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A Quality Improvement Program to Reduce Central Line Associated Blood Stream Infections in Neonates

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Authors' contributions

This work was carried out in collaboration between all authors. Authors AAM, FH and MR were responsible for the coordination of the overall study, including: the study design, collaboration amongst investigators, data analysis, and manuscript preparation. Author AM wrote the first draft of the manuscript. Authors AAM and FH managed the analyses of the study and the literature searches. Authors MR, AAM and FH contributed to the study design and selection of cognitive bio behavioral instruments. Authors MR, AAM and FH assisted with staff training, manuscript review, and study design. All authors read and approved the final manuscript.

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ABSTRACT

Introduction: Late onset sepsis is a common problem among neonatal intensive care unit (NICU) population with central venous catheter (CVC) being the primary source of infection in the majority of the cases. Central line associated bloodstream infections (CLABSIs) have been significantly reduced by care bundles implanted in NICUs. This study is conducted to detect the overall CLABSI rate, by comparing the rate per 1000 line days in the pre-intervention to that in the post-intervention periods, to prove that change could be attributed to the quality improvement bundles.
Methods: This was a retrospective observational study. It included all patients with central line inserted at NICU of MGH from January 2012 to February 2014 and compared these patients with historical cohort from 22 months of 2010 and 2011. Specific interventions were designed for the central line related practices. Specific interventions according to CDC recommendations emphasize best practices in all areas of central line care: reduction of line entries, aseptic entries

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into the line, and aseptic procedures when changing line components.
Results: Overall, CLABSI rates, in our NICU, declined significantly by 57.3% from 15 CLABSI per 1000 central line days in the pre-intervention period to 6.4 CLABSI in 1000 central line days in the post-intervention period ($P<0.05$). Significant reductions in CLABSI rates were noted for neonates with birth weight less than <1000g and neonates between 1001 g and 1500 g during the post-intervention period, compared with the CLABSI rates for neonates from pre-intervention period.
Conclusion: We found that our efforts didn't result in a decrease in the use of CVC among neonates. Hence, central line utilization rate was not associated, in our study, with CLABSI risk. Our quality improvement effort was successful in significantly reduced CLABSI rates. The majority of our success can be linked to educational efforts based on pertinent and timely data and literature.

Keywords: Central line; NICU; CLABSI; care bundle.

1. INTRODUCTION

Late onset sepsis (bloodstream infection with onset at more than 72 hours of life) is a common problem among neonatal intensive care unit (NICU) population [1-5]. Some studies revealed that a central venous catheter was the primary source of infection in the majority of the cases [6]. Central line associated bloodstream infections (CLABSIs) are an important cause of prolongation of hospital, increased cost and risk of mortality [6].

Central venous catheters (CVCs) are widely used in NICUs. They provide an intravenous route for the safe administration of hyper-osmolar fluids and medications. The most common types of CVCs used in NICUs are umbilical catheters (UC), and peripherally inserted central catheters (PICC) [7].

CLABSI, according to CDC's National Healthcare Safety Network (NHSN), is defined as a primary BSI in a patient that had a central line within the 48-hour period before the development of the BSI and is not bloodstream related to an infection at another site [8].

There are four recognized routes for contamination of catheters: 1) migration of skin organisms at the insertion site into the cutaneous catheter tract and along the surface of the catheter with colonization of the catheter tip; this is the most common route of infection for short-term catheters; 2) direct contamination of the catheter or catheter hub by contact with hands or contaminated fluids or devices; 3) less commonly, catheters might become hematogenously seeded from another focus of infection; and 4) rarely, infusate contamination might lead to CLABSI [9].

Neonates, especially those requiring NICU care, are more susceptible to nosocomial infections. Multiple factors contribute to this population's high risk for infection, including prematurity and the related relative immunodeficiency, use of central venous catheters, ventilator support, use of urinary catheters, receipt of parenteral nutrition and lipids, and exposure to broad-spectrum antimicrobials. Lower birth weight is directly related to a higher risk of developing device-associated infections, including CLABSI [10].

CLABSIs are increasingly recognized as preventable life threatening adverse events, [11,12] even among neonates who may be more biologically at risk for these infections than other infants or adults [13,14]. Primary prevention consists of avoiding line insertion which is often not feasible in premature and critically ill neonates [15]. However, secondary prevention strategies are very feasible in neonates.

CDC based best-practice central line care bundles have been successfully implanted in pediatric intensive care units and NICUs, significantly reducing CLABSI rates [16,17]. According to CDC, CLABSI can be prevented through proper insertion techniques and management of central line. In addition, recent evidence indicates that central line maintenance bundle is important to prevent CLABSIs in neonates [18].

Although this patient population is at risk for nosocomial infection, all NICUs should maintain a belief that such infections are preventable and unacceptable; a "zero tolerance unit culture" is the first step toward a sustained reduction. Recognizing the need to improve perinatal health outcome, Makassed General Hospital (MGH) adopted the standardized evidence-based central line insertion and maintenance bundles.

This study is conducted to detect the overall CLABSI rate, by comparing the rate per 1000 line days in the pre-intervention to that in the post-intervention periods, to prove that change could be attributed to the quality improvement bundles.

2. METHODS AND PATIENTS

2.1 Study Design

The study was approved by hospital's Institutional Review Board. This was a retrospective observational study. It included all patients with central line inserted at NICU of MGH from January 2012 to February 2014 and compared these patients with historical cohort from 22 months of 2010 and 2011.

We specified 2 periods: pre-intervention period from March 2010 till December 2011, and post-intervention period from January 2012 till February 2014.

The following specific interventions were designed for the central line related practices.

2.2 Central Line Placement

2.2.1 Pre-intervention

The majority of central lines, in our NICU, were placed by pre-doctoral pediatric team. Prior to intervention, the accepted practice was for existing chiefs and fellows to instruct incoming trainees in catheter placement. There was variability in aseptic technique and no system in place to oversee whether these techniques were in compliance with evidence based standards.

2.2.2 Intervention

Beginning in January 2012, all those responsible for central line placement were required to attend theoretical and practical sessions aimed at teaching evidence- based techniques for hand hygiene, cutaneous antisepsis, catheter insertion and dressing placement.

2.3 Central Line Dressing Changes

2.3.1 Pre-intervention

Recommendations were in place for whom or how a dressing should be changed, but there was inconsistency with practice.

2.3.2 Intervention

Dressing would be changed only if visibly soiled or damp, or if their integrity was comprised. A uniform, 2-person procedure was adopted, that required, under sterile precautions, the removal of the existing dressing, cutaneous anti-sepsis, and placement of sterile, transparent dressing to allow a direct view of the insertion site.

2.4 Central Line Entry and Closed Medication System

2.4.1 Pre-intervention

Central lines were used for administration of continuous total parental nutrition (TPN) and intermittent medications. The catheter was accessed several times per day for administration of TPN, medication and flush solution.

2.4.2 Intervention

Central lines were utilized, but a close medication system was employed. Proper antiseptic techniques for the line entry were reinforced.

The CDC recommendations emphasize best practices in all areas of central line care: reduction of line entries, aseptic entries into the line, and aseptic procedures when changing line components (Appendix 1). Anonymous doctor self-practice audits were performed on a randomly chosen nursing shift, 1 day every week, as a sampling strategy for all unit patients with central lines. Through these audits, compliance of bedside nurses with the 3 main bundle elements was tracked and reinforced: (1) daily discussion of line entry reduction with medical team, (2) aseptic entries into the line, and (3) aseptic procedures when changing line components.

2.5 Definitions

In neonates, central line refers to intravascular catheter introduced either through the umbilical artery or vein and any others that terminate at or close to the heart or one of the great vessels that is used for infusion, withdrawal of blood or hemodynamic monitoring.

For laboratory confirmed BSI with a common skin contaminant, the definition included signs or

symptoms of infection and 2 positive blood culture results.

Duration of mechanical ventilation was defined as the number of days during which a newborn required intubation and mechanical ventilation.

2.6 Measures

The primary outcome measure was reported laboratory confirmed CLABSI rate per 1000 central line days stratified by four birth weight groups. Central line catheter days were the sum of central line duration for all patients. Mean utilisation rate was central line catheter days divided by patient days.

2.7 Data Analysis

In order to characterise the paediatric patients in this study, we performed descriptive statistical analysis. Frequencies, medians and percentages of aggregated catheter types were determined and the clinical details of all patients were noted. P- value< 0.05 was considered significant.

3. RESULTS

3.1 Comparison of Neonates during the Pre-intervention and Post-intervention Periods

General characteristics of patients under study are shown in Table 1. No statistically significant differences were noted with respect to gender, gestational age, birth weight and mode of birth between the two periods. In addition, during the two periods, the median mechanical ventilation days and median length of stay have no significant difference.

3.2 Central Line Use

Overall, there were 261 CVCs in 213 patients under study resulting in 2298 catheter line days. 134 central lines (31 PICC and 103 UVC) were placed for 120 newborn during the pre-intervention period compared with 127 central lines (43 PICCs and 84 UVC) placed for 93 patients during post-intervention period. No significant difference between pre-intervention and post-intervention periods was observed in the median duration of time that a central line was maintained as shown in Table 2.

As summarized in Table 3, pre-intervention period compromised 1064 central line days and 3688 patient days in comparison with 1234 central line days and 3747 patient days in post-intervention period. Central line utilization rates did not significantly decline between the two periods.

3.3 Comparison of CLABSI Rates during Pre-intervention and Post-intervention Periods

Overall, CLABSI rates, in our NICU, declined significantly by 57.3% from 15 CLABSI per 1000 central line days (16 cases of CLABSI in 1064 central line days) in the pre-intervention period to 6.4 CLABSI in 1000 central line days (8 cases of CLABSI in 1234 central line days) in the post-intervention period ($P<0.05$), as shown in Table 4.

Significant reductions in CLABSI rates were noted for neonates with birth weight less than <1000 g and neonates between 1001 g and 1500 g during the post-intervention period, compared with the CLABSI rates for neonates from pre-intervention period. For neonates with birth weight less than 1000 g, CLABSI rates declined by 54.1%, from 16.9 CLABSI per 1000 central line days (5 CLABSI per 296 central line days) in the pre-intervention period to 7.75 CLABSI per 1000 central line days (3 CLABSI per 387 central line days) in the post-intervention period with $P < 0.001$. Neonates with birth weight between 1001 g and 1500 g, CLABSI rates decreased by 73.11%, from 15.1 CLABSI per 1000 central line days (7 CLABSI per 397 central line days) in the pre-intervention period to 4.06 CLABSI per 1000 central line days (2 CLABSI per 492 central line days) in the post-intervention period with $P< 0.05$. Among patients with birth weight more than 1501 g, CLABSI rates declined by 21.6% between the two periods with no significant P-value.

4. DISCUSSION

Late onset sepsis is a major threat to the high-risk NICU population. Mortality is approximately three times as high for neonates with very low birth weight (VLBW) who develop late-onset sepsis as for neonates with VLBW who do not [19,20]. Late-onset sepsis can prolong hospitalization and impair the neurodevelopment and growth of those who survive, which may further increase the risk of associated morbidity,

as well as increasing health care costs [21,22]. Unlike early-onset sepsis (at <72 hours of life), for which an intervention (intrapartum antibiotic prophylaxis) has resulted in a marked decrease in overall incidence of the disease, [23,24] rates of late onset sepsis have remained relatively constant to slightly increased during recent years [1-5].

This increase is likely related to advances in prenatal and postnatal care, which have resulted in the increased survival and increased duration of hospital stay for a vulnerable patient population [25,26]. Of these devices, CVCs are required for optimal treatment in neonates whose underlying conditions influence their risk for CLABSI [27-30].

A recent analysis of laboratory confirmed BSI in the Yale-New Haven Children's Hospital Newborn Special Care Unit indicated an alarming increase in the rate of late-onset sepsis with CVC being the primary source of infection in the majority of the cases [6]. We therefore chose to focus our efforts on restricting CVC use and on ensuring the use of proper techniques for their placement and management.

Table 1. Characteristics of neonates with central catheters during the two periods

Characteristics	Pre-intervention period n= 134	Post-intervention period n= 127	P-value
Gender			
Female	67 (50.0%)	78 (61.4%)	0.064
Male	67 (50.0%)	49 (38.6%)	
Gestational age			
<29^{+6} week	30	39	
30-33^{+6} week	58	58	0.206
34-36^{+6} week	24	14	
>37 week	22	16	
Birth weight			
<1000 g	27	30	
1001-1500 g	40	44	0.600
1501-2500 g	35	29	
>2501 g	32	24	
Mode of birth			
NVD	31	23	0.317
C-section	103	104	
Mechanical ventilation, mean, days	4.78	6.04	0.138
Length of stay, median, days	27.52	29.50	0.483

Table 2. Median duration of central lines used according to type of central line during the two periods

Central line	Period	Mean duration of central lines	P-value
PICC	period 1	16.42 (8.81 SD)	
	period 2	18.26 (9.39 SD)	0.397
UVC	period 1	5.4 (3.12 SD)	
	period 2	5.35 (2.74 SD)	0.903

Table 3. Patient exposure in pre- versus post-intervention periods

	Pre-intervention	Post-intervention
Central line days	1065	1234
Patient days	3688	3747
Central line utilization rate	0.288	0.329
Mean central line utilization rate	0.4294 [minimum:0.03-maximum:1] (SD:0.301)	0.4292 [minimum:0.03-maximum;1.75 (SD:0.295)

Table 4. Comparison of central line-associated bloodstream infection rates during the pre-intervention and post-intervention periods by birth weight

Birth weight	Pre-intervention		Post-intervention		P-value
	Cases per 1000 central line-days	Cases per total central line-days	Cases per 1000 central line-days	Cases per total central line-days	
All	15	16 per 1064	6.4	8 per 1234	0.044
<1000g	16.9	5 per 296	7.75	3 per 387	<0.0001
1001-1500 g	15.1	6 per 397	4.06	2 per 492	0.0445
1501-2500 g	14.6	3 per 205	8.5	2 per 236	0.887
>2501 g	12	2 per 166	8.4	1 per 119	0.766

To our knowledge, this is the first report to demonstrate reduction on CLABSI rates in the NICU population in Lebanon in a quality improvement program. In this study we compare the incidence of CLABSI and CVC complication rates before and after CLABSI bundles were implemented at the NICU of MGH. We found that our efforts didn't result in a decrease in the use of CVC among neonates. Hence, central line utilization rate was not associated, in our study, with CLABSI risk. In addition, we found that population demographics, mechanical ventilation and mean duration of central line days were among independent predictors of CLABSI.

Although the intervention and magnitude of protective effects to prevent NICU infection varied in different studies, all indicate that applying current evidence for central line care leads to fewer NICU infections [31,32,33-36]. A prospective study in 18 regional referral NICUs in New York State showed a decline of 67% in CLABSI rates [37]. Similarly our data demonstrated a 57.3% decline in CLABSI rates (from 15 CLABSI per 1000 central line days to 6.4 CLABSI per 1000 central line days). The reduction in NICU CLABSIs reported here extends the proof of concept about evidence-based, monitored, central-line bundle and checklist effectiveness.

In 2002, the National Institute of Child Health and Human Development Neonatal Research Network suggested that "strategies to reduce late infections in VLBW neonates and their medical, social, and economic toll are needed urgently" [2]. Our study showed that such strategies and their implementation are possible by decreasing CLABSI rates in this group of neonates by 54.1% (16.9 CLABSI per 1000 central line days in the pre-intervention period to 7.75 CLABSI per 1000 central line days in the post-intervention period). However, additional efforts are needed to identify other risk factors for this high population. If sustained, our efforts could not only affect morbidity and mortality but also potentially enable us to limit the use of antimicrobial agents.

Although our quality improvement effort was successful, this study and its results have limitation. The case number was relatively low; thus, the statistical analysis may not have sufficient power to draw definitive conclusions. However, we carefully collected and analyzed the data, which revealed significant information in CLABSI rates.

5. CONCLUSION

It is clear that many NICU CLABSIs that occurred in past years were instances of preventable harm. Applying standardized evidence-based central-line care significantly reduced CLABSI rates. The majority of our success can be linked to educational efforts based on pertinent and timely data and literature. These techniques and their implementation are not unique to the NICU population and may serve as a model to reduce the rate of CLABSI and the significant morbidity and mortality rates associated with CLABSI in other healthcare settings.

CONSENT

It is not applicable.

ETHICAL APPROVAL

All authors hereby declare that all experiments have been examined and approved by the appropriate ethics committee and have therefore been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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APPENDIX 1

TABLE 2 Bundles for Catheter Insertion and Maintenance

Catheter insertion checklist

1. Perform hand hygiene before insertion
2. Unit time out before procedure
3. All supplies required available at bedside before insertion
4. Inserter and assistant use maximal sterile barrier precautions (ie, mask, cap, gown, sterile gloves, and full body drape)
5. Face mask worn by those within 3 feet of sterile field
6. Perform skin antisepsis with povodone-iodine, CHG, or alcohol
7. Skin preparation agent completely dry at time of first skin puncture
8. Procedure stopped if anyone notes sterility compromised

Catheter maintenance checklist

1. Volume of infant feedings in mL/kg per day
2. Daily assessment of catheter need
   a. "Do we need the line today?"
   b. "If there was no line in place today, would we place one?"
3. Dressing integrity and site cleanliness assessed (daily at minimum)
4. Dressing and site care if dressing change performed
   a. Site cleansed with an appropriate solution (povodone-iodine, CHG, or alcohol)
   b. Cleansing solution allowed to air-dry completely
5. Use of a closed system: closed system maintained for infusion, blood draws, and medication administration; closed system is one in which entries are made through needleless connectors or hubs that have been disinfected before use
6. For all catheter entries/access
   a. Scrub needleless connector or hub using friction with alcohol or CHG for ≥15 seconds
   b. Allow surface of connector or hub to dry before entry
   c. Staff wear clean gloves when accessing or entering catheter (if not using closed system)

CHG, chlorehexidine gluconate.

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