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CLINICAL AND EPIDEMIOLOGICAL STUDY

Impact of a multidimensional infection control strategy on central line-associated bloodstream infection rates in pediatric intensive care units of five developing countries: findings of the International Nosocomial Infection Control Consortium (INICC)

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Abstract

Purpose To analyze the impact of the International Nosocomial Infection Control Consortium (INICC) multidimensional infection control strategy including a practice bundle to reduce the rates of central line-associated bloodstream infection (CLAB) in patients hospitalized in pediatric intensive care units (PICUs) of hospitals, which are members of the INICC, from nine cities of five developing countries: Colombia, India, Mexico, Philippines, and Turkey.

Methods CLAB rates were determined by means of a prospective surveillance study conducted on 1,986 patients hospitalized in nine PICUs, over a period of 12,774 bed-days. The study was divided into two phases. During Phase 1 (baseline period), active surveillance was performed without the implementation of the multi-faceted approach. CLAB rates obtained in Phase 1 were compared with CLAB rates obtained in Phase 2 (intervention period), after implementation of the INICC multidimensional infection control program.

Results During Phase 1, 1,029 central line (CL) days were recorded, and during Phase 2, after implementing the CL care bundle and interventions, we recorded 3,861 CL days. The CLAB rate was 10.7 per 1,000 CL days in Phase 1, and in Phase 2, the CLAB rate decreased to 5.2 per 1,000 CL days (relative risk [RR] 0.48, 95% confidence interval [CI] 0.29–0.94, $P = 0.02$), showing a reduction of 52% in the CLAB rate.

Conclusions This study shows that the implementation of a multidimensional infection control strategy was

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associated with a significant reduction in the CLAB rates in the PICUs of developing countries.

Keywords Catheter-related infections · Bundle · International Nosocomial Infection Control Consortium · Multidimensional approach · Hand hygiene · Developing countries

Introduction

Central line-associated bloodstream infections (CLABs) have long been associated with excess lengths of stay (LOS), increased hospital costs, and attributable mortality in studies both from high-income countries [1–4] and limited-resource countries [5–7]. The vulnerability of children hospitalized in pediatric intensive care units (PICUs) to mortality and morbidity due to CLABs was highlighted in the scientific literature [6–9]. However, the burden of CLAB in the PICU is not limited to mortality, and in different studies, CLAB was related to other adverse consequences and independent risk factors, such as longer duration of mechanical ventilation, extended device use, unplanned hospital admissions, specific medical therapies, and the presence of noncardiac comorbidities [8, 10, 11].

In addition, the socio-economic level of a country was reported to have an adverse effect on device-associated healthcare-associated infection (DA-HAI) rates in the ICU settings of developing countries. CLAB rates were shown to be higher in low-income countries than in lower–middle- and upper–middle-income countries [12]. In the same manner, hospital type is also considered to be a significant factor influencing DA-HAI rates, which were reported to be substantially higher in "academic and public hospitals" than in private ones [12].

In a wide number of studies, it was demonstrated that implementing infection control programs and practice bundles—including hand hygiene, skin antisepsis, maximal barriers, and timely central line (CL) removal, among others—were associated with a reduction in the incidence density of CLAB [8, 11, 13–19].

Within the particular context of limited-resource countries, there is insufficient recognition of CLABs as a preventable DA-HAI, which is fundamental in order to achieve surveillance for measuring infection risks, outcomes, and processes [20, 21]. Nevertheless, in addition to the implementation of an effective infection control program, there is a pressing need for feedback of surveillance data [14, 19, 22]. Since 2002, the International Nosocomial Infection Control Consortium (INICC) has performed outcome and process surveillance, as part of an integral program specifically designed for ICUs in developing countries [23, 24]. The results reported from INICC hospitals revealed that DA-HAI rates in the ICUs of limited-resources countries are 3–5 times higher than rates in the ICUs of high-income countries [25, 26].

The implementation of the INICC multidimensional program for CLAB prevention is based on the recommendations and guidelines published by the Society for Healthcare Epidemiology of America (SHEA) and the Infectious Diseases Society of America (IDSA) in 2008. These guidelines describe different recommendations for CLAB prevention in the ICU that are classified into categories regarding the existing scientific evidence, applicability, and their prospective economic effects [27–29].

With the aim of reducing these high CLAB rates, we implemented a multidimensional infection control program—which included specific interventions for CLAB prevention, education, practice bundle, outcome surveillance, process surveillance, feedback of CLAB rates, as well as performance feedback of infection control practices—in 11 PICUs of the following five countries: Colombia, India, Mexico, Philippines, and Turkey.

This study analyzes the particular effect of this preventive multidimensional strategy on CLAB rates in the PICUs of developing countries from October 2003 to December 2010.

Methods

Setting and study design

The study was conducted in nine PICUs in nine hospitals which are members of the INICC in the following five countries: Colombia, India, Mexico, Philippines, and Turkey. Each hospital had been actively participating in the INICC surveillance program for at least 3 months and has an infection control team (ICT) comprised of a medical doctor trained in pediatrics, with formal education and background in internal medicine, infectious diseases, and/or hospital epidemiology, and infection control professionals (ICPs). This study was performed in two phases: Phase 1 (baseline period) and Phase 2 (intervention period). The Institutional Review Board (IRB) at each hospital approved the study protocol. Other hospital and PICU characteristics are summarized in Table 1.

Intervention period (Phase 2)

The intervention period was initiated after 3 months of participation in the INICC surveillance program. The average length of the intervention period was 12.8 months ± standard deviation (SD) 8.9 (range 3–24). The INICC multidimensional infection control strategy includes the following: (1) bundle of infection control

Table 1 Characteristics of the participating hospitals (from October 2003 to December 2010)

Data	PICUs, *n*	PICU patients, *n*
Country		
Colombia	3	318
India	2	1,060
Mexico	1	254
Philippines	1	244
Turkey	2	110
Type of hospital, *n* (%)		
Academic teaching	4 (44)	403
Public hospital	1 (12)	254
Private community	4 (44)	1,329

PICU pediatric intensive care unit

interventions, (2) education, (3) outcome surveillance, (4) process surveillance, (5) feedback of CLAB rates, and (6) performance feedback of infection control practices.

Components of the CL care bundle for CLABs

The bundle consisted of the following interventions:

1. Performance of hand hygiene before CL insertion or manipulation [24].
2. Use a chlorhexidine-based antiseptic for skin preparation [16, 30, 31].
3. Use of an all-inclusive catheter cart or kit [32].
4. Use of maximal sterile barrier precautions during CL insertion [33].
5. Disinfection of line hubs, needleless connectors, and infection ports before accessing the CL [34, 35].
6. Removal of nonessential catheters [36, 37].

Education

Education of healthcare personnel involved in the insertion, care, and maintenance of CLs about CLAB prevention [38].

INICC methodology

The INICC surveillance program includes two components: outcome surveillance (DA-HAI rates and their adverse effects, including mortality rates) and process surveillance (adherence to hand hygiene and other basic preventive infection control practices) [23].

Investigators were required to complete outcome and process surveillance forms at their hospitals, which were then sent to the INICC headquarters office in Buenos Aires, Argentina, for their monthly analysis.

Outcome surveillance

The performance of active surveillance for CLAB was associated with a reduction of CLAB rates [39].

The INICC surveillance program applies methods and definitions for HAI developed by the U.S. Centers for Disease Control and Prevention (CDC) for the National Nosocomial Infections Surveillance/National Healthcare Safety Network (NNIS/NHSN) program [40, 41]; however, INICC methods have been adapted to the setting of developing countries, due to their different socio-economic status and specific resource limitations 23.

Outcome surveillance includes rates of CLAB, ventilator-associated pneumonia (VAP), and catheter-associated urinary tract infection (CAUTI) per 1,000 device-days, microorganism profile, bacterial resistance, length of stay, and mortality in their ICUs.

Process surveillance

The infection control and prevention strategies implemented in INICC member hospitals are based on inexpensive and basic evidence-based measures, including outcome surveillance, process surveillance, education, and performance feedback of outcome surveillance and process surveillance [19, 24, 42, 43].

Process surveillance was designed to assess compliance with easily measurable key infection control practices, such as the surveillance of compliance rates for hand hygiene practices and specific measures for the prevention of CLAB, CAUTI, and VAP [23]. Hand hygiene compliance by healthcare workers (HCWs)—based on the frequency with which hand hygiene is performed when clearly indicated—is monitored by the ICPs during randomly selected 1-h observation periods three times a week. Although HCWs are aware that hand hygiene practices are regularly monitored, they are not informed of the schedule for hand hygiene observations. Contacts are monitored through direct observation, and the ICPs record the hand hygiene opportunities and compliance before contact with each patient. ICPs are trained to detect hand hygiene compliance and record it on a form specifically designed for the study. In particular, the INICC direct observation comprises the "five moments for hand hygiene" as recommended by the World Health Organization (WHO). The "five moments" were designed on the basis of the evidence concerning HAI prevention and control, being rational, plausible, and fully appropriate for the healthcare setting. Namely, they include the monitoring of the following moments: (1) before patient contact, (2) before an aseptic task, (3) after body fluid exposure risk, (4) after patient contact, and (5) after contact with patient surroundings [44].

CL care compliance is also monitored and recorded 5 days a week by means of completing surveillance forms that evaluate whether infection control procedures were correctly carried out by the HCW. The ICP observing the activity in the ICU filled out a standardized form that contained the following data: total number of inserted CLs for each patient for the whole ICU; total number of dressings placed to protect the puncture site; total number of dressings, specifying the type of dressing (sterile gauze or transparent dressing) used to protect the puncture site; total number of dressings in correct condition, evaluating whether the dressing was clean, dry, and correctly adhered to the puncture site; and the total number of cases, in which the dates of insertion were written in the administration set of the patient or the dressing [23].

Performance feedback

Performance feedback of infection control processes is an essential tool for improving adherence with preventive strategies and guidelines, as shown in different INICC studies [19, 24, 42, 43, 45].

Upon processing the hospitals' surveillance data on a monthly basis, the INICC research team, at INICC Headquarters located in Buenos Aires, Argentina, prepares and sends to each ICT a final report on the results of outcome surveillance, that is, monthly DA-HAI rates, length of stay, bacterial profile and resistance, and mortality, as well as process surveillance rates, including compliance with hand hygiene, care of CL and urinary catheter, and measures for VAP prevention [23].

Performance feedback is provided to HCWs working in the PICU by communicating the assessment of practices routinely performed by them. The resulting rates are reviewed by the ICT at monthly meetings, where charts are analyzed, and statistical graphs and visuals are posted inside the ICU, to provide an overview of rates of DA-HAIs and rates measuring compliance with infection control practices. This infection control tool is key to enabling the ICT and ICU staff to focus on the necessary strategies for the improvement of low compliance rates.

Definitions

Laboratory-confirmed CLAB

When CLAB is suspected, the CL is removed aseptically and the distal 5 cm of the catheter is amputated and cultured, using the standardized semi-quantitative method [46]. Concomitant blood cultures are drawn percutaneously in most cases. In each hospital, standard laboratory methods are used to identify microorganisms and standardized susceptibility testing is performed.

A patient with a CL who has a recognized pathogen isolated from one or more percutaneous blood cultures after 48 h of catheterization; the pathogen cultured from blood is not related to an infection at another site; and a patient has one or more of the following signs or symptoms: fever (≥38°C), chills, or hypotension. With skin commensals (diphtheroids, *Bacillus* spp., *Propionibacterium* spp., coagulase-negative staphylococci or micrococci), the organism has been recovered from two or more separate blood cultures [41].

Clinically suspected CLAB

A patient with a CL who has at least one of the following clinical signs, with no other recognized cause: fever (≥38°C), hypotension (systolic blood pressure ≤90 mmHg), or oliguria (≤20 mL/h), but blood cultures were either not obtained or no organisms were recovered from blood cultures; there is no apparent infection at another site; and the physician instigates antimicrobial therapy [41].

Statistical methods

Patient characteristics during the baseline and intervention periods in each PICU were compared using Fisher's exact test for dichotomous variables and unmatched Student's *t*-test for continuous variables. Relative risk (RR) ratios with 95% confidence intervals (CIs) were calculated for comparisons of rates of CLAB and CL care bundle at baseline and the subsequent intervention period. *P*-values <0.05 by two-sided tests were considered to be significant.

We used a negative binomial regression model to attempt to describe the relationship between the lengths of time an ICU participates in the INICC with the CLAB rate recorded. The dependent variable is the number of CLABs recorded (a negative binomial model is used because, although this is count data, there are a large number of zero counts) and the independent variable is the length of time that a unit participated in the INICC in months. CLAB counts are grouped across ICUs in 1-month periods.

Results

Over the whole study period, 1,986 patients hospitalized for 12,774 days in nine PICUs were enrolled, and totaling 4,890 CL days. The participating hospitals were summarized and classified according to number of PICUs, type of hospital, and country. The first ICUs that participated in the study began collecting data in October 2003, and the latest information we included in this analysis is from November 2010 (Table 1).

Patient characteristics, such as gender, underlying diseases, previous infection, and length of stay with the CL in place, were similar during the baseline and intervention phases (Table 2).

The microorganisms profile is shown in Table 3.

In relation to compliance rates, during Phase 2, hand hygiene compliance improved significantly to 79%. Likewise, the presence of CLs with sterile gauze or sterile transparent dressing rose from 84.0 to 97.2% (RR 1.16, 95% CI 1.07–1.26, $P = 0.0004$) and the presence of sterile gauze or sterile transparent dressing in good condition rose from 83.9 to 93.9% (RR 1.12, 95% CI 1.03–1.21, $P = 0.0068$), showing a significant improvement in the performance of infection control practices (Table 4).

Regarding CLAB rates, during Phase 1 (baseline period), there were 1,029 documented CL days, for a mean CL use of 0.41. There were 11 CLABs, for an overall baseline rate of 10.7 CLABs per 1,000 CL days. In Phase 2, after the implementation of the multidimensional infection control program, there were 3,861 CL days, for a mean CL use of 0.38. There were 20 CLABs, for an incidence density of 5.2 per 1,000 CL days. These results showed a CLAB rate reduction from a baseline of 52% (10.7–5.2 CLABs per 1,000 CL days; RR 0.48, 95% CI 0.29–0.94, $P = 0.0271$) (Table 5).

Our negative binomial regression model describes the relationship between the lengths of time an ICU participates in the INICC with the CLAB rate recorded. Although this method does not account for the correlation in counts across ICUs over the study period, it is a simple way to describe the relationship between the two, and, as the data is sparse (only 31 CLAB in total across the whole study) and the number of CL days contributed in each study period low, it provides a simple graph that is relatively easy to interpret. Figure 1 shows the pooled mean CLAB rate per 1,000 CL days plotted for each month, with the predicted line giving the CLAB count from this negative binomial model.

Discussion

Our findings showed how improvements in CL care practices are associated with a reduction in the risk of CLABs. Our multidimensional infection control program was focused on CLAB outcome and process surveillance, the implementation of a bundle of CL care techniques, education, adherence to infection control guidelines, and performance feedback, which were adapted as a simple but effective strategy for the limited-resource setting.

The reduction of CLABs is considered of primary importance in public health in the developed world. In developing countries, CLAB rates were reported to be 3–5 times higher than in US ICUs [26, 47]. There are intrinsic factors which contribute to these higher DA-HAI rates, associated with their lower socio-economic level and lack of adequate financial resources, personnel levels, and medical supplies [12]. CLAB rates in ICUs from developing countries were found to be higher in low-income countries than in lower–middle and upper–middle-income countries [12]. Similarly, the type of hospital also influences DA-HAI rates in ICUs, which were shown to be statistically significantly higher in “academic and public hospitals” than in “private” ones [12].

Successful CLAB preventive strategies have been described in the literature over the last several decades [8, 11, 15–18, 48]. It was shown that the CLAB rate in the PICU can be reduced by more than 30% [15, 16]. The implementation of a multidimensional infection control program focused on CLAB surveillance was proved to be an essential tool to countervail CLABs and their severe consequences in the PICU setting [8, 11, 13, 17]. In a study

Table 2 Characteristics of patients hospitalized in pediatric intensive care units (PICUs) in Phase 1 (baseline period) and in Phase 2 (intervention period)

	Baseline	Intervention	RR	95% CI	*P*-value
No. of patients	378	1,608			
Study period by hospital (months), mean ± SD (range)	3	12.8 ± 8.8 (3–24)			
Central line duration, mean ± SD	2.73 ± 5.3	2.40 ± 5.7			0.312
Sex, *n* (%)					
Male	220 (58)	923 (57)	0.98	0.86–1.12	0.7446
Female	156 (42)	683 (42)			
Age, mean ± SD	5.6 ± 4.6	6.5 ± 7.1			0.046
Abdominal surgery, *n* (%)	4 (1)	8 (0.5)	0.47	0.14–1.56	0.2069
Thoracic surgery, *n* (%)	1 (0.3)	12 (1)	2.82	0.37–21.70	0.8775
Previous infection, *n* (%)	23 (6)	29 (2)	0.30	0.17–0.51	0.3851

RR relative risk, *CI* confidence interval, *SD* standard deviation

Table 3 Microorganism related to central line-associated bloodstream infection (CLAB) in PICUs in Phase 1 (baseline period) and in Phase 2 (intervention period)

Isolated microorganisms	Baseline, % (*n*)	Intervention, % (*n*)
Acinetobacter spp.	0 (0)	9 (1)
Candida spp.	0 (0)	9 (1)
Klebsiella spp.	20 (1)	18 (2)
Pseudomonas spp.	60 (3)	36 (4)
Coagulase-negative staphylococci	0 (0)	9 (1)
Stenotrophomonas spp.	20 (1)	0 (0)
Streptococcus spp.	0 (0)	9 (1)
Other microorganisms	0 (0)	9 (1)

Table 4 Hand hygiene, CL use, and CL care improvement in PICUs in Phase 1 (baseline period) and in Phase 2 (intervention period)

	Phase 1 (1–3 months)	Phase 2	RR (95% CI)	*P*-value
No. of hand hygiene observations	512	2,180		
Hand hygiene compliance, % (*n*)	56 (285)	79 (1,721)	1.42 (1.25–1.61)	0.0001
No. of inserted CLs	887	2,686		
CLs with sterile gauze (%)	84.0 (745)	97.2 (2,610)	1.16 (1.07–1.26)	0.0004
CLs with sterile gauze in good condition (%)	83.9 (744)	93.9 (2,522)	1.12 (1.03–1.21)	0.0068
No. of CL days	1,029	3,861		
CL use, mean	0.41	0.38	0.93 (0.87–0.99)	0.01

RR relative risk, *CI* confidence interval

Table 5 CLAB rate in Phase 1 (baseline period) and in Phase 2 (intervention period)

	Baseline period (months 1–3)	Intervention period	RR (95% CI)	*P*-value
No. of CLABs	11	20		
No. of CL days	1,029	3,861		
CLAB rate per 1,000 CL days	10.7	5.2	0.48 (0.29–0.94)	0.02

RR relative risk, *CI* confidence interval, *CLAB* central line-associated bloodstream infection, *CL* central line

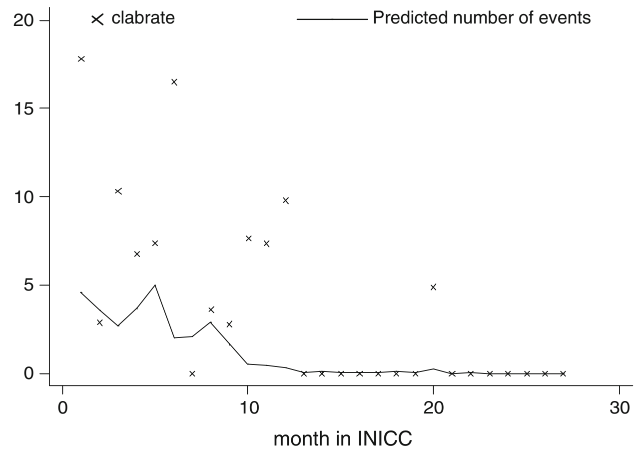

Fig. 1 Central line-associated bloodstream infection (CLAB) rates by month with fitted values: negative binomial regression. Note that the variation in the predicted CLAB rate is shown as a straight line because of the variation in central line (CL) days contributed by the intensive care units (ICUs) during the study period

conducted by the INICC in 15 developing countries, it was shown that, after the inception of a strategy that included education, performance feedback, outcome, and process surveillance, there was a cumulative reduction of 54% in the CLAB rate and of 58% in the mortality rate in the ICU [49].

The INICC multidimensional strategy for CLAB prevention is based on the guidelines published by the SHEA and the IDSA in 2008. These guidelines provide evidence-based recommendations and cost-effective infection control measures, which can be feasibly adapted to the ICU setting in developing countries [29]. Our multidimensional approach was based on infection control measures, which were previously assessed in the developed world, such as hand hygiene [24, 45] and CL care techniques, education, and performance feedback [50, 51]. The successful results obtained with performance feedback have also been evaluated as a key measure to reduce and control DA-HAI in different studies conducted in the INICC member hospitals and the developing world [19, 24, 42, 43, 45, 49, 52–55].

In this respect, it was shown in studies performed in Argentina and in Mexico that the sequential implementation of education and performance feedback programs led to substantial reductions in the incidence of CLAB [19, 54].

The analysis on our baseline data showed a high incidence density of CLAB in our PICUs, which was reduced by 52% after the implementation of the multidimensional strategy. During baseline and intervention, patients' characteristics (gender, underlying diseases [abdominal surgery, thoracic surgery, previous infection], and CL duration) were similar. All participating hospitals are from countries with low, lower–middle, and upper–middle economies. The type of hospital was not considered to be a factor that could explain the high CLAB incidence, because most of the enrolled patients were from academic and private hospitals, and only 12% were from public hospitals, whose DA-HAI rates have been reported to be negatively affected by their limited financial resources and insufficient ICU staff if compared to the other types of hospitals [12].

We found statistically significant improvements in hand hygiene compliance, within the CL care bundle, in relation to the presence and good condition of catheters with sterile gauze or sterile transparent dressing, and we had a significant reduction in the use ratio of CL. In this respect, in a study performed in Argentina, it was demonstrated that the inception of a program focused on education and frequent performance feedback resulted in a sustained improvement with hand hygiene compliance, which also coincided with a reduction in DA-HAI rates in the ICU setting [24].

These findings were similar to the results reported in a study performed in Mexico, in which the effectiveness of an infection control program consisting of education, process control, and performance feedback was associated to significant reductions in the rates of CLAB and mortality [54].

In conclusion, an analysis of the implementation of the multidimensional infection control program for CLAB prevention showed that the reduction in the CLAB rate of our PICUs was associated with the effective impact of our multidimensional strategy in the pediatric setting of developing countries. Clearly, the results from Fig. 1 are encouraging: the CLAB rates dropped to almost zero as the time in the INICC increases.

However, despite our motivating results, we consider that our rates also indicated there is a need for continuous and sustained improvement in practices, as they are higher than the rates reported from the developed world [26, 47].

Limitations of this study are based around the fact that our findings are not to be generalized to PICU patients from every developing country; however, this study proved that a multidimensional approach, including process and outcome surveillance in addition to a bundle of CL interventions, is fundamental to understand and fight against the adverse effects of CLAB in the PICUs of limited-resource settings. Second, the setting of a 3-month baseline period may be short and might have overestimated the effect of the intervention; however, this duration of baseline period is common in the scientific literature [18]. Finally, we could not quantify in detail information for each PICU on the compliance of each bundle component and other non-quantifiable interventions included in our multidimensional approach, such as education and training.

We expect that the infection control and prevention multifaceted approach fostered by the INICC will increasingly be carried out in the context of the developing world to achieve successful reductions in DA-HAIs.

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Conflict of interest The authors state that they do not have any conflicts of interest to declare.

Ethical standard Every hospital's Institutional Review Board agreed to the study protocol, and patient confidentiality was protected by codifying the recorded information, making it identifiable only to the ICT.

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