogeneity of variance was met. As descriptive statistics, medians and interquartile ranges (IQRs) were calculated for continuous variables, and numbers of cases and percentages were calculated for categorical variables. The Mann-Whitney U test was used to examine differences between groups in non-normally distributed continuous variables. Categorical variables were evaluated by the Fisher exact test when the expected frequency was <5 and by the χ^2 test with continuity correction when the expected frequency was 5-25. Otherwise, the Pearson χ^2 test was used. Results were accepted as statistically significant when $P < .05$.

The number of CLABSI cases per day was calculated for each group. The rate of infection (with a 95% Poisson confidence interval) in each bundle group and the relative risk reduction (determined by comparing groups) were calculated and are given as percentages. The relative risk ratio was also calculated to compare risks in the 2 groups, and a 95% confidence interval was used for the incidence rate. Statistical analyses were performed using MedCalc Version 11.6 (MedCalc Software BVBA, Ostend, Belgium).

RESULTS

During the study period, 1,124 patients were monitored on 14,558 hospital days. During the total study period, UVCs were inserted in a total of 156 patients. The median number of catheter days was 6 (IQR, 4-9), and the median hospitalization period was 19 days (IQR, 9-36.5 days).

Clinical features of the patient population

The 156 patients with UVCs comprised 87 (55.8%) male and 69 (44.2%) female newborns. The median birth week was 35.0 (IQR, 28.0-38.0), and the median birth weight was 2,300 g (IQR, 1,152-3,219 g). Fifteen (9.6%) patients had low birth weights for their gestational weeks. Descriptive statistics for the study population are presented in Table 1.

In the prebundle period, 589 patients were monitored on 6,769 hospitalization days. In the bundle period, 535 patients were monitored on 7,789 hospitalization days. The median birth week was 35.0 (IQR, 28.0-38.0) in the prebundle period, and 61.4% of infants were premature. The median birth week and preterm rate did not differ significantly between groups ($P = .61$ and $P = .57$, respectively). The median birth weight was 2,153 g (IQR, 1,149-3,241 g) in the

Table 1
Descriptive statistics for the bundle and prebundle periods

	Prebundle period	Bundle period	*P* value
Gestational age, week, median (IQR) (%)	35.0 (28.0-38.0)	35.0 (29.0-38.0)	.61*
<37.0, preterm	43 (61.4)	49 (57.0)	.57†
≥37.0, term	27 (38.6)	37 (43.0)	.57†
Birth weight, g, median (IQR) (%)	2,153 (1,149-3,241)	2,380 (1,133-3,225)	.97*
<750	8 (11.4)	14 (16.3)	.53‡
751-1,000	4 (5.7)	6 (7.0)	>.99§
1,001-1,500	15 (21.4)	8 (9.3)	.06‡
1,501-2,500	11 (15.7)	20 (23.3)	.33‡
>2,500	32 (45.8)	38 (44.1)	.85†
Sex (male) (%)	38 (54.3)	49 (57.0)	.74†
SGA (%)	5 (7.1)	10 (11.6)	.50‡
SNAPPE score, median (IQR)	10 (0-34)	7.5 (0-29)	.24*
Catheter duration, median (IQR)	6 (4-10)	5 (3-8)	.07*
Hospitalization period, median (IQR)	22 (10-38)	16.5 (9-35)	.16*
Mortality (%)	12 (17.1)	7 (8.1)	.14‡
Number of patients	70	86	—
Total hospitalization days	6,769	7,789	—
Umbilical venous catheter days	485	503	—
CLABSI (%)	6 (8.6)	2 (2.3)	.14§
CLABSIs per 1,000 catheter days	12.4	3.9	—
Central catheter utilization rate	0.07	0.07	—

CLABSI, central line–associated blood stream infection; *IQR*, interquartile range; *SGA*, small for gestational age; *SNAPPE*, score for neonatal acute physiology with perinatal extension.
*Mann-Whitney U test.
†Pearson χ^2 test.
‡χ^2 test with continuity correction.
§Fisher exact test.

prebundle period and 2,380 g (IQR, 1,133-3,225 g) in the bundle period ($P = .97$). In the prebundle period, 54.3% of cases were boys; in the bundle period, 57.0% of cases were boys ($P = .74$). When accounting for gestational age, 7.1% of patients in the prebundle period and 11.6% of patients in the bundle period had low birth weights ($P = .50$). The median score for neonatal acute physiology with perinatal extension was 10 (IQR, 0-34) in the prebundle period and 7.5 (IQR, 0-29) in the bundle period ($P = .24$).

Comparison of CLABSIs between the prebundle and bundle periods

UVCs were inserted in 70 patients in the prebundle period and in 86 patients in the bundle period; the utilization rate was 0.07 in both periods. The median duration of catheterization was 6 (IQR, 4-10) days in the prebundle period and 5 (IQR, 3-8) days in the bundle period ($P = .07$). CLABSI was observed in 6 (8.6%) cases in the prebundle period and in 2 (2.3%) cases in the bundle period. During the prebundle period, *Klebsiella pneumoniae* was isolated from 5 patients and *Acinetobacter baumannii* was isolated from 1 patient. During the bundle period, the 2 bacteria isolated were *K pneumoniae* and *Staphylococcus aureus.* The UVC-associated BSI rate was 12.4 per 1,000 catheter days in the prebundle period, and it decreased to 3.9 per 1,000 catheter days in the bundle period. The relative risk reduction was 68.5%, which was a significant difference between periods ($P < .01$).

DISCUSSION

In this study, the effectiveness of bundle application in central catheter care was evaluated by comparing data from time periods before and after bundle implementation in the same hospital. The UVC-associated BSI rate decreased significantly from 12.4 per 1,000 catheter days to 3.9 per 1,000 catheter days during the implementation of a central line bundle, which included the use of prefilled syringes and needleless connectors. To our knowledge, this is the first published study in which split-septum (SS) and SUF syringes have been used effectively in neonates.

The most frequently suspected mechanism in CLABSI pathogenesis is colonization of the catheter hub by skin flora and intraluminal contamination.[13] Therefore, most bundle applications have focused on issues such as good hand hygiene practices—in addition to maximum barrier precautions, skin antisepsis, and catheter selection—to prevent catheter hub colonization. In this study, we used a more comprehensive approach to evaluate the efficacy of measures taken to prevent catheter hub and intraluminal colonization and biofilm formation (ie, SS and SUF syringe use).

The umbilical cord is an important site for both bacterial colonization and vascular access. Although it provides easy and fast vascular access, the umbilical cord is the portal of entry for an infectious organism. Also, proximity of the umbilicus to the thigh, groin, and genital areas contributes to an increased risk of infection.[14]

Many studies have shown bundle care applications can prevent CLABSI.[15-17] The CLABSI rate in our study decreased by 68% during the implementation period, supporting the application of CLABSI bundles in UVC use in NICUs. Kime et al[18] reported that the application of a care bundle led not only to a decrease in the incidence of CLABSI but also to an increase in the level of CLABSI awareness in the hospital unit. Increased awareness is very important because it is a key factor in the initiation of prevention procedures. In a similar study conducted by Devrim et al[6] with pediatric hematology-oncology patients, bundle applications led to an 82% decrease in the port-related CLABSI rate, increasing patient quality of life. Moreover, the authors reported that the CLABSI rate was reduced by nearly half within a short period of time after the integration of central line bundles.[6] Miller and Maragakis[19] developed a statistical model to identify aspects of prevention programs that reduced CLABSI rates. According to this model, to achieve a significant decrease in CLABSI rates, intensive care units should have comprehensive prevention policies, policy compliance should be monitored, and at least 95% compliance with at least 1 component of the program should be achieved. Therefore, we plan to implement a more user-friendly bundle to increase compliance.

Patients in NICUs are at increased risk of serious infection because of the limitations of fetal growth and preeclampsia-related leukopenia; changes in the natural immune response due to gestational age; neutrophil function; relative deficiencies in immunoglobulin and complements, especially in premature infants; the absence of maternal opsonic anticoagulants; and immature skin barrier function.[13] Gestational age and birth weight are the main risk factors for CLABSI, with lower age and weight increasing infection risk.[13] In both study periods, patients with similar gestational ages and birth weights were monitored. Notably, although more high-risk patients (eg, small-for-gestational-age infants) received care during the bundle period, the CLABSI rate was lower.

CONCLUSIONS

We found that central line bundle programs, including the use of SS and SUF devices, effectively prevented CLABSI in umbilical catheters when used together in NICUs. Thus, bundles for central lines should be used not only in adult and pediatric intensive care units but also in NICUs.

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