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Implementation of tailored interventions in a statewide programme to reduce central line-associated bloodstream infections

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SUMMARY

Background: There have been few studies exploring implementation strategies to central line-associated bloodstream infections (CLABSIs) in low- or middle-income countries.
Aim: To implement tailored interventions to reduce CLABSI rates in adult intensive care units.
Methods: The implementation strategy of the State Health Department was performed in São Paulo State, Brazil, over two cycles. Cycle 1 (56 hospitals) was exploratory and cycle 2 (77 hospitals) was designed to confirm the hypothesis generated by the first cycle, with three phases each (pre-intervention, intervention, post-intervention). Cycles included: evaluation of healthcare workers' knowledge, observation of practices, and CLABSI rates monthly report. In cycle 1, a log–normal mixed model was used to select variables significantly associated with the reduction of CLABSI. In cycle 2, CLABSI rates were evaluated.
Findings: Healthcare workers' practices improved after intervention. In cycle 1, reduction of CLABSI rates was more pronounced in hospitals with initial CLABSI rates >7.4 per 1000 catheter-days ($P < 0.001$) and those that introduced the use of peripherally inserted central catheters ($P = 0.01$). For hospitals with high CLABSI initial rates, simulation demonstrated that the rates were expected to decrease by 36% (95% CI: 9–63), no matter the type of intervention. In cycle 2, there was an overall decrease in CLABSI rates during the intervention period; whereas the mean rate fell further post-intervention, rates at the 90th percentile increased.
Conclusion: The implementation strategy may have had an effect on infection rates independently of the specific interventions implemented; however, the sustainability of reduction in the post-intervention period remains a challenge.

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Introduction

Central line-associated bloodstream infections (CLABSIs) are a common healthcare-associated infection (HCAI) and a major cause of morbidity and mortality in intensive care units (ICUs) [1]. Low- and middle-income countries may have rates up to 16–19 times higher for CLABSI compared to developed countries [2]. Therefore, efforts to prevent these infections are of the utmost relevance [3].

Several studies have shown the feasibility and cost-effectiveness of interventions to reduce CLABSI, and governmental initiatives seem to be important [4–6]. HCAIs are a global concern requiring evidence-based strategies to be carried out by governments to achieve national and regional results. However, few studies have explored implementation strategies in low- or middle-income countries.

The objective of this study was to evaluate the impact of a government programme to implement tailored interventions aiming to reduce rates of CLABSI in adult ICUs in the state of São Paulo, Brazil.

Methods

Study design and context

This was a prospective quasi-experimental study of implementation carried out in São Paulo, the most populous state in Brazil with ~42 million inhabitants; 383 out of 838 hospitals have ICUs. There is a surveillance system to monitor HCAI rates in the state. From 2004 to 2006, the median rates of CLABSI in the state ranged from 4.1 to 4.2 per 1000 catheter-days [7].

Implementation strategy

The implementation strategy was performed by State Health Department along two cycles (cycles 1 and 2) with three phases each (pre-intervention, intervention, post-intervention) (Figure 1), based on four pillars: (a) engagement of hospital administration; (b) building of a networked community among participants; (c) co-design of action plans and interventions; (d) stepwise monitoring of tailored interventions. Cycle 1 was exploratory, aimed at identifying factors associated with CLABSI reduction, and lasted from March 2011 to February 2012. Cycle 2 was designed to confirm our hypothesis that CLABSI rate reduction would occur among participant hospitals, and lasted from March 2015 to December 2016. In both cycles, a letter was sent to the hospital administration departments to engage them and obtain their official acceptance. Hospitals formed work teams which were summoned to an inception meeting to explain the project. Further meetings occurred to perform the steps: co-design of work plan, tailored interventions, and strategies to overcome barriers; exchange of experiences among participants; and feedback and discussion of results.

Inclusion criteria

In order to define the sample of hospitals of exploratory cycle 1, the CLABSI rates from 383 hospitals notified over the previous three years (2007–2009) were divided into 20 strata, each with amplitude of 0.99. A sample was selected for each stratum. A weighted mean CLABSI rate was obtained for each

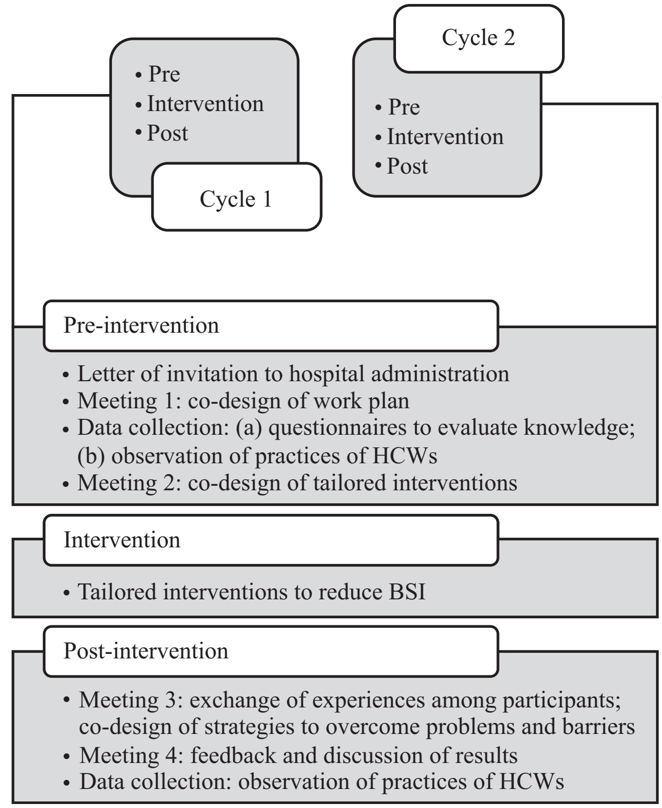

Figure 1. Cycles and phases of the implementation strategy of tailored interventions to reduce central line-associated bloodstream infections, São Paulo, Brazil, March 2011 to February 2016. HCWs, healthcare workers; BSI, bloodstream infection.

hospital, in which the more recent years were considered more important. The first stratum began with a CLABSI rate of zero and the last with a CLABSI rate of 30 per 1000 catheter-days. The sample for each stratum was determined through a pilot sample, with a maximum estimation error of 0.05. In each stratum, hospitals were randomly selected using statistical software R. The estimated sample size was 54 hospitals. Of these, 18 declined to participate, whereas 20 hospitals not originally selected requested to participate, resulting in a final number of 56 hospitals in cycle 1. In cycle 2, hospitals whose rates were positioned in the highest two tertiles, i.e. rates >6.11 per 1000 catheter-days in 2013, were invited to participate ($N = 134$), and 77 accepted. For logistic reasons, these hospitals were organized into two groups that worked asynchronously (34 in group 1 and 43 in group 2). Hospitals could choose one or more ICUs for the study; the final number of participant ICUs in cycle 2 was 99.

Data collection

Figure 1 represents the data collection process, which included outcomes and process indicators. CLABSI was defined according to Centers for Disease Control and Prevention criteria. The work teams used two standard tools to support the implementation: (a) quantitative questionnaires were applied in the ICU to assess knowledge of healthcare workers (HCWs) on hand hygiene, catheter insertion and maintenance; (b) observation of HCW compliance with prevention measures in procedures involving central lines (CL), including insertion (site selection, hand hygiene, use of mask, sterile gown, sterile gloves, and sterile full-body drapes) and ongoing care (hand hygiene before and after handling, hub disinfection, appropriate dressings). Each work team defined the number of observations according to their capabilities. Work teams summarized the data and sent them to the State Health Department; pooled data were fed back to participants at meetings.

Tailored interventions

The following interventions were co-designed by participants based on the results of data collected: provision and reinforcement of use of alcohol hand rub; provision of catheter insertion kits and alcohol wipes for disinfection of the CL hub, training of HCWs, strengthening of leadership within ICU; HCW feedback; and routine use of peripherally inserted central catheters (PICCs). Work teams were encouraged to implement the interventions tailored to their hospital's needs.

Data analysis

In cycle 1, the aggregated rates of CLABSI were analysed quarterly. The rate of CLABSI was the average rate of CLABSI during the pre, post and intervention periods. To evaluate whether the interventions had an impact on hospitals with different pre-intervention rates of CLABSI, the 56 hospitals were categorized by the corresponding tertiles according to their initial rates per 1000 catheter-days. The categories were: low ($N = 18$ hospitals <2.6), medium ($N = 19$ hospitals from 2.6 to 7.0), and high ($N = 19$ hospitals >7.4). Log–normal mixed effects models and generalized estimating equation-based models were used: (i) to select variables significantly associated with the variation in rates of CLABSI; (ii) to simulate estimates of their expected values; and (iii) to quantify the variation in these rates in different periods of observation. Initially, we used fitting models with the period effect and each variable individually. Subsequently, the significant variables plus the period effect and number of alcohol dispensers (even if not significant) were jointly fitted. In the third step, we eliminated the non-significant variables in the joint model and included the remaining variables along with their interactions with period and pre-intervention CLABSI. In the final statistical analysis, we excluded hospitals with missing values, reducing the sample to 40 hospitals. In cycle 2, for each period (pre, post and intervention period), the pooled mean of CLABSI rates of each participant hospital was determined and the results were presented as medians, interquartile ranges, and overall ranges.

Ethical approval

This study was approved by the Institutional Committee for Ethics in Research (number 302/11). Informed consent was waived. The identification of observed HCWs remained anonymized during the entire study.

Results

Characteristics of participant hospitals did not present relevant differences between the two cycles (Supplementary Table I). Work teams were composed of two to 26 participants. In 95% of work teams, infection control staff participated, and only 13% included members of the hospital's upper management.

Cycle 1

Assessment of knowledge was performed by 2186 HCWs who completed the questionnaire. Regarding CL insertion, correct answers were 99% on hand hygiene; 70% on skin preparation; 96% on the use of mask, sterile gown, sterile gloves; 85% on the use of sterile full body drapes; 74% on the choice of insertion site. Regarding CL care, 96% answered correctly on hand hygiene; 92% on hub disinfection; and 61% on early catheter removal. Practices improved after the intervention (Table I).

Regarding tailored interventions, most hospitals (96%) conducted training programmes with a total of 323 sessions involving 1573 HCWs. A large proportion of the hospitals (71%) implemented CL insertion kits; 42% of hospitals implemented alcohol hand rubs and 15% implemented the use of PICCs.

Over the six trimesters we observed that hospitals with higher rates demonstrated more pronounced positive results than the others (Supplementary Figure I); this was the main reason to focus on them in cycle 2. In hospitals with high initial CLABSI rates, the median rates of CLABSI decreased significantly post-intervention ($P < 0.0001$). However, in hospitals with initial low or moderate CLABSI rates, there was no relevant change in medians post-intervention. In the final model, the observation period ($P < 0.001$), the initial CLABSI rates ($P < 0.001$) and the use of PICCs ($P < 0.1$) were associated with decreasing rates. Installation of additional dispensers of alcohol hand rubs was not associated with reduction of rates ($P = 0.38$) (Supplementary Table II).

The expected CLABSI rates simulated in the final model are shown in Table II. From these simulations we demonstrated that for those hospitals with higher rates, the decrease would occur no matter the changes in the variables.

Many work teams declared that their direct contact with the State Health Department empowered them and increased their importance in the eyes of their hospital administrators.

Cycle 2

The questionnaire to assess knowledge on the prevention of infection was completed by 2655 HCWs. Questions were correctly answered by up to 80% of HCWs; however, in questions regarding the choice of insertion site (72%) and early catheter removal (69%) performance was lower (Table I).

In this cycle, hospitals showed a positive response, demonstrating overall better percentage of compliance. Significant results were observed regarding CL handling and catheter site dressing. There was an overall reduction in CLABSI rates in the intervention period. However, rates at the 90th percentile were higher in the post-intervention period compared to the intervention period (Figure 2).

Discussion

Traditionally, strategies to reduce HCAI have been performed using a fixed model in which measures are implemented seeking to reduce HCAI rates. More recently, the strategy 'bundle' has been the paradigm for improvement in this field. CL bundles have been proven effective in preventing CLABSI in the ICU [4,5].

Table I

Healthcare workers' practices during insertion, handling of central lines (CLs), and catheter site dressing; before and after interventions in 56 hospitals (cycle 1) and 77 hospitals (cycle 2)[a]

Practices observed	Cycle 1			Cycle 2		
	% compliance (no. of observations)		*P*-value	% compliance (no. of observations)		*P*-value
	Pre-intervention	Post-intervention		Pre-intervention	Post-intervention	
Insertion						
Performed subclavian insertion	49 (1864)	57 (1434)	<0.0001	46 (1201)	53 (1439)	<0.0001
Performed hand hygiene before CL insertion	96 (1739)	97 (1288)	0.18	100 (1265)	99 (1617)	0.14
Used alcoholic solution for skin preparation	98 (1503)	84 (1146)	<0.0001	97 (1235)	97 (1666)	0.91
Used sterile full-body drapes	90 (1586)	92 (1166)	0.048	98 (1240)	99 (1596)	0.15
Used cap, mask, sterile gown, sterile gloves	93 (1554)	93 (1174)	0.51	95 (1219)	96 (1593)	0.12
CL handling						
Performed hub disinfection	63 (4017)	79 (4395)	<0.0001	74 (4612)	82 (2836)	<0.0001
Performed hand hygiene before CL handling	77 (4595)	91 (4512)	<0.0001	80 (4394)	91 (3117)	<0.0001
Performed hand hygiene after CL handling	80 (4106)	89 (4816)	<0.0001	83 (4473)	95 (3361)	<0.0001
Catheter site dressing						
Used occlusive dressing	95 (5290)	94 (4126)	0.017	96 (6076)	95 (4244)	0.006
Dressing was dry and clean	93 (5157)	92 (4119)	0.31	92 (6121)	94 (4222)	0.004
Used alcoholic solution for skin antisepsis during dressing	88 (2338)	89 (2032)	0.24	93 (2054)	94 (1663)	0.025
Performed hand hygiene before CL dressing	89 (2463)	96 (1806)	<0.0001	92 (2075)	89 (1740)	0.0005
Performed hand hygiene after CL dressing	86 (2390)	96 (2061)	<0.0001	93 (2081)	96 (1667)	<0.0001

[a] Statewide programme to reduce central line-associated bloodstream infection. São Paulo, Brazil, 2011/2015–2016.

The main innovation of our study was the use of an implementation strategy using tailored interventions co-designed by the participants. Definitions of tailored interventions may vary depending on the authors and purposes [8,9]. In the present study we used the term to define a set of measures to target the specific needs of healthcare institutions for CLABSI prevention. The success of the interventions was assessed by the reduction in CLABSI rates and the improvement in practices of CL care.

Our primary assumption was that co-design of tailored interventions, along with giving autonomy to work teams to decide the set of interventions that was most suitable to them, would empower and entrust the work teams. Work teams were engaged in the implementation process and were supplied with tools to help each hospital to improve their practices and infection rates. Therefore, we worked to strengthen the role of the public health agency in the leadership of the process of continuous improvement toward HCAI elimination [10]. Nevertheless, building up knowledge among HCWs was challenging, and knowledge around a few subject areas remained below expectations; thus there remained ample room for further and ongoing education.

The perception of empowerment that came from this process, and was mentioned by the work teams, should be further explored in future research. A combination of engagement of the hospital administration departments; a networked community; and support from the State Health Department probably led to the process of mimetic and normative institutional isomorphism that was also described regarding the Michigan Keystone Project, in the USA [5,11]. This is of singular importance in the challenging context of most of low- and middle-income countries due to insufficient resources, while facing a greater burden of HCAI compared with high-income countries [2].

In cycle 1, the reduction of CLABSI rates was more significant in hospitals with initial rates >7.4 per 1000 catheter-days. It was unclear why hospitals with lower rates did not experience improvement in reducing HCAI. In this cycle we observed a decrease in HCAI rates in those participant hospitals that implemented the use of PICCs as part of their intervention. The use of PICCs to prevent CLABSI is widespread in neonatal ICUs; however, in adult ICUs the evidence for their effectiveness in reducing HCAI rates remains inconclusive [12–15]. Our results contribute to broadening the knowledge about the use of PICCs as a measure to decrease CLABSI rates.

Unexpectedly, increasing the number of alcohol hand rub dispensers installed was not associated with reduction of CLABSI rates. This may be explained by the high adherence to hand hygiene even before the intervention (between 75% and 91%), much higher than that reported by other authors worldwide [4,16,17]. However, hand hygiene adherence rates may have been overestimated, since observations were performed by the work teams. Nevertheless, our results point to there being other reasons underpinning the acquisition of CLABSI in the hospitals.

Remarkably, the final model simulation performed in cycle 1 showed that, for hospitals with high initial rates, even without the implementation of PICCs and without the installation of alcohol hand-rub dispensers, the infection rates were expected to decrease by 36%. This suggests that our implementation strategy may have had an effect on rates independently of any

Table II
Examples of simulated CLABSI rates in pre, post and intervention periods, according to variation in use of PICCs and number of alcohol dispensers[a]

Initial CLABSI rate	Use of PICC	No. alcohol hand-rub dispensers installed	Period	Estimated CLABSI rate (95% CI)
High	No	0	Pre	12.1% (8.9–16.4)
			Intervention	7.7% (4.7–12.1)
			Post	7.8% (4.8–12.2)
Variation post/pre				−36% (−63 to (−)9)
High	Yes	5	Pre	11.7% (7.8–17.3)
			Intervention	7.4% (4.2–12.5)
			Post	7.5% (4.3–12.6)
Variation post/pre				−36% (−63 to (−)9)
Medium	Yes	5	Pre	9.2% (5.6–14.6)
			Intervention	8.0% (4.4–14.0)
			Post	9.5% (5.2–16.8)
Variation post/pre				3% (−38 to 46)
Medium	No	10	Pre	4.5% (2.9–6.9)
			Intervention	3.9% (2.1–6.7)
			Post	4.7% (2.6–8.2)
Variation post/pre				4% (−41 to 51)
Low	Yes	0	Pre	1.6% (0.6–3.3)
			Intervention	3.9% (1.8–7.5)
			Post	2.9% (1.2–5.9)
Variation post/pre				81% (1–162)
Low	Yes	3	Pre	0.3% (0.0–0.8)
			Intervention	1.5% (0.7–2.7)
			Post	1.0% (0.3–2.0)
Variation post/pre				233% (1–405)

CLABSI, central line-associated bloodstream infection per 1000 catheter-days; PICC, peripherally inserted central catheter; CI, confidence interval.
[a] Statewide programme to reduce infection, São Paulo, Brazil, 2011.

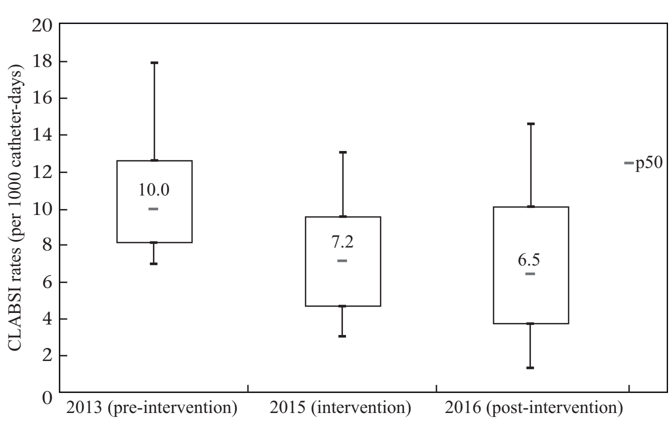

Figure 2. Rates of central line-associated bloodstream infections (CLABSIs) per year. Statewide programme to reduce central line-associated bloodstream infection, cycle 2 ($N = 77$ hospitals), São Paulo, 2015–2016.

specific type of intervention adopted. Reinforcing this, during cycle 2 CLABSI rates went down during the intervention period. A valuable lesson to be learned is that health authorities should exert a positive leadership and establish a supportive environment. Nevertheless, in cycle 2, the high rates of 10% of hospitals in the post-intervention period showed that the sustainability of the process was not achieved by all participant institutions.

As a limitation of our study, the initial sample was not attained because some hospitals declined to participate and were replaced by others that requested participation. Thus, potential for selection bias was unavoidable. Another concern is whether a surveillance effect, as described by Gastmeir *et al.*, caused a decrease in rates. We do not believe that this effect occurred in our study because all the participants already were engaged in the surveillance system before the interventions [18].

In conclusion, the programme for reducing CLABSI achieved better results in hospitals that had high initial rates and those that introduced the use of PICC. Our findings suggested that the implementation strategy may have had an effect on infection rates independently of the specific interventions implemented. Factors that affect sustainability of the process should be further explored.

Acknowledgement

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Conflict of interest statement

Communication with the participant hospitals and infrastructure to hold meetings was provided by the Secretary of Health of the State of São Paulo, Brazil. None of the authors has relationships with the industry, specifically producers and sellers of peripherally inserted central catheters.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.jhin.2018.04.020.

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