PARTNERSHIP AMONG HOSPITALS TO REDUCE HEALTHCARE ASSOCIATED INFECTIONS: A QUASI-EXPERIMENTAL STUDY IN BRAZILIAN ICUS

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Conflicts of interest: None to report

Abstract

Background: Healthcare-associated infections (HAIs) are relevant in developing countries where frequencies can be at least 3 times higher than in developed countries. The purpose of this research was to describe the intervention implemented in ICUs to reduce HAIs through collaborative project and analyze the variation over 18 months in the incidence density (ID) of the three main HAIs: ventilator associated pneumonia (VAP), central line-associated bloodstream infections (CLABSIs) and catheter-related urinary tract infections (CAUTIs) and also the length of stay and mortality in these ICUs.

Methods: A quasi-experimental study in 5 public adult clinical-surgical ICUs, to reduce HAIs, through interventions using the BTS-IHI "Improvement Model", during 18 months. In the project, promoted by the Ministry of Health, Brazilian philanthropic hospitals of excellence (HE) regularly trained and monitored public hospitals in diagnostics, data collection and in developing cycles to improve quality and to prevent HAIs (bundles). In the analysis regarding the length of stay, mortality, the IDs of VAP, CLABSIs and CAUTIs over time, a GEE (Generalized Estimating Equation) model was applied for continuous variables, using the constant correlation (exchangeable) between assessments over time. The model estimated the average difference (β coefficient of the model) of the measures analyzed during two periods: a period in the year 2017 (prior to implementing the project) and in the years 2018 and 2019 (during the project).

Result: A mean monthly reduction of 0.427 in VAP ID ($p = 0.002$) with 33.8% decrease at the end of the period and 0.351 in CAUTI ID ($p = 0.009$) with 45% final decrease. The mean monthly reduction of 0.252 for CLABSIs was not significant ($p = 0.068$).

Conclusions: Given the success in reducing VAP and CAUTIs in a few months of interventions, the achievement of the collaborative project is evident. This partnership

among public hospitals/HE may be applied to other ICUs including countries with fewer resources.

Trial registration:

This research was promoted and authorized by Brazilian Ministry of Health, carried out through the Institutional Development Program of the Integrated Health System PROADI-SUS[12] and approved by the Ethics Committee of the Hospital das Clínicas - UFPE, under No. 3,307,293.

Key words: Healthcare-associated infections; Breakthrough Series; collaborative; intensive care units; prevention bundles

Background:

Healthcare-associated infections (HAIs) are relevant to global public health, especially in developing countries where the frequency may be at least 3 times higher than in developed countries.[1] In Brazil, the incidence density (ID) of HAIs related to devices in the year 2016 indicated ventilator associated pneumonia (VAP) of 13.6/1000, central line-associated bloodstream infections (CLABSIs) of 4.6/1000 and catheter-related urinary tract infections (CAUTIs) of 5.1/1000,[2] while the 2016 European annual report registered IDs for VAP of 3.9/1000, CLABSIs of 1.7/1000 and CAUTIs of 2.1/1000[3]. Although these are frequent adverse events, with high morbidity and mortality rates and high costs, HAIs are recognized as being preventable in up to 70% of cases.[4]

Outstanding amongst the strategies for healthcare quality improvement, including the reduction of HAIs, is the Breakthrough Series Collaborative method - BTS, by the Institute for Healthcare Improvement - IHI.[5] Since 1996, this has been implemented in a number of health systems, initially and chiefly in developed economies in North America, Europe and Australia,[6] and even in low-to-middle income countries, such as those in Latin America and Africa.[7]

In 2018, Susan Wells et al published the results of a thorough systematic review, studying collaborative methods published between 1995 and 2014 and concluded that, despite methodological limitations and little description regarding aspects of implementation, they were nonetheless effective in improving processes and results. In 83% of hospital studies, there was an improvement in at least one of the investigated indicators and, when a more conservative criterion was used, this effectiveness was 73%.[8]

In Brazil, where there are interstate and regional socioeconomic differences, quality improvement programs (QIPs) using the BTS collaborative method are still rare,

although they were employed in 2015/16 in the southeast of the country for good childbirth[9] and in ICUs in Central, Southeast and South Brazil in combating HAIs,[10] with successful results. However, no publications on QIPs were observed in the current literature in ICUs in the Northeastern region of the country, which has more limited resources.[11]

To reduce the incidence of HAIs, the Brazilian Ministry of Health promoted the collaborative project "The large-scale improvement of patient safety in Brazil", through the Institutional Development Program of the Integrated Health System (PROADI-SUS), with BTS large-scale improvement methodology. In this, Brazilian philanthropic hospitals of excellence (HE) applied their technical capacity and knowledge to promote healthcare improvement in public hospitals across the country (the Integrated Health System, known in Brazil as SUS).[12]

The project took place in 120 adult Brazilian intensive care units (ICUs), five of which were in the Metropolitan Region of Recife, in the northeast of the country, which a population of around 4 million. The purpose of this research was to describe how the PROADI-SUS project was implemented in these five ICUs, and to assess the 30% reduction, over 18 months, in the incidence density (ID) of the three main HAIs: VAP, CLABSIs and CAUTIs,[13] as well as the length of stay and mortality in these ICUs. It should be noted that the majority of existing collaborative projects focus on indicators for only one or two HAIs.[8]

Methods

Study location

This study was conducted in 48 adult ICU beds in five public tertiary hospitals in Recife, in the Northeastern region of Brazil, from January/2018 to June/2019. These were clinical-surgical ICUs with an admission rate of around 1800 patients per year.

Study setting and design

In this quasi-experimental time-series study, interventions were carried and data was collected on a monthly basis for 18 months, including all patients admitted to the ICUs. The methodology was the BTS[5] using the "Improvement model".

Hospital teams were trained in diagnostics, data collection and in developing cycles to improve quality and to prevent HAIs (VAP, CLABSIs and CAUTIs). These face-to-face and online training sessions took place during periodic sessions for sharing questions, experiences and results. The hospitals received educational visits every 4 months together with online consultations with facilitators on the improvement model, patient safety, intensive care and infectious diseases.

The methodology included following instructional diagrams demonstrating the preventive measures for HAIs, implemented through PDSA (Plan-Do-Study-Act) rapid cycle testing.[5] Improvement tests were first performed with a small group of patients and healthcare professionals, thereby enabling small-scale testing to result in learning and adaptations. Once the process was considered suitable for the local reality and the tests had achieved success, it was progressively implemented throughout the rest of the unit. The implemented improvements were monitored by indicators and the institutions received technical visits from the HE.

After each learning session with specialists in quality improvement and HAIs, with the presence of four representatives from each of the hospitals (local management

team), periods of action were initiated, during which the teams returned to their organizations and tested the changes in their contexts.

Result indicators were monitored monthly: incidence densities (ID) of the HAIs, length of stay and mortality in ICUs and process indicators: the rate at which devices were used and adherence to the preventive measures (bundles).

The local teams were instructed to carry out systematic educational observations on the diagnoses and adherence to the bundles, with at least 20 monthly observations per indicator, in order to plan new PDSAs. The established bundles were: 1- VAP: oral hygiene, raised headboard (30 -45º), reduced sedation, verifying the possibility of extubation, maintaining the cuff pressure of the tracheal cannula (25-30cm of H_2O or 20-22 mmHg) and adequate maintenance of the mechanical ventilation system. 2- CLABSIs: on insertion of the central venous catheter (CVC) – check indications, precautions for maximum barrier, skin antisepsis with chlorhexidine, optimal selection of insertion site, adequate dressing after insertion; maintenance of CVC - indication of permanence, aseptic technique in handling, maintenance of the infusion system, correct dressing technique. 3- CAUTIs: when inserting the urinary catheter (UC) – check indication, aseptic technique; maintenance of the UC - permanence of the closed system, correct technique during drainage manipulation, hygiene of the urethral meatus, check the need to maintain the UC.

The local teams monitored and shared the active PDSAs with the ICU team, on a weekly basis - through rounds -, and the indicators, on a monthly basis. The monthly data on the frequency of HAIs and adherence to bundles were recorded on a digital platform to be analyzed in order to direct the necessary actions to improve the team's performance.

Definitions

Surveillance of the HAIs was conducted by professionals trained in infection control, using the definitions of the US Centers for Disease Control and Prevention - CDC[14] and their incidence was expressed as cases per 1,000 devices-day, obtained by the ratio of the monthly number of cases of infection by the number of patients using the device-day related to this infection.

The utilization rate of the devices was the percentage calculated by adding the number of patients using the device-day divided by the sum of the total number of patient-days in the same period.

The percentage of adherence to bundles was assessed by dividing the number of patients observed with 100% adherence to all items in the bundle by the number of patients observed with the device.

Microbiological methods

All isolates were identified by manual or automated methods and confirmed with the Vitek 2 system (bioMerieux Vitek, Inc., Hazelwood, MO).

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Ethical aspects

This research was promoted and authorized by Brazilian Ministry of Health, carried out through the Institutional Development Program of the Integrated Health System PROADI-SUS[12] and approved by the Ethics Committee of the Hospital das Clínicas - UFPE, under No. 3,307,293.

Statistical analysis

In the presentation of hospital characteristics, absolute and percentage frequency measurements were performed for categorical variables, and the mean and standard deviation were calculated, as well as the medians and interquartile ranges for

quantitative variables. The hypothesis of normality for incidence densities (ID) was tested by the Shapiro-Wilks test, and the hypothesis of normality was accepted.

In the analysis regarding the length of stay, mortality, the IDs of VAP, CLABSIs and CAUTIs over time, a GEE (Generalized Estimating Equation) model was applied for continuous variables, using the constant correlation (exchangeable) between assessments over time. The model estimated the average difference (β coefficient of the model) of the measures analyzed during two periods: a period in the year 2017 (prior to implementing the project) and in the years 2018 and 2019 (during the project).

The Spearman's correlation coefficient was estimated in the assessment of process indicators as explanatory variables of the behavior of the result indicators. The percentage of variation in the intervention period was based on the difference between the result indicator in January 2018 and June 2019. All tests of statistical significance were bilateral, with a significance level of 0.05 ($p < 0.05$). All data analyzes were performed using STATA 14.

Results

Characteristics of the hospitals in the study

Five ICUs were selected for the study, totaling 48 beds in the 5 hospitals included in the study. Three were general ICUs, one was a cardiac ICU and the other was a neurological ICU. Table 1 presents the characteristics of the studied hospitals, in which the mean number of patients-day admitted to the analyzed ICUs varied between 179 and 298 patients each month and was higher in hospitals H1, H2 and H3 when compared to hospitals H4 and H5, which presented a lower mean patient-day rate. The mean number of hospitalizations per month ranged from 23 to 31 patients. In the half-yearly assessment, there was an increase in the implementation of PDSAs in most hospitals, with hospitals H1, H2 and H5 presenting a higher percentage of total implementation when compared to the others (Table 1).

Table 1. Characteristics of the five hospitals assessed in the study from January 2018 to June 2019

Characteristics	H1	H2	H3	H4	H5
Total number of beds	234	444	170	415	413
Number of beds in ICU	30	31	30	17	12
Number of beds studied	10	10	10	10	8
Type of ICU studied	Cardiology	General	Neurology	General	General
Patient-day ICU admissions per month [ab]	291 ± 22 (216 – 306)	298 ± 11 (270 – 310)	297 ± 19 (210 – 310)	191 ± 32 (101 – 246)	179 ± 22 (116 – 219)
Monthly number of ICU admissions [a]	31 ± 8 (12 – 45)	23±7 (12 – 45)	30±8 (15 – 51)	25±5 (13 – 33)	24±6 (8 – 33)
PDSAs implemented/carried out (% implemented)					
1º semester	21/36 (58.3%)	9/11 (81.8%)	3/49 (6.1%)	4/30 (13.3%)	19/30 (63.3%)
2º semester	13/18 (72.2%)	2/4 (50.0%)	2/5 (40.0%)	11/25 (44.0%)	14/16 (87.5%)
3º semester	8/9 (88.9%)	2/3 (66.7%)	12/13 (92.3%)	2/3 (66.7%)	4/5 (80.0%)
Total [d]	**42/63 (66.7%)**	**13/18 (72.2%)**	**17/67 (25.4%)**	**17/58 (29.3%)**	**37/51 (72.5%)**
Number of monthly meetings held during the period [c]	4 (3 – 4)	1 (0.25 – 2.75)	2 (1 – 3)	1 (1 – 3)	3 (3 – 3.75)
Percentage of patients with daily defined objectives in ICU [c]	100 (100 – 100)	Not assessed	31.1 (13.6 – 66.9)	53.8 (50.8 – 56.9)	100 (100 – 100)
Assessment period of the defined objectives	Jan/19 to June/19	-	Jan/19 to June/19	Nov/17 to July/18	Jan/18 to June/19
Percentage of patients who received daily multidisciplinary visits in ICU	100 (100 – 100)	19.9 (19.1 – 22.1)	23.1 (13.5 – 26.9)	61.5 (49.7 – 64.0)	100 (100 – 100)
Assessment period of the multidisciplinary visits	Jan/19 to June/19	Feb/19 to June/19	Jun/18 to June/19	Nov/18 to June/19	Jan/18 to June/19

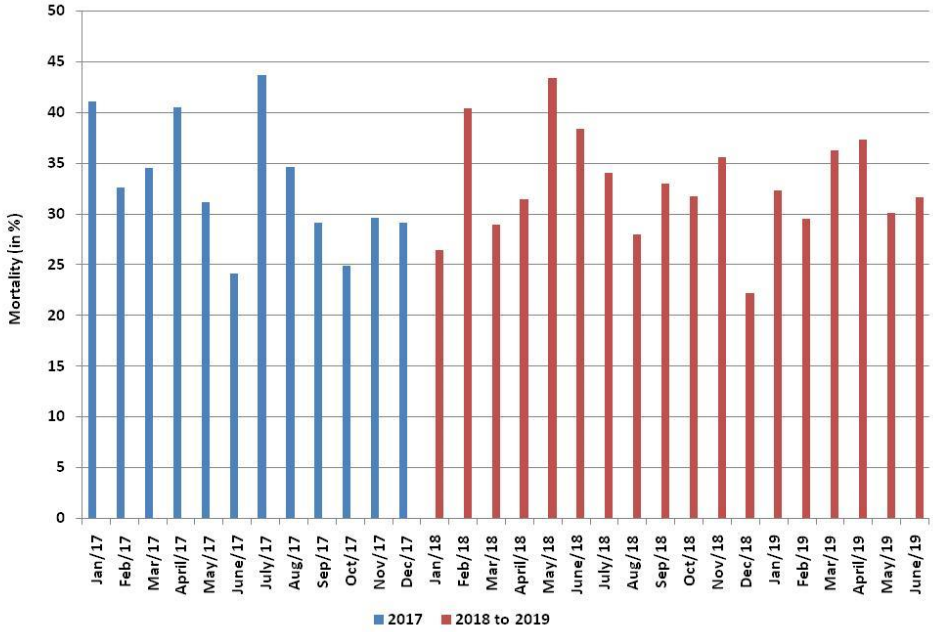
[a] Mean ±SD (min – max) in the studied ICUs b ANOVA: $p < 0,001$ – significant statistical difference: H4 & H5 ≠ H1, H2 & H3 c Median (P25 – P75) d There was a significant statistical difference of the H3 & H4 hospitals when compared to the others ($p<0.05$).

Result indicators

With regard to the group of the 5 ICUs studied, over the 18-month period, there was no variation in relation to mortality (2017: $\beta = -0.889$ ($p = 0.089$) and 2018/2019: $\beta = -0.113$ ($p = 0.646$)) (Graph 1). The mean monthly time of stay decreased in 2017 ($\beta = -0.292$ ($p = 0.033$)) and 2018 ($\beta = -0.276$ ($p = 0.047$)) although in the 6 months of 2019 there was an increase, with no statistical significance ($\beta = 1.399$ ($p = 0.183$)). During the

intervention, there was a mean monthly reduction of 0.427 in the VAP ID (p = 0.002) with a 33.8% decrease at the end of the period, and 0.351 in the CAUTI ID (p = 0.009), which corresponded to a 45% decrease at the end. There was a mean monthly reduction of the CLABSI ID of 0.252, which was not significant (p = 0.068) (Table 2).

Graph 1 Mortality in the ICUs of the five hospitals in the study assessed between January 2017 and June 2019



Before intervention 2017: β = -0.889 (p = 0.089) During intervention 2018 to 2019: β = -0113 (p = 0646).

Table 2. Incidence densities of HAIs in the ICUs analyzed in the periods with no intervention (2017) and during the intervention (2018 and 2019)

Result indicators	Before intervention 2017	During intervention 2018 - 2019	p-value	Variation %
Incidence density of VAP				
Variation over time				
Coefficient β (p-value)	-0.040 (0.934)	-0.427 (0.002)	-	↓33.8%
Assessment by hospital[b]				
H1	-3.784 (0.349)	-0.630 (0.069)	0.123	
H2	-2.143 (0.151)	-0.825 (0.015)	0.019	
H3	0.004 (0.988)	-0.302 (0.287)	0.568	
H4	-0.679 (0.135)	-0.040 (0.862)	0.323	
H5	1.167 (0.070)	-0.337 (0.302)	0.114	
Incidence density of CAUTI				
Variation over time				
Coefficient β (p-value)	0.300 (0.292)	-0.351 (0.009)	-	↓45.0%
Assessment by hospital[b]				
H1	-1.131 (0.530)	-0.720 (0.012)	0.035	
H2	0.097 (0.688)	-0.859 (<0.001)	<0.001	
H3	0.624 (0.252)	-0.479 (0.036)	0.057	
H4	0.191 (0.256)	0.264 (0.377)	0.355	
H5	-0.282 (0.490)	-0.111 (0.304)	0.439	
Incidence density of CLABSI [a]				
Variation over time[b]				
Coefficient β (p-value)	0.251 (0.333)	-0.252 (0.068)	-	NS
Assessment by hospital[b]				
H1	2.611 (0.016)	0.059 (0.841)	0.055	
H2	0.296 (0.275)	-0.202 (0.152)	0.198	
H3	-0.171 (0.745)	0.021 (0.905)	0.942	
H4	0.118 (0.699)	-0.748 (0.022)	0.067	
H5	-0.181 (0.386)	-0.408 (0.308)	0.408	

[a] Before the intervention the date for the period between July and December 2017 (6 months)
b Linear regression model for each period
NS – No significant variation

Process indicators

VAP

The drop in the rate of monthly percentage utilization of mechanical ventilation in the 5 ICUs from 61.2 ± 5.5 to 54.5 ± 5.1 ($p = 0.002$) demonstrated a correlation with around 50% ($r = 0.485$, $p = 0.007$) in the final drop of the VAP ID of 33.8%. A low adherence to the preventive measures was recorded (median 48%) and no correlation with the ID (0.079, $p = 0.487$). There was no correlation between the number of monthly meetings held and the VAP ID. (Table 3). Description by hospital regarding the utilization rate of mechanical ventilation and adherence to the single prevention package is presented in Supplementary Table 1.

CAUTI

There was a reduction in the monthly percentage utilization rate of UCs in the 5 ICUs from 60.6 ±7.9 to 43.4 ± 6.1 ($p = <0.001$) demonstrating a correlation of 37% ($r = 0.374$, $p = 0.042$) with the final reduction in the ID of 45%. Preventive measures for UC insertion and maintenance demonstrated a median adherence of 79% and 71%, respectively, and there was no correlation with the CAUTI ID. There was no correlation between the number of monthly meetings held and the CAUTI ID. (Table 3). Description by hospital of the UC utilization rate and the respective adherence to the preventive insertion and maintenance measures is presented in Supplementary Table 2.

CLABSI

The monthly percentage utilization rate of the central venous catheter decreased from 81.7 ± 3.1 to 77.2 ±2.9 ($p = <0.001$) but there was no correlation with a reduction in the CLABSI ID. The median adherence to the preventive measures for CVC insertion of 63% correlated with 53% ($r = -0.535$, $p = 0.041$) of reduction in the ID (not significant).

The median adherence to the maintenance measures was 53% and there was no correlation with the ID of the infection. There was no correlation between the number of monthly meetings held and the CLABSI ID. (Table 3). Description by hospital of the CVC utilization rate and respective adherence to preventive insertion and maintenance measures is presented in Supplementary Table 1.

Table 3. Analysis of the process indicators in relation to the IDs of the HAIs

Process indicators	Before intervention 2017	During intervention 2018 - 2019	p-value	Correlation coefficient (p-value)
Mechanical ventilation utilization rate				
Mean ±SD (in days)	61.2±5.5	54.5±5.1	0.002	0.485 (0.007)[c]
Adherence to preventive measures of VAP (in %)				
Median (P_{25} – P_{75})	-	48 (12 – 84)	-	0.079 (0.487)
Number of monthly meetings				
Median (P_{25} – P_{75})	-	2.7 (1.8 – 3.2)	-	0.049 (0.847)
UC utilization rate				
Mean ±SD (in days)	60.6 ± 7.9	43.4 ± 6.1	<0.001	0.374 (0.042)
Adherence to preventive measures for INSERTION of UC (in %)				
Median (P_{25} – P_{75})		79 (50 – 100)	-	-0.169 (0.138)[d]
Adherence to preventive measures for MAINTENANCE of UC (in %)				
Median (P_{25} – P_{75})	-	71 (60 – 77)	-	0.289 (0.342)
Number of monthly meetings				
Median (P_{25} – P_{75})	-	2.7 (1.8 – 3.2)	-	0.195 (0.437)
CVC utilization rate				
Mean ±SD (in days)	81.7 ± 3.1	77.2 ± 2.9	<0.001	-0.199 (0.291)[b]
Adherence to preventive measures for INSERTION of CVC (in %)				
Median (P_{25} – P_{75})	-	63 (53 – 73)	-	-0.535 (0.041)[b]
Adherence to preventive measures for MAINTENANCE of CVC (in %)				

Median (P_{25} – P_{75})	-	53 (47 – 58)	-	0.005 (0.986)
Number of monthly meetings				
Median (P_{25} – P_{75})	-	2.7 (1.8 – 3.2)	-	0.288 (0.264)

[a] Data collection on adherence to the preventive measures took place from July/2018; [b] Correlation with CLABSI ID; [c] Correlation with VAP ID; [d] Correlation with CAUTI ID

Discussion

Our study has demonstrated that the "Improvement Model" method is effective in implementing projects for healthcare improvement in public hospitals aided by philanthropic hospitals of excellence (HE)[12]. After just a few months of preventive interventions in ICUs, a significant result was obtained in reducing VAP and CAUTIs. Internal infection control programs were already in place in ICUs, however, the incidence of HAIs remained high. Thus, this project, promoted by the Brazilian Ministry of Health, based on the improvement model of the BTS-IHI[5], provided the ICUs with an opportunity to gradually implement or ratify the preventive measures of the bundles, using a new methodology whereby participation by the areas in question (ICUs) gained prominence and empowerment over the infection prevention process.[13]

The main result indicators of this quasi-experimental study, in relation to the group of 5 ICUs studied, were an average monthly decrease of 0.427 ($p = 0.002$) in the VAP ID and 0.351 ($p = 0.009$) in the CAUTI DI over a period of 18 months. The final reduction during this period of the VAP ID by 34% and the CAUTI ID by 45%, is in accordance with the prevention percentages obtained in the revised multifaceted interventions, from 2005-2016, by Schreiber et al, also including high-income countries. The authors considered that the potential for reducing HAI by around 30 to 50%, through evidence-based strategies, demonstrates that the current recommendations have not been sufficiently implemented.[15] The mean monthly reduction of CLABSI ID by 0.218 ($p = 0.07$) was not significant, although it demonstrated a downward trend and reflects the

need for more follow-up time for this measure. It is probable that the moderate adherence to the preventive measures for CLABSIs (63% and 53%), even resulting in a reduction in the monthly percentage of the CVC utilization rate from 81.7 $\pm$ 3.1 to 77.2 $\pm$ 2.9 ($p = < 0.001$) was insufficient to reduce the incidence of CLABSIs. Our result coincides with the findings of a large study on implementing the CLABSIs bundle in ICUs in the USA, which demonstrated that CLABSIs are only reduced when adherence to the bundle is at least 95% .[16]

The length of stay and mortality throughout the 18 months did not significantly decrease. In part, this may signify that patient death with HAIs is not always only attributed to this adverse event[17] and, since there are multiple causes, the role of infection is not always clear.[4] However, since it is indisputable that HAIs increase mortality and hospital stay[18] we believe that the reductions obtained in the ID were not sufficient to alter the length of stay and mortality in the ICUs.

With regard to the process indicators in the prevention of VAP, a decrease was observed in the rate of the monthly percentage utilization of mechanical ventilation in the 5 ICUs, from 61.2 $\pm$5.5 to 54.5 $\pm$5.1 ($p = 0.002$) which correlates with around 50% (0.485, $p = 0.007$) of the reduction, at the end of the period, in the VAP ID. The importance of the utilization rate and its reduction explain the significant reduction in VAP ID even with insufficient adherence to the bundle.[19] However, it is important to emphasize that the median of 38% adherence to the preventive measures of VAP is not realistic, since there occurred a divergence in the understanding of the cuff pressure measurement methodology, thereby negatively interfering with the assessment of the adherence to the bundle. In summary, the 35% reduction in the VAP ID was associated with a drop in the utilization of mechanical ventilation ($r=0.485$, $p=0.007$), and a possible contribution from other preventive measures although registered at low levels.

In processes involving the prevention of CAUTI, there was also a significant decrease in the monthly percentage utilization of UCs in the 5 ICUs, from 60.6 $\pm$7.9 to 43.4 $\pm$ 6.1 ($p = <0.001$) representing a 37% correlation with a reduction in the CAUTI ID at the end of the period (0.374, $p = 0.042$). Adherence to the preventive measures for insertion and maintenance of the UC presented a median of 79% and 71%, respectively, and there was no correlation with the CAUTI ID. As Titsworth demonstrated, there is a linear relationship between the UC utilization rate and the CAUTI ID that explains the 45% reduction in the ID.[20]

Unlike most intervention projects that aim to reduce just one or two HAIs, [8,15] our study has demonstrated that it is possible to confront 3 HAIs while at the same time expanding interventions. This aspect is corroborated by the work of Miller et al. [21] when relevant reductions were obtained in ICUs of the 3 HAIs over an intervention period of 2 years and in the same follow-up period. This seeks to improve care and the overall safety culture in the work unit, since it is known that there are many other infections that have been generated by health care, little studied in projects[15], which indirectly may be avoided by improving the patient care.

The data on infections were collected by the hospitals themselves by trained professionals, using the criteria of the CDC.[14] The major flaws in executing the project were those related to registering and adherence to bundles, which did not occur in the expected frequencies (Table 3), and which differs from the improvement results of the VAP and CAUTI IDs. Thus, in contrast to the improvement in results, we also observed that some items in the bundles were not executed, there was an insufficient number of audits and that executing professionals failed to complete the medical records. Additionally, the hospitals participating in this research considered that the methodology for measuring the cuff pressure of the orotracheal tube produced measurement

inconsistencies, which should have been standard, thereby temporarily affecting the faithful measurement of adherence. All these facts explain the difficulty in assessing the true adherence to bundle items. Certainly, the gaps in execution are related to the results, although the exact preventive contribution of each item in the bundles is unknown.[15] It is our conclusion that with a lower utilization of devices, even with limited adherence to the bundles, there was a significant reduction in infections.

Despite the difficulties in achieving the adherences, we believe that this study may be applied to other ICUs as a successful experience within a brief period of time. There are a number of limitations to this study for being quasi-experimental,[22] rather than randomized, however, when planning the study, it was considered unethical to maintain a control group without receiving preventive measures.

Conclusion

Given the success in reducing VAP and CAUTI, there is no doubt regarding the success of the collaborative project, using improvement cycles. The remaining challenges are to guarantee a 95% adherence to the CLABSI prevention bundles, as well as the continued encouragement and involvement of the teams in the processes for consolidating the results. This partnership among public hospitals/HE may be applied to other ICUs including countries with fewer resources.

List of abbreviations

BTS	Breakthrough Series Collaborative method
CAUTIs	Catheter-related urinary tract infections
CDC	US Centers for Disease Control and Prevention
CLABSIs	Central line-associated bloodstream infections
CVC	Central venous catheter
GEE	Generalized Estimating Equation
HAIs	Healthcare-associated infections
HE	Brazilian philanthropic hospitals of excellence
ICU	Intensive care units
ID	Incidence density
IHI	Institute of Healthcare Improvement
PDSA	Plan-Do-Study-Act rapid cycle testing
PROADI-SUS	Institutional Development Program of the Integrated Health System
QIPs	Quality improvement programs
SUS	Integrated Health System in Brazil
UC	**U**rinary catheter
UFPE	Federal University of Pernambuco
VAP	Ventilator associated pneumonia

Declarations

Ethics approval and consent to participate

This research was promoted and authorized by the Ministry of Health, carried out through the Institutional Development Program of the Integrated Health System PROADI-SUS[12] and approved by the Ethics Committee of the Hospital das Clínicas - UFPE, under No. 3,307,293.

Consent for publication

Not applicable

Availability of data and materials

The data that support the findings of this study are available from Brazilian Ministry of Health and Institutional Development Program of the Integrated Health System - PROADI-SUS but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are however available from the authors upon reasonable request and with permission of Brazilian Ministry of Health and Institutional Development Program of the Integrated Health System - PROADI-SUS.

Competing interests

The authors declare that they have no competing interests.

Funding

The complete research was promoted and authorized by the Brazilian Ministry of Health, carried out through the Institutional Development Program of the Integrated Health System PROADI-SUS. This study was privately funded by the first author.

Authors' contributions

LWM, CLV and HRL designed the study, supervised the data collection, analysis and interpretation. MVA, BRS, MGC, MFS and MCA participated in the interpretation of results and assisted in manuscript write-up. All authors read and approved the final manuscript.

Acknowledgements

Special thanks go to Brazilian Ministry of Health and Institutional Development Program of the Integrated Health System PROADI-SUS for providing necessary data for this study.

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