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Effectiveness of a multidimensional approach for the prevention of ventilator-associated pneumonia in an adult intensive care unit in Cuba: Findings of the International Nosocomial Infection Control Consortium (INICC)

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Multidimensional approach

Abstract
Objective: This study sought to assess the effect of the multidimensional approach developed by the International Nosocomial Infection Control Consortium (INICC) on the reduction of ventilator-associated pneumonia (VAP) rates in patients hospitalized in an adult intensive care unit (AICU) in an INICC member hospital in Havana, Cuba.
Methods: We conducted a prospective surveillance pre-post study in AICU patients. The study was divided into two periods:baseline and intervention. During the baseline period, we conducted active prospective surveillance of VAP using the Centers for Disease Control and Prevention (CDC) National Health Safety Network (NHSN) definition and INICC methods. During the intervention period, we implemented the INICC multidimensional approach for VAP, in addition to performing active surveillance. This multidimensional approach included the following measures: a bundle of infection control interventions, education, outcome surveillance, process surveillance, feedback of VAP rates and performance feedback of infection control practices. The baseline rates of VAP were compared to the rates obtained after intervention, and we analyzed the impact of our interventions by Poisson regression.

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Results: During the baseline period, we recorded 114 mechanical ventilator (MV) days, whereas we recorded 2350 MV days during the intervention period. The baseline rate of VAP was 52.63 per 1000 MV days and 15.32 per 1000 MV days during the intervention. At the end of the study period, we achieved a 70% reduction in the rate of VAP (RR, 0.3; 95% CI, 0.12—0.7; *P* value, 0.003.).

Conclusions: The implementation the INICC multidimensional approach for VAP was associated with a significant reduction in the VAP rate in the participating AICU of Cuba.

Introduction

Ventilator-associated pneumonia (VAP) is one of the most common device-associated infections (DAI) among intensive care unit patients, contributing to substantial increases in hospital costs and length of stay (LOS) [1]. According to the scientific literature, VAP is the leading cause of morbidity and mortality in the adult intensive care unit (ICU) setting, both in developed [2] and developing countries [3,4].

According to a systematic review, the burden of VAP has not been systematically addressed in developing countries [4]. Although it has been demonstrated that surveillance plays a substantial role in the reduction of VAP in the developed world [5], in developing countries, its importance for measuring ICU patient infection risks, outcomes and processes remains under-recognized [4,6]. To counteract the adverse effects of DAI in limited-resource countries, in 2002 the International Nosocomial Infection Control Consortium (INICC) developed a multidimensional approach for DAI prevention specifically devised for ICUs in developing countries [7,8].

The results of the INICC program showed that there was a marked difference in the VAP rates between the ICUs of hospitals from the industrialized world and those from limited-resource healthcare settings, whose rates were between 3 and 5 times higher [9—11].

The INICC multidimensional approach for VAP includes an infection prevention bundle based on the preventive strategies described by the Society for Health Care Epidemiology of America (SHEA) and the Infectious Diseases Society of America (IDSA) [12]. Such recommendations provide feasible and cost-effective infection control measures that are applicable to limited-resource ICU settings. In turn, the INICC prevention bundle follows the recommendations of the Institute of Healthcare Improvement (IHI) stating that a ventilator bundle should be implemented at every ICU to reduce the incidence of VAP to zero. These steps are part of the 5 Million Lives campaign, which has been endorsed by leading US agencies and professional societies [13].

Nevertheless, very few studies have shown successful interventions for VAP reduction, which would provide guidance to address this problem [4]. Likewise, study heterogeneity in developing countries may cause variation in the reported rates [4].

Within the context of developing countries, outcome and process surveillance that is integrated into an intervention bundle containing performance feedback of infection control practices has been shown to successfully reduce and control DAIs, as shown by different studies conducted in INICC member hospitals [14,15].

For analytical purposes, the World Bank classifies economies as low income, middle income, or high income. As of 1 July 2011, low-income economies are those that had average incomes of $1005 or less in 2010; lower-middle-income economies had average incomes of $1006 to $3975; upper-middle-income economies had average incomes of $3976 to $12,275 and high-income economies had average incomes of $12,276 or more. Low- and middle-income economies are commonly referred to as developing economies. However, this does not imply that economies in the same income group have reached similar stages of development or that high-income economies have reached a preferred or final stage of development. This study was conducted in Cuba, which is classified as an upper-middle-income economy.

The current study sought to advance the knowledge of necessary scientific evidence in Cuba by assessing the specific impact of a multidimensional approach for VAP—which includes a bundle of infection control interventions, education, outcome surveillance, process surveillance and feedback regarding VAP rates and infection control practices—on the reduction of the incidence of VAP among adult ICU patients at an INICC member hospital in Havana, Cuba.

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Methods

Setting and study design

This pre-post prospective cohort study was carried out in the AICU of an INICC member hospital in Havana, Cuba. This hospital actively participated in the study and employed an infection control team (ICT) that was comprised of a medical doctor with formal education in internal medicine and epidemiology and 2 infection control professionals (ICPs).

The study period spanned from January 2007 to November 2010 and was divided into 2 phases: Phase 1 (baseline period, consisting of the first three months of participation in the INICC program) and Phase 2 (intervention period). The Institutional Review Board at each hospital approved the study protocol.

Intervention period

The intervention period began after three months of participation in the INICC Surveillance Program. The length of the intervention period was 47 months. The INICC multidimensional approach includes the following practices: a bundle of infection control interventions, education, outcome surveillance, process surveillance, feedback of VAP rates and performance feedback of infection control practices.

INICC methodology

The INICC Surveillance Program includes two components: outcome surveillance (VAP rates and consequences) and process surveillance (adherence to hand hygiene and other basic preventive infection control practices) [7].

The investigators at the participating hospital were required to perform outcome and process surveillance by completing forms, which were sent for monthly analysis to the INICC office in Buenos Aires [7].

Outcome surveillance

The INICC Surveillance Program applies the definitions for DAI developed by the U.S. Centers for Disease Control and Prevention (CDC) for the National Nosocomial Infection Surveillance System (NNIS)/National Health Safety Network (NHSN) program, thereby minimizing the potential surveillance bias [16,17]. Furthermore, the INICC methods take into consideration the different socioeconomic statuses and specific limitations of limited-resource countries and were adapted for their application in this setting [7]. Outcome surveillance includes VAP rates per 1000 device-days, microorganism profile, bacterial resistance, length of stay and mortality in the ICU.

Process surveillance

Process surveillance is designed to monitor compliance with easily measurable, key infection control measures, and it includes the surveillance of compliance rates for hand hygiene practices and some specific infection control measures for the prevention of VAP [14,15]. In our study, we collected process surveillance data only on hand hygiene compliance because we did have the necessary resources to collect data regarding compliance with other measures included in the process surveillance for VAP prevention. Therefore, we could not evaluate the implications of all the interventions individually.

Hand hygiene (HH) compliance by healthcare workers (HCWs) was determined by measuring the frequency of HH performances when clearly indicated, and such practices were monitored by the hospital's ICP during randomly selected 1-hour observation periods, 3 times a week. Although HCWs know that HH practices are regularly monitored, they are not actually aware of the precise moment in which the observations are taking place [7].

ICPs were trained to detect HH compliance and record HH opportunities and compliance through direct observation. 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 DAI prevention and control and include the monitoring of the following moments: (1) before patient contact, (2) before an aseptic task, (3) after body fluid exposure, (4) after patient contact and (5) after contact with patient surroundings [18].

Training and validation

Investigators were trained in the INICC methods through a manual and a training tool that described how to perform surveillance and complete surveillance forms. Furthermore, investigators had continuous e-mail and telephone access to a support team at the INICC Central Office in Buenos Aires, Argentina, which is responsible for replying to queries within 24 h. The INICC Chairman further reviewed every question and reply.

Surveillance forms for individual patients allow internal and external validation because they

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include every clinical and microbiological criterion for each type of DAI, such as temperature, blood pressure, use of invasive devices, cultures taken, culture results and antibiotic use. Surveillance also includes a form where positive cultures are registered and matched with patient forms.

Every month, investigators from the participating hospital submitted the completed surveillance forms to the INICC Central Office, where the validity of each case was verified and the recorded signs and symptoms of infection and the results of laboratory studies, radiographic studies and cultures were scrutinized to assure that the NNIS System criteria for device-associated infection were met.

Investigators who reviewed the forms verified that criteria for infection had been met accurately in each case. Additionally, the original patient data forms were further validated at the INICC Central Office before data on the reported infection were entered into the INICC database. To that end, queries were submitted from the INICC office in Buenos Aires to the hospital investigators, challenging cases with suspected VAP. Data were uploaded only after receiving confirmation from hospital teams. Finally, the INICC team performed database consistency analyses for factors such as age, gender and dates and reviewed medical records that compared data registered in forms to data in medical records.

Performance feedback

The concept of using feedback from outcome surveillance and process surveillance as a valuable control measure in limited-resource hospitals was based on its effectiveness in previous INICC studies [14,15].

The INICC Central Office team prepared and sent monthly chart reports to the participating hospital that detailed their rates of VAP, microbiology profile and rates of adherence to hand hygiene. As mentioned before, because of our limited resources, we did not collect data on the other measures of process surveillance for VAP prevention.

The participating ICU staff received feedback on their performance at monthly meetings, by means of the review of patient charts, and the feedback was posted in a prominent location in the ICU.

Bundle components

Our bundle included the following elements:

1. Active surveillance for VAP [19];
2. Adherence to hand-hygiene guidelines [20];
3. Maintenance of patients in a semi-recumbent position (30—45° elevation of the head of the bed) [12];
4. Performance of daily assessments of readiness to wean and the use of weaning protocols [21];
5. Performance of comprehensive regular oral care with an antiseptic solution [22];
6. Use of noninvasive ventilation whenever possible and the minimization of the duration of ventilation [12];
7. Preferable use of orotracheal instead to nasotracheal intubation [23];
8. Maintenance of an endotracheal cuff pressure of at least 20 cm H_2O [24];
9. Removal of the condensate from ventilator circuits [12] and keeping the ventilator circuit closed during condensate removal [25];
10. Change of the ventilator circuit only when visibly soiled or malfunctioning [26];
11. Avoidance of gastric overdistention [27];
12. Avoidance of histamine receptor 2 (H_2)-blocking agents and proton pump inhibitors [28];
13. Use of sterile water to rinse reusable respiratory equipment [12];
14. Performance of direct observation of hand hygiene compliance, duration of the ventilation and ventilation ratio use, using structured observation tools at regularly scheduled intervals [7].

As mentioned above, because of our insufficient resources, we did not collect process surveillance data on the components of our bundle for VAP prevention, with the exception of hand hygiene.

Definitions

We applied the CDC NHSN definitions for VAP [17], whereby VAP is diagnosed in a mechanically ventilated patient with a chest radiograph showing new or progressive infiltrates, consolidation, cavitation, or pleural effusion. The patient also must meet at least one of the following criteria: new onset of purulent sputum or change in character of sputum; organism cultured from the blood; or isolation of an etiologic agent from a specimen obtained by tracheal aspirate, bronchial brushing or bronchoalveolar lavage, or biopsy [17].

Statistical methods

Patient characteristics during baseline and during the last three months of the intervention period in the ICU were compared using Fisher's exact test for dichotomous variables and an unmatched Student's

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Table 1 Patient characteristics, device use, and ventilator-associated pneumonia rates during Phase 1 (baseline period) and Phase 2 (intervention period).

Patient Characteristics	Baseline	Intervention	RR[a]	95% CI	*P*-Value
Study period in months, *n*	3	47	–	–	–
Patients, *n*	67	1008	–	–	–
[a]Bed days, *n*	363	5648	–	–	–
[b]MV days, *n*	114	2350	–	–	–
[c]MV use, mean	0.31	0.42	1.32	1.1–1.6	0.0032
MV duration, mean ± SD	1.7 ± 3.0	2.34 ± 4.6	–	–	0.265
Age, mean ± SD	60.0 ± 19.0	61.4 ± 17.6	–	–	0.534
Male	31(46%)	501(50%)	1.07	0.75–1.54	0.7
Female	36(46%)	506(50%)	–	–	–
Pulmonary disease, *n* (%)	11(16%)	247(25%)	1.54	0.84–2.81	0.16
Abdominal surgery, *n* (%)	5(7%)	112(12%)	1.54	0.63–3.78	0.34
Chronic obstructive, *n* (%)	11(16%)	186(19%)	1.16	0.63–2.12	0.64
Trauma, *n* (%)	2(3%)	18(2%)	0.62	0.14–2.68	0.52
Previous infections, *n* (%)	14(21%)	511(50%)	2.54	1.5–4.32	0.0004
Cardiac failure, *n* (%)	15(22%)	449(45%)	2.03	1.21–3.4	0.006
Endocrine diseases, *n* (%)	9(13%)	238(24)	1.8	0.93–3.51	0.08
Renal impairment, *n* (%)	4(6%)	31(3%)	0.53	0.2–1.51	0.23
Hepatic failure, *n* (%)	2(3%)	32(3%)	1.1	0.26–4.61	0.9
Thoracic surgery, *n* (%)	2(3%)	27(3%)	0.93	0.22–3.92	0.924
Stroke, *n* (%)	14(21%)	287(29%)	1.4	0.82–2.4	0.215
VAP, *n*	6	36	–	–	–
VAP rate per 1000 MV days	52.63	15.32	0.3	0.12–0.7	0.003

VAP, ventilator-associated pneumonia; MV, mechanical ventilator; RR, relative risk; CI, confidence interval; SD, standard deviation; ASIS, average severity of illness score.

[a] Bed-days are the total number of days that patients were in the ICU during the selected time period.

[b] MV-days: the total number of days of exposure to mechanical ventilation by all of the patients in the selected population during the selected time period.

[c] MV use ratios were calculated by dividing the total number of MV-days by the total number of Bed-days.

t-test for continuous variables. We calculated 95% confidence intervals (CI) using VCStat (Castiglia). Relative risk (RR) ratios with 95% confidence intervals (CI) were calculated for the comparison of rates of VAP using EPI Info V6. *P*-values < 0.05 by two-sided tests were considered significant. Furthermore, we explored the change in VAP rates following an ICU joining the INICC by stratifying the follow-up period into three-month periods over the first year and six-month periods over the second and third years, which then transitioned to yearly review. We also performed an additional regression considering ''time since the ICU started the intervention period'' as a continuous variable (excluding the baseline period) and calculated the RR for reduction in DAI for each three-month period of follow up.

Results

During the study period, there were 1075 patients hospitalized for 6011 days in the participating AICU. We recorded 2464 mechanical ventilator (MV)-days (Table 1).

Regarding patient characteristics, we found that patient age, gender, pulmonary disease, abdominal surgery, trauma, endocrine disease, renal impairment, hepatic failure, thoracic surgery and stroke were similar during both periods. However, previous infection and cardiac failure were more prevalent during the intervention period. (Table 1)

MV duration mean was similar during both phases, whereas MV use mean was higher during the intervention period (Table 1).

Process surveillance for HH compliance was measured during Phase 2, from September 2008 to November 2010. We recorded 434 opportunities for HH and 244 compliance opportunities, showing a compliance rate of 56% (95% CI: 51–61) by the end of the study period. HH compliance was not measured during the baseline period.

Due to budgetary limitations, we did not collect data regarding the other individual interventions included in our bundle for VAP prevention.

During baseline, the VAP rate was 52.63 VAPs per 1000 MV-days, whereas the VAP rate was 15.32 per 1000 MV days during intervention (RR 0.3; 95% CI 0.12–0.7; *P* 0.003). These results showed a 70% VAP rate reduction (Table 1).

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Table 2 ventilator-associated pneumonia rates stratified by ICU length of participation in INICC and obtained by poisson regression analysis.

Months since joining INICC	MV-days	VAP	Crude VAP rate/1000 MV days	RR (95% CI)	*P*-Value
1–3 months (baseline)	114	6	52.63	–	1
4–12 months	557	8	14.36	0.27 (0.09–0.79)	0.0099
Second year	686	15	22	0.42 (0.16–1.07)	0.0604
Third year	545	10	18.35	0.35 (0.13–0.96)	0.0326
Fourth year	562	3	5.34	0.10 (0.03–0.41)	0.0001

INICC, International Nosocomial Infection Control Consortium, VAP, ventilator-associated pneumonia; MV, mechanical ventilator; RR, relative risk; ICU, intensive care unit.

In comparison to the baseline VAP rates for the 3 months before the intervention, VAP rates were reduced by 73% after 9 months of participation (from 52.63 to 14.36 VAPs per 1000 MV-days.) This rate was further reduced by 58% during the second year (from 52.63 to 22 VAPs per 1000 MV-days), 75% during the third year (from 52.63 to 18.35 VAPs per 1000 MV-days) and 90% during the fourth year (from 52.63 to 5.34 VAPs per 1000 MV-days) (Table 2).

Regarding the microorganism profile, we found that during phase 1, the predominant agent detected was *Acinetobacter*, whereas *Pseudomonas* spp. and *Klebsiella* were the predominant agents identified during Phase 2 (Table 3).

Discussion

According to the scientific literature from developed [2] and developing countries [1,4], the most serious adverse effects of VAP include increased mortality rates [1], significant morbidity [29], and increased LOS [1]. Additionally, VAP is responsible for higher hospital costs, as stated in studies from both developed [2] and developing countries [1].

In developing countries, many health care facilities do not apply infection control programs, and the incidence of VAP in the ICU setting remains obscure [4]. Other studies from limited-resource countries have reported that the rates of VAP were more than three-fold higher than those in developed countries [9–11,30]. In the current study, the baseline rate of VAP (52.63 per 1000 MV-days) was more than twenty-five times higher than that in the US (1.8 VAP rate per 1000 MV-days determined by the CDC/NSHN) [31] and more than eight-fold higher than the rate of 6.8 reported by KISS [32].

As compared to the VAP rates from other developing countries, the VAP baseline rate obtained in the current study was much higher than those published by international INICC reports in 2006 (24.1 VAPs per 1000 MV-days) [9], in 2008 (19.5 VAPs per 1000 MV-days) [10], in 2010 (13.16 VAPs per 1000 MV-days) [30] and in 2012 (15.8 VAPs per 1000 MV-days) [11]. To our knowledge, the only published reference indexed in Pubmed/Medline that addressed the burden of VAP in AICUs in Cuba was a study on DAI rates conducted in two Cuban INICC member hospitals, in which the VAP rate was 52.5 VAPs per 1000 MV-days [33].

The considerable influence that socioeconomic status and hospital type have on DAIs in developing countries has been assessed in very few studies [34]. Regarding the hospital type, VAP rates in pediatric ICUs from academic hospitals were higher than those in private or public hospitals at 8.3 vs. 3.5 VAPs per 1000 MV-days, respectively [34]. With regard to the socioeconomic level, it was shown that lower-middle-income countries had higher VAP rates than upper-middle-income countries (9.0 vs. 0.5 per 1000 MV-days) [34].

These VAP reduction strategies have been effective for a long time. In developed countries, it has been demonstrated that the incidence of VAP can be substantially reduced by more than 30% through basic but effective measures, such as hand hygiene compliance [20], semi-recumbent positioning [12], early removal of endotracheal tubes [35]

Table 3 Microorganism profiles of ventilator-associated pneumonia in the participating adult intensive care unit for Phase 1 and Phase 2.

Isolated microorganisms	Baseline	Intervention
Acinetobacter spp. % (*n*)	100% (1)	7% (1)
Pseudomonas spp. % (*n*)	0% (0)	36% (5)
Klebsiella % (*n*)	0% (0)	29% (4)
Escherichia coli % (*n*)	0% (0)	14% (2)
Pneumococcus % (*n*)	0% (0)	7% (1)
Staphylococcus spp. % (*n*)	0% (0)	7% (1)
Total % (*n*)	100% (1)	100% (14)

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and maintenance of endotracheal cuff pressure and continuous subglottic suctioning [12]. Similarly, it was shown in studies conducted by the INICC that implementation of a multi-dimensional approach for VAP, including a bundle of interventions, education, outcome and process surveillance, feedback of VAP rates and performance feedback, resulted in significant reductions in VAP rates in Argentina (51.28 vs. 35.50 VAPs per 1000 MV-days) [14] and China, amounting to a 79% cumulative VAP rate reduction during the 3-year study period [36] and a reduction in the pooled VAP rates of pediatric ICUs (31% VAP rate reduction) [37], neonatal ICUs (33% VAP rate reduction) [38] and adult ICUs (55.83% VAP rate reduction) of limited-resource countries [39].

The INICC multidimensional approach for VAP includes six elements. The first element consists of the implementation of an infection prevention bundle that can be feasibly adapted to the ICU setting in developing countries and that is based on the guidelines published by the SHEA and the IDSA [12], which provide evidence-based recommendations and cost-effective infection control measures. The second element consists of the education of HCWs about infection prevention measures. Third, VAP outcome surveillance should apply the definitions for DAI developed by the U.S. CDC/NHSN [16,17]. Fourth, VAP process surveillance should monitor compliance HH performance. Fifth, feedback should be provided on VAP rates and sixth, performance feedback, particularly by reviewing and discussing chart results at monthly infection control meetings, should occur.

In this study, patient characteristics, such as age, gender, pulmonary disease, abdominal surgery, trauma, endocrine disease, renal impairment, hepatic failure, thoracic surgery and stroke, were similar during both periods and therefore demonstrated similar levels of patient intrinsic risk. However, previous infection and cardiac failure were more prevalent during the intervention period, as well as the MV mean, suggesting that patient intrinsic risk was higher during the intervention period. In the implementation of the INICC multidimensional approach, we found that HH compliance rate was 56% in Phase 2.

During the study period, the high VAP rate at baseline was reduced from 52.63 to 15.32 per 1000 MV days (RR 0.3; 95% CI 0.12–0.7; *P* 0.003), showing a 70% VAP rate reduction. As compared to the baseline VAP rates for the 3 months before the intervention, the VAP rates were reduced by 73% after 9 months of participation. Moreover, this rate was further reduced by 58% during the second year, 75% during the third year and 90% during the fourth year.

Regarding the microorganism profile, we identified a predominance of *Pseudomonas* and *Acinetobacter* spp. in Phase 1 and a predominance of *Pseudomonas* spp and *Klebsiella* in Phase 2. According to the scientific literature from Cuba, the predominant agents reported for VAPs are *Klebsiella pneumoniae*, *Pseudomona Aeruginosa* and *Enterobacter* [40].

Study limitations

There were several limitations of this study.

First, the study findings cannot be generalized to all AICU patients from Cuba; however, this study demonstrated that a multidimensional approach is fundamental for understanding and combating the adverse effects of VAP in the AICU setting in Cuba.

Second, the three-month baseline period may have been too short and may have overestimated the effect of the intervention. Nevertheless, during the baseline period, the sample size was large enough, and the CIs for the baseline rate were narrow. In addition, this length for a baseline period is commonly reported in the scientific literature.

Third, we were unable to perform process surveillance for HH compliance during baseline as well as for the following bundle components: maintenance of patients in a semi-recumbent position (30–45° elevation of the head of the bed); performance of daily assessments of readiness to wean and use of weaning protocols; performance of regular oral care with an antiseptic solution; use of noninvasive ventilation whenever possible and minimization of the duration of ventilation; preferable use of orotracheal instead to nasotracheal intubation; maintenance of an endotracheal cuff pressure of at least 20 cm H_2O; removal of the condensate from ventilator circuits and keeping the ventilator circuit closed during condensate removal; change of the ventilator circuit only when visibly soiled or malfunctioning; avoidance of gastric overdistention; avoidance of histamine receptor 2 (H_2)-blocking agents and proton pump inhibitors; and the use of sterile water to rinse reusable respiratory equipment. We were also unable to collect sufficient information on other non-quantifiable interventions included in our multidimensional approach, such as education and training. During the study period, we did not possess the necessary resources to collect more data on process surveillance and measure compliance with these interventions. Therefore, we could not evaluate their individual implications or other contextual factors related to the ICU or hospital. These data would greatly advance the knowledge on quality

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improvement in Cuban hospitals. Nevertheless, our main goal was to reduce the high baseline VAP rates found in our ICU, and although our interventions were inexpensive, the individual evaluation would have required greater allocation of time, thereby contributing to unnecessary harm for ICU patients. Fortunately, as of January 2012, we have been able to collect all of these process surveillance data.

Conclusions

This study is among the first to report a substantial reduction in VAP rates in the AICU setting, thereby demonstrating that this type of infection control approach is successful [4]. Despite higher patient intrinsic risk characteristics during Phase 2, infection control professionals at the AICU setting of this INICC member Cuban hospital were able to achieve successful control of VAP. It is worth highlighting that the reduction in VAP rates did not occur due to surveillance alone. These data should serve as a guide for infection control professionals as to what strategies should be attempted for improvement of patient care practices, such as performance feedback [14,41]. Therefore, to obtain the greatest benefit from preventive strategies, it is essential to support educational efforts with regular feedback of monthly incidence rates of VAPs and performance feedback of all bundle components in addition to HH compliance rates, as shown in different studies carried out in INICC member hospitals [14,41—43,15].

The successful preventive strategies shown in this study were adopted as part of the multidimensional approach for VAP prevention in hospital infection control programs worldwide and have led to significant VAP reductions. As part of the INICC network, investigators are freely provided with training and methodological tools to perform outcome and process surveillance and to implement an effective infection prevention model for VAPs. At the same time, the publication of these findings serves to foster relevant scientific evidence-based literature. For this reason, we invite hospitals worldwide to participate in the INICC project, which was set up to respond to the compelling need in limited-resource settings to significantly prevent, control and reduce VAPs and their adverse effects.

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Conflicts of interest

All authors report no conflicts of interest related to this article. Each hospital's Institutional Review Board agreed to the study protocol, and patient confidentiality was protected by deindentifying the recorded information, making it only identifiable to the infection control team. All authors submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest, and the conflicts that the editors consider relevant to this article are disclosed here.

Authors' contributions

a. Idea, conception and design: Victor D. Rosenthal.
b. Software development: Victor D. Rosenthal.
c. Assembly of data: Victor D. Rosenthal.
d. Analysis and interpretation of the data: Victor D. Rosenthal.
e. Epidemiological analysis: Victor D. Rosenthal.
f. Statistical analysis: Victor D. Rosenthal.
g. Administrative, technical, and logistic support: Victor D. Rosenthal.
h. Drafting of the article: Victor D. Rosenthal.
i. Critical revision of the article for important intellectual content: All authors.
j. Final approval of the article: All authors.
k. Provision of study patients: All authors.
l. Collection of data: All authors.
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