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Original Article

Strategies to reduce hospital-associated bloodstream infections in a limited resource setting: Preventing Infections in Neonates (PIN) collaborative

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Abstract

Background: Hospitalized neonates are at high risk for hospital-associated bloodstream infections (HA-BSI) and require locally contextualized interventions to prevent HA-BSI.

Methods: The *Preventing Infections in Neonates (PIN)* collaborative aimed to reach a 50% decrease in neonatal HA-BSI rates for a 27-bed Level IV neonatal intensive care unit (NICU). Using quality improvement (QI) methodologies, a multidisciplinary cross-cultural collaborative implemented phased and bundled interventions from July 2017 to September 2019. Descriptive statistics and statistical process control charts were used to analyze infection rates.

Results: There were 916 admissions, 19,812 patient-days, and 4264 central line days in the NICU during the project period. Monthly baseline preintervention HA-BSI median rate was 3.95/1000 patient-days and decreased to 1.73/1000 patient-days (56% change) during the bundled interventions. Quarterly HA-BSI rates also decreased from the preintervention median of 4.5/1000 patient-days to 3.3/1000 patient-days during the intervention period (IRR 0.73; 95%CI 0.39, 1.36). Staff were highly compliant with hand hygiene and environmental cleaning. Through project efforts, compliance with bundle elements increased from 25% at baseline to a peak of 97% for central line (CL) insertion checklists and from 13% to a peak of 56% for CL maintenance checklists.

Conclusions: Unit-based bundled interventions can reduce neonatal HA-BSI in limited resource settings. Future studies can assess similar practices in other units and the impact of the pandemic on interventions to reduce HA-BSIs.

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Introduction

Bloodstream infections (BSI) cause significant neonatal morbidity and mortality especially for neonates hospitalized in low- and middle-income countries (LMIC).[1] Globally, there are increasing reports of hospital-associated infections (HAIs) with multidrug-resistant organisms (MDROs) which negatively impact neonatal outcomes.[2–4] HAI rates are higher in LMIC settings and account for a large proportion of reported neonatal mortality in Southeast Asia and sub-Saharan Africa.[5] In particular, the estimated HAI prevalence in Malaysia is 13.9% among all age groups with neonatal sepsis rates as high as 25%.[6] Neonatal HAI leads to prolonged hospital stays, increased MDROs prevalence, mortality risk, and financial burdens.[7]

Hospitalized neonates are a high-risk population for infections and associated complications. With earlier viability, broad antibiotic exposure, and device utilization, neonatal HAI rates are expected to increase if prevention measures are not prioritized.[8,9] Multipronged strategies targeting hospital-onset bacteremia and central line-associated bloodstream infections (CLABSIs) are needed. Based on reports of successful infection prevention models focused on neonatal HAI reduction, we proposed that a multidisciplinary collaborative implementing bundled interventions can decrease neonatal HAIs in LMIC.[10]

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In a single Malaysian neonatal unit, the *Preventing Infections in Neonates (PIN)* collaborative implemented phased interventions to reach a goal of decreasing neonatal HA-BSI by 50% within 12 months. Here, we describe a 26-month multidisciplinary cross-cultural collaborative to create a data-driven, locally contextualized intervention bundle to decrease the incidence of hospital-associated bloodstream infections (HA-BSI) among hospitalized neonates.

Methods

Study setting and overview

University of Malaya Medical Center (UMMC), a 1600 bed academic medical center located in Kuala Lumpur, Malaysia, includes a 27-bed Level IV neonatal intensive care unit (NICU) that admits nearly 350 infants per year. UMMC is a regional referral center with an annual cesarean section rate of up to 25%. Inborn infants make up 90% of admissions, and the most commonly reported cause of neonatal mortality is prematurity.

The PIN collaborative was centered on a pre-existing relationship between Johns Hopkins Hospital (JHH), an academic medical center located in Baltimore, Maryland, US, and UMMC infection prevention partners. Support was provided by a JHH Hospital Epidemiology team—Pediatric Infectious Diseases fellow and faculty participating primarily remotely as well as an on-site Infection Preventionist (IP). The study was authorized by the Johns Hopkins Institutional Review Board and separately by UMMC Review Board with a waiver of consent (JHH IRB # IRB00137448).

Study period

The study period, divided into preintervention and postintervention periods, spanned July 2017 to September 2019. The preintervention period was defined as the 7 months of prospective data collection from July 2017 to January 2018. Due to delays in project setup and unit preference, the postintervention period was extended past the planned 12 months and consisted of 19 months between March 2018 and September 2019. To account for the bundle rollout in February 2018, the month of February was not included in the analyses.

Baseline assessments

During the preintervention period, baseline assessments of HA-BSI incidence and local prevention practices were collected to inform the HA-BSI prevention bundle and achievable improvement targets.

HA-BSI incidence

As there was no ongoing HA-BSI surveillance and a global lack of standardized BSI definitions uniquely designed for the NICU, standardized case definitions were established. These standardized case definitions were used to review UMMC NICU's historic bacteremia data (January–June 2017) to estimate typical baseline rates.

Study definitions

We defined a BSI event as one or more blood culture(s) growing at least one recognized pathogen or common commensal and defined events as HA-BSI if collected on or after hospital day 3 (where the day of NICU admission was day 1). Rates were calculated as HA-BSI per 1000 patient-days.[11] Prior to the study, routine CLABSI surveillance was not conducted at UMMC. Therefore, during the study, we also monitored "BSI with a central line" events defined as microbial growth from a blood culture collected while the central catheter was in place, on the day the line was removed or the day after line removal. Detailed definitions are included in Box 1. During the preintervention phase, IPC nurses were trained to apply CDC NHSN 2014 CLABSI definitions suitable for this LMIC setting to remain consistent with the required Malaysia Ministry of Health's (MoH) CLASBI criteria at the time.[12] CLABSIs were adjudicated if there was no infection at another site after detailed chart reviews by UMMC IP, IPC Hospital Epidemiologist with support from the PIN collaboration Infection Preventionist. UMMC IP department was also familiarized with updated CDC CLABSI definitions.[13]

Box 1. PIN-BSI Collaborative Definitions of Events in the Neonatal Intensive Care Unit (NICU)

Bloodstream Infections (BSI) =
Infant with one or more blood cultures growing at least one recognized pathogen or commensal.
Hospital-associated BSI (HA-BSI) =
BSI (see above)
and
positive blood culture is collected on or after hospital day 3 (where the day of admission to NICU is day 1, that is, collected day 3 of admission or later)
Report as BSI per 1000 patient-days
BSI with central line =
BSI (see above)
and
positive culture is collected on or after day 3 of insertion of a central line or umbilical catheter (where the day of line placement is day 1)
and
the positive culture was collected while the central line was still in place
or
the positive culture was collected on the day the line was removed or next day
CLABSI for UMMC NICU =
BSI with central line (see above)
and
there is no infection at another site* determined by Infection Control Department chart review using Ministry of Health/NHSN 2014 definitions[11,12]
Report as CLABSI per 1000 central line days
** defined as meeting the NHSN Secondary BSI criteria and an NHSN site-specific definition for infection at another site*

Site visits

Two comprehensive site visits were conducted by the JHH team with bi-directional goals established prior to each visit and detailed summary reports developed after the visits. Goals for the initial visit in July 2017 were to review retrospective data, establish data collection methods, and begin bi-directional learning via presentations or webinars. Goals for the subsequent visit in February 2018 included technical input for initiating data-driven HA-BSI prevention bundle, data collection, and management review, as well as infection prevention and control (IPC) and NICU capacity building to manage denominator data collection, surveillance, and reporting. Ongoing support from an in-country JHH IP was provided with targeted monthly NICU visits, multidisciplinary team meetings, and conference calls.

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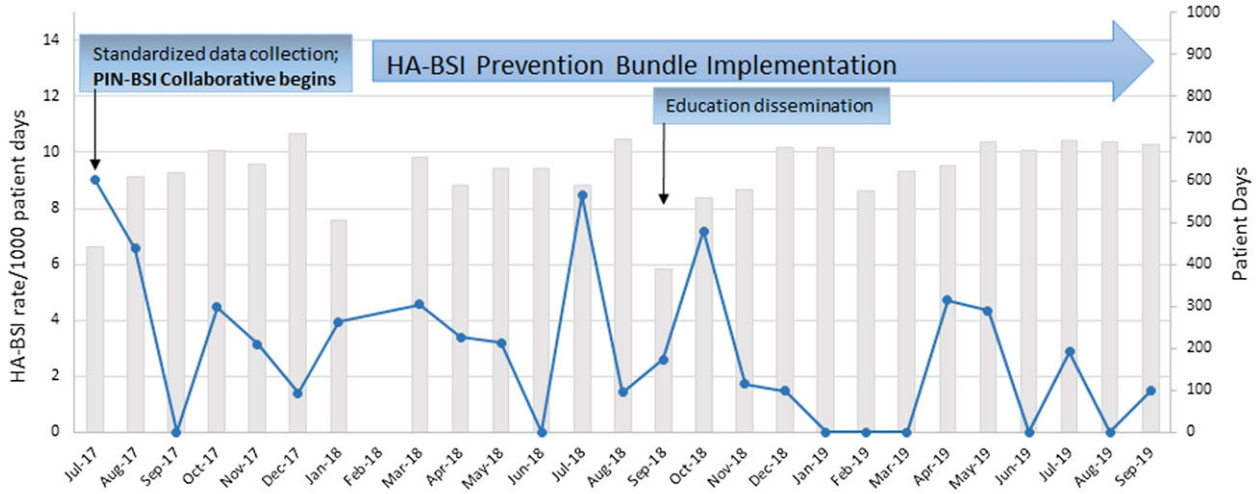
Table 1. Bundled elements to prevent neonatal hospital-associated bloodstream infections in a single Malaysian Neonatal Intensive Care Unit (NICU)

Bundle element	Baseline assessment	Goal
Hand hygiene compliance with focus on: Before touching patient; before touching IV line	94%	Support the existing hand hygiene compliance program to maintain compliance >90%.
Cleaning and equipment		
Frequently touched surface cleaning compliance	62%	Increase daily cleaning compliance for frequently touched surfaces in the NICU to >90%.
Syringe drivers	Shared between infants.	Individual patient use throughout NICU stay.
Retinopathy of prematurity speculum	At best, intermediate-level disinfection at beside between patient use.	Sterilize between patient use.
Blood culture technique	Using 0.05% chlorhexidine.	Achieve effective skin antisepsis using an evidence-based skin cleansing product.
	Drip from IV cannula into vial and transfer to blood culture bottle.	Utilize a closed system to obtain blood culture.
Central line (CL) maintenance		
CL maintenance checklist	Presence of checklist 38%	100% compliance with the use of and completion of checklist.
	Fully completed 13%	
Aseptic central line access	Residents infuse medications and draw labs. No regular competency for nurses or physicians.	Aseptic line entry: • Scrub the hub. • Standard line entry, tubing change, and dressing maintenance techniques
Insertion and dressing technique	Using 0.05% chlorhexidine.	Achieve effective skin antisepsis using an evidence-based skin cleansing product.
Use of multi-dose vials/containers	Utilizing a centrally located shared common IV bag for flushes.	Decreased use of multi-dose vials and where not possible use smallest sized vial, avoid multi-patient use, and develop a standard operating procedure.



	Jul-17	Aug-17	Sep-17	Oct-17	Nov-17	Dec-17	Jan-18	Feb-18	Mar-18	Apr-18	May-18	Jun-18	Jul-18	Aug-18	Sep-18	Oct-18	Nov-18	Dec-18	Jan-19	Feb-19	Mar-19	Apr-19	May-19	Jun-19	Jul-19	Aug-19	Sep-19
Patient Days	442	609	618	670	638	711	506	656	588	628	628	590	699	387	557	578	677	679	575	622	635	692	670	694	693	684	
HA-BSI Rates	9.05	6.57	0.00	4.48	3.13	1.41	3.95	4.57	3.40	3.18	0.00	8.47	1.43	2.58	7.18	1.73	1.48	0.00	0.00	0.00	4.72	4.34	0	2.88	0.00	1.46	

Figure 1. Monthly hospital-associated bloodstream infection rates in a Malaysian Neonatal Intensive Care Unit with bundled interventions to reduce HA-BSI. The monthly HA-BSI rates are calculated as events per 1000 patient-days. HA-BSI were defined as infections in infants with one or more blood cultures growing at least one recognized pathogen or commensal positive if blood culture was collected on or after hospital day 3 (where the day of admission to NICU is day 1). HA-BSI, Hospital-Associated Bloodstream Infections; NICU, Neonatal Intensive Care Unit.

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Bundled interventions to prevent HA-BSI

Using the baseline assessment data, the PIN collaborative created bundled interventions and targets as detailed in Table 1. Subsequently, the PIN collaborative implemented phased interventions to reduce HA-BSI in NICU and improve infection prevention processes. Unit feedback and multidisciplinary reviews informed changes to bundle elements optimized to fit the local context. During the ensuing intervention phase, bundle elements were incrementally adopted, specifically: hand hygiene prioritization, environmental cleaning, equipment reprocessing, injection safety, central line (CL) insertion and care, skin antisepsis, and BSI/HA-BSI/CLABSI case reviews with staff feedback. Unit leaders provided resources, specifically allotted education time, auditors, and cleaning supplies, to facilitate bundle adoption by staff. UMMC Department of Quality provided support for meetings while UMMC Infection Control Department provided auditors, surveillance expertise and developed process checklists. Unit reminders, pictorial guides, and simple tools were developed to support bundle adoption by staff (Example included in Supplementary Figure 1). Sustainable and electronic methods for collecting NICU BSI data were also established using Microsoft Excel 2017.

Outcomes

The primary outcome was calculated as HA-BSI rate per 1000 patient-days during study period. As this was an iterative process with multiple interventions implemented, secondary outcomes included process measures assessing bundle compliance rates for hand hygiene, environmental cleaning, and central line checklists completion. These process measures were determined prior to project initiation.

Statistical analyses

We performed descriptive analyses of infections and processed audit data. HAI per 1000 patient-days, HA-BSI per 1000 patient-days, and CLABSI rates per 1000 CL days were separately calculated monthly as well as for the preintervention and postintervention periods. To account for monthly rate variations, the quarterly incidence of HAI, HA-BSI, and CLABSI was calculated by dividing the number of events by the number of patient-days at risk in that quarter. The incidence of HAI, HA-BSI, and CLABSI were compared before and after the intervention using a non-parametric Mann-Whitney test, where the observational unit is the monthly incidence of infection. The monthly HA-BSI rates were plotted over time. Statistical process control (SPC) analyses, an X-bar chart, and a moving range (mR) chart were produced to further assess HA-BSI rates. Data analyses were conducted on SAS software version 14 (SAS Institute, Inc., Cary, NC USA) and Quality Improvement Macros on Microsoft Excel 2017.

Results

During the 7 preintervention months (July 2017–January 2018) and 19 months of bundled interventions (March 2018–September 2019), there were 916 admissions, 19,812 patient-days, and 4264 central line days in the UMMC NICU. HA-BSI counts, including historic data collected prior to study, were routinely as high as 5 per month prior to PIN-BSI bundle rollout but reached a nadir of zero for 3 consecutive months during the intervention period. With the exclusion of February 2018 to allow for bundle rollout, monthly incidence of HA-BSI reduced from a preintervention median of 3.95/1000 patient-days to a median of 1.73/1000 patient-days during the intervention achieving a 56% reduction (Fig. 1). Quarterly HA-BSI rates also decreased from the preintervention median of 4.5/1000 patient-days to 3.3/1000 patient-days during the intervention period (IRR 0.73; 95%CI 0.39, 1.36). A concurrent decrease in median rate of all BSI was observed (Table 2). Notably, CLABSI rates reached a median of 8.95/1000 central line days during the intervention period. Due to missing data on central line days and limited application of NHSN definitions, preintervention CLABSI rates were unable to be correctly calculated. SPC analyses of HA-BSI rates showed a decline but did not identify process shifts (Fig. 2).

Table 2. Infection rates among hospitalized neonates in a Malaysian Neonatal Intensive Care Unit (2017–2019)

Period	Quarter	BSI	CLABSI*	HA-BSI
Preintervention	1	5.39	0.00	4.19
Preintervention	2	3.47	4.76	2.97
Postintervention#	4	3.25	7.22	2.17
Postintervention	5	4.77	14.89	3.58
Postintervention	6	3.86	12.11	3.31
Postintervention	7	0.53	0.00	0.00
Postintervention	8	4.01	10.66	3.00
Postintervention	9	2.41	4.33	1.45

BSI, Bloodstream infections; CLABSI, Central line-Associated Bloodstream Infection; HA-BSI, Hospital-Associated Bloodstream Infections;
#Quarter 3 was excluded in the analyses to account for bundle rollout in February 2018
*CLABSIs were determined by the Infection Control Department chart review using Malaysia's Ministry of Health and Centers for Disease Control and Prevention National Healthcare Safety Network 2014 definitions[11,12]

Hand hygiene compliance and environmental cleaning audits were >90% for consecutive months in the postintervention period. Compliance with CL insertion checklist improved from preintervention baseline of 25% to an average of 94% and CL maintenance checklist compliance improved from 13% to an average of 53% during the intervention period (Supplementary Figure 3). Monthly compliance rates for bundled interventions are summarized in Supplementary Table 1.

Discussion

Our study describes a successful cross-cultural collaborative to reduce neonatal bloodstream infections in a tertiary Malaysian NICU. In a critical care environment consistently following standardized regulatory guidelines and using a locally adapted bundle, multidisciplinary unit-focused efforts led to a 56% reduction in neonatal HA-BSIs measured as discrete events per 1000 patient-days. Bundle compliance audits reached >90% during the intervention.

With bundled interventions focusing on standardizing HAI definitions, environmental and equipment cleaning, and device (ie, central catheters) maintenance, we report a 26% reduction in median rates for all types of BSI. Of note, SPC analyses did not identify a shift in monthly HA-BSI rates despite a decrease in the monthly incidence of HAIs and HA-BSIs. In contrast, CLABSI rates increased during the bundled intervention period. Minimal reduction in median monthly central line days (129 preintervention to 124 postintervention) may account for rate changes. However, a key reason for increase in CLABSI rates may be the use

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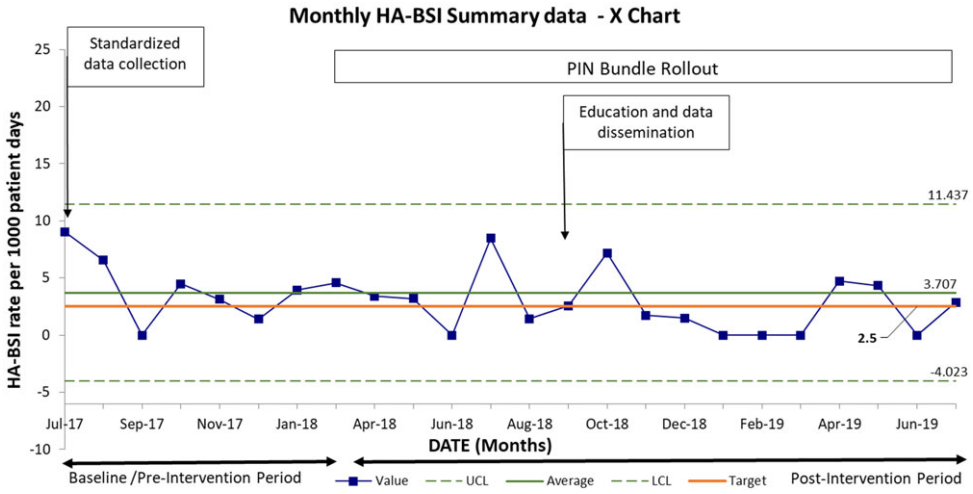

Figure 2. PIN-BSI Collaborative Aggregate Monthly HA-BSI rates HA-BSI rate. The number of HA-BSIs per 1000 patient-days is plotted monthly on an X-bar control chart. Key dates include July 2017—standardized data collection with electronic tools; February 2018—PIN-BSI bundled intervention rollout; and October 2018, Education and data dissemination. The green line denotes the centerline, the blue line denotes HA-BSI rate, and the orange line denotes the target (50% below preintervention HA-BSI rate). The green dashed lines denote control limits. Readjustment of the centerline required 8 consecutive points above or below the centerline. PIN-BSI, Preventing Infections in Neonates—Bloodstream Infections; HA-BSI, Hospital-Associated Bloodstream Infection; UCL, upper control limits; LCL, lower control limit.

of more stringent chart review criteria by the IPC team to adjudicate CLABSI events during the intervention. Other studies have reported near elimination of CLABSIs in critical care units with bundled interventions confirming the need for sustainable interventions targeting BSIs and in tandem, CLABSIs.[14–16]

The major strength of this study is the real-world implementation of a collaborative project focused on reducing neonatal BSIs. Limitations include the use of data from a single LMIC setting hospital with resource allocation that might not be replicable in other settings, lack of consistent data collection methodology prior to the study which limited historical comparisons and non-standardized local public health guidance for determining HAI events. Future efforts will focus on improving mechanisms already in place to reduce infections specifically, increased compliance with contact precautions, hand hygiene, maintenance of medical devices, and developing antibiotic stewardship programs to achieve sustainability.

Conclusion

A well-defined, locally contextualized bundle of interventions was successfully implemented in a limited resource setting to reduce HA-BSI. Identification of factors promoting sustainability and implementation in other settings are urgently needed.

Supplementary material. To view supplementary material for this article, please visit https://doi.org/10.1017/ash.2023.415

Data availability statement. All data generated or analyzed during this study are included in this published article and its supplementary information files.

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Authors' contributions. The project was conceptualized, designed, conducted, and analyzed by the authors. ICK drafted original manuscript. All authors participated in data collection, management, data interpretation, manuscript review/edits, and decision to submit for publication.

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