Ventilator-associated pneumonia prevention by education and two combined bedside strategies

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Accepted for publication 20 February 2013

Abstract

Objective. The objective of the study was to reduce the ventilator-associated pneumonia (VAP) incidence rates through a rational prevention program.

Design. The study was a non-controlled clinical trial with a set of interventions in mechanically ventilated patients from April 2006 until June 2008. Pneumonia rates were analyzed as time series and their mean risks of development were compared before and after the interventions with a non-concurrent cohort using the same time frame (January 2004–March 2006).

Setting. The study was conducted in a 14-bed medical intensive care unit of private general hospital in Rio de Janeiro, Brazil.

Participants. The study included invasively ventilated patients (n = 224; intervention group) compared with 294 controls (historical cohort).

Interventions. An educational module about VAP prevention was introduced at the start of the trial (April 2006). A bundle checklist was used daily concomitantly with a standardized oral care in all patients afterwards.

Main outcome measure. The main outcome measure was reduction in VAP incidence rates.

Results. The observed mean rate before the intervention was 18.6 ± 7.8/1000 ventilator-days (95% CI 8.7–14.9), decreasing to 11.8 ± 7.8/1000 ventilator-days (95% CI 15.5–21.7) (P = 0.002) after the interventions. Under the adoption of non-informative prior distributions for the parameters of the proposed statistical model, there was a 70% posterior probability in favor of the hypothesis of risk reduction associated with the interventions, regardless their seasonality or secular trends. There was a 38% relative risk reduction.

Conclusions. A reduction in VAP rates and on their risk after a set of preventive tools was observed. However, some other co-interventions not related to the primary interventions may have contributed to these results.

Keywords: ventilator-associated pneumonia, intensive care unit, VAP bundle, checklist

Introduction

Ventilator-associated pneumonia (VAP) remains an important cause of intensive care unit (ICU) morbidity and mortality. Despite advances in antimicrobial therapy, better basic care of intubated patients on mechanical ventilation and a wide variety of preventive measures [1], VAP continues to complicate the natural history of 8–28% of invasively ventilated patients [2] and its incidence varies from 10 to 30 episodes per 1000 ventilator-days [3]. Strategies aimed at reducing the incidence of this complication may improve clinical outcomes; minimize costs related to health care; and foster patient safety [4].

Recent data indicate that there is substantial lack of knowledge among ICU professionals on VAP prevention. A European study showed that intensive care nurses scored an average of 45% correct responses in a questionnaire testing evidence-based guidelines for the VAP prevention [5]. On the other hand, it has already been demonstrated that a training program for the ICU staff can promote a decrease in
VAP rates [6–8]. Thus, the involvement of all ICU professionals dealing with mechanically ventilated patients can result in greater attention to every detail of care and greater recognition of the importance of the teamwork. Awareness of prevention and control of VAP also can avoid overdiagnosis and excessive use of antibiotics, mitigating the emergence of multidrug-resistant microorganisms, resulting in better ICU performance.

The VAP bundle, made with the recommendations of the Institute of Healthcare Improvement (IHI) to prevent major complications for patients on mechanical ventilation, may also promote a reduction in its incidence [9]. This bundle may be organized as a checklist and must be verified daily during multidisciplinary ICU rounds at the bedside, avoiding at the bedside, with purpose of avoiding that some checkpoint may be omitted or skipped due to memories failures or inattention [10]. Until 2008, VAP bundle was composed of four key elements: keeping the head of the bed elevated between 30 and 45° degrees, daily interruption of sedation to assess the possibility of extubation and prophylaxis for peptic ulcer disease and for deep vein thrombosis. This approach has been most successful when all elements are executed together, as an ‘all or none’ strategy. The key points of this approach are to decrease VAP incidence, decrease the time spent on the ventilator and mitigate severe complications, which could prolong the length of stay on mechanical ventilation [11].

Lastly, organization of a training on oral hygiene protocol, focusing on the nursing and applied daily, aims at standardization of care and is also considered crucial in VAP prevention due to its pathophysiological importance.

The purpose of this study was to implement an educational module for VAP prevention, the use of a daily bundle checklist and a standardized daily oral care, verifying the effect on VAP rates.

Methods

Study design and settings

We developed a non-controlled clinical trial, from April 2006 to June 2008. Secondarily, we used a non-concurrent cohort of similar time frame for comparison, which lasted from January 2004 to March 2006.

This study was performed in a 14-bed medical ICU from a private general hospital in Rio de Janeiro, Brazil. Admissions in this ICU were preferentially medical, although occasionally surgical patients could be admitted. Surgical patients corresponded roughly to <2% of the admissions.

Interventions

An educational module was developed and consisted of lectures on VAP prevention. These lectures were preceded by a pre-test and followed by a post-test. Also, lessons on the proper use of the VAP bundle checklist were given. All ICU professionals (doctors, nurses and physiotherapists), who delivered care for patients on mechanical ventilation, attended these lectures. And, finally, a standardized training on oral hygiene directed to the nursing team was done. The main author gave the lectures and the phonoaudiology team leader performed the training on the oral hygiene protocol.

The four key components of the 2008 VAP bundle from IHI were organized as a checklist and were executed as follows: verifying the head of the bed’s elevation above 30° was done twice a day. Each bed had an analog goniometer to assess this angle. When the headboard was not above 30°, if there was no medical reason to justify it, the head of the bed was returned to the pre-established position. Then the professional was re-educated about optimal care. Daily interruption of intravenous sedation was performed at the discretion of the physician responsible for the patient, whose goal was to keep the patient under moderate to deep sedation. There was no standard protocol for withholding sedation, so that sedation could be reduced, completely stopped or remain unchanged. This definition was established by using the RASS scale (Richmond Agitation Sedation Scale) [12]. The patient should remain with values between −3 and −4 in the scale. And finally, peptic ulcer disease and deep vein thrombosis prophylaxis were prescribed and checked daily during bedside rounds.

The oral hygiene protocol was not performed with oral rinses with chlorhexidine. Although nowadays this is a guideline’s recommendation, according to the Surviving Sepsis Campaign 2013 [13], by that time, the best concentration of chlorhexidine had not yet been established, neither the exact formulation, nor the frequency of use or the best administration technique [14]. Oral hygiene was just performed with sponges (toothettes) and Biotène® mouthwashes (GlaxoSmithKline), and was provided by nurses or nursing technicians, six times per day. Phonoaudiologists inspected the oral cavity regularly together with the nurses during the intervention period.

Informed consent

Strategies implemented for VAP prevention were based on measures that were part of the basic daily care, recommended for all patients on mechanical ventilation. No invasive intervention or collection of any biological material of the patients was foreseen by this study. For this reason, the Ethics Committee in Research of the Copa D’Or Hospital has waived informed consent.

Population

All patients on invasive mechanical ventilation, intubated or tracheostomized, were allocated. Patients under the age of 18 years, those considered terminal and pregnant women were excluded from the study.

Study endpoints

The primary objective was to verify the effects of the implementation of the educational module, the daily VAP bundle checklist, and of the standardized oral care on the monthly VAP incidence rates. The secondary objective was to
compare the mean risk of VAP between the historical control and intervention groups.

**Data and statistical analysis**

The diagnosis of VAP followed the CDC (Centers for Disease Control and Prevention) standard criteria, based on the NNIS (National Nosocomial Infections Surveillance) methodology [15]. Since 2005, the Brazilian Agency of Sanitary Surveillance has also been adopting these criteria, and their use is mandatory. These criteria are fever (>38.3°C), leukocytosis (>10 000/mm³) and a new or progressive pulmonary infiltrates on chest X-ray. The same group of doctors was present on a daily basis throughout the study period, including during the historical control. Every case was discussed during the rounds, when other physicians were also involved, and later, the infectology consultants actively validated compliance with the diagnostic criteria as an external audit. Thus, clinical, laboratory and radiological data used to validate this diagnosis originated from chart review. The microbiological diagnosis was stimulated, but was not mandatory.

VAP rates of the precedent month were consolidated by the same infectology consultant before and after the interventions, and for that reason he was not blinded to the interventions. VAP rates were compared by Student’s t-test between these two groups.

Demographic variables such as age, gender, main cause of admission and APACHE II (Acute Physiology and Chronic Health Evaluation II) score [16] were obtained on each group but were not included in the adjusted model, since a monthly consolidated, epidemiological approach was adopted. On the same way, other data, such as number of admissions to the ICU per month, number of patients on mechanical ventilation per month, patient-days on mechanical ventilation and the number of VAP episodes, were obtained separately before and after the interventions. Student’s t-test, Mann–Whitney and the approximate normal test with correction for continuity were adopted to compare normal and non-normal proportions under both approaches.

In order to deal with the temporal and discrete nature of the data, time series with 54 monthly records of VAP, ranging from January 2004 to June 2008, were analyzed following a Poisson dynamic model [17, 18]. At each month \(t\), the expected number of patients (\(\lambda_t\)) with VAP was described by the product of \(V_t\), \(R_s\) with \(V_t\) denoting the total size of the population at risk, per month, multiplied by the monthly average length of stay in mechanical ventilation (mean ventilator-day). Thus, \(R_s\) denotes the risk of VAP, free of the exposure length at each month and was modeled by a time-varying level \(\mu_t\), and by a dummy component (\(1_t\)), indicating if month \(t\) belongs to the period before or after the intervention (respectively, 0 or 1). In addition, to describe the temporal fluctuation of the basic risk function, the dynamics imposed to \(\mu_t\) formally addresses the autocorrelation present in time series data.

A Bayesian inferential approach was applied, although subjective information has not influenced the estimation of parameters, since vague prior distributions were adopted. Monte Carlo Markov chain methods [19], implemented in the software WinBUGS 1.4.3, were applied to approach the posterior distribution of the parametric vector, which describes the uncertainty on the parameters, updated by the observed data.

**Results**

**Demographics**

The intervention group studied during 27 months had 224 patients, with a median age of 77 years (IQR 65–85), and 52.7% were females. The historical control group had 294 patients, with a median age of 76 years (IQR 61–83), and 47.6% were females. Table 1 illustrates these and other data group separately before and after the interventions.

**Intervention outcomes and time series analysis**

The VAP incidence rates have decreased over time. The observed monthly mean VAP rate before the intervention was 18.6 ± 7.8/1000 ventilator-days (95% CI 8.7 – 14.9), decreasing to 11.8 ± 7.8/1000 ventilator-days (95% CI 15.5 – 21.7) (\(P = 0.002\)) after the intervention.

The resulting posterior distribution shows that, despite the great uncertainty (due to the small length of the time series observed) on the estimation of the parameter controlling for the specific effect of the intervention, there is a 70% probability in favor of the hypothesis of risk reduction associated to the intervention. The mean of the basic risk function \(R_s\) along with 95% credibility limits, is presented in Fig. 1.

The Monte Carlo approach enabled the attainment of a sample of the distribution of the quantity \(D = R_{po} - R_{pi}\), with \(R_{po}\) denoting the mean pre-intervention risk and \(R_{pi}\) denoting the mean post-intervention risk. Figure 2 exhibits the distribution of such differences, with 99.9% probability assigned to lower mean risk at the intervention period. The mean of this distribution, \(-0.0072\), is a point estimate of \(D\), with 95% credible interval (\(-0.012, -0.003\)). The mean difference corresponded to a 38% reduction in VAP risk, if compared with the mean risk before the interventions.

**Discussion**

The present study demonstrated that there was a reduction in monthly VAP incidence rates after the implementation of an educational module, after the use of a daily checklist, which followed IHI recommendations, and with a standardized daily oral care. The mean VAP rate has decreased to values close to that of the International Nosocomial Infection Control Consortium 2003–08 (14.7, 95% CI 14.2–15.2), which included 173 ICUs from 25 developing countries (including 19 Brazilian ICUs). Although these results are still far from those of the United States National Healthcare Safety Network 2006–07 (3.3, 95% CI 3.1–3.6) [20], we
could show a fall in VAP rates over time (Fig. 3), and we considered it appropriate to the reality of our country.

Some studies addressed the use of the VAP bundle checklist, using the traditional ‘before–after’ design, in which the outcomes were compared before and after this intervention [21–23]. Although these studies had already been subjected to a critical analysis of their methodology [24], none of them approached the fact that the compared groups were not independent, and this could have limited their conclusions.

In our study, we performed a time series analysis taking into account that the groups before and after the proposed interventions were not considered as independent. For instance, we had patients on mechanical ventilation in the last week of March 2006, which remained on the ventilator through the subsequent month, denoting dependency in the analyzed variables. For this reason, a prediction dynamic risk model was adjusted using the Poisson distribution and the Bayesian inferential approach, so that we were able to remove the effect of seasonality or secular trend over the outcomes, and to estimate the risk reduction after that, even with the great uncertainty on the estimation of the parameter that addresses the specific effect of the intervention. In turn, we could also ascertain that there was a risk reduction of VAP
that could be associated with the interventions proposed by the study.

During the whole study period, including the control (January 2004 to June 2008), there were no changes in ICU leadership. Thus, we could ensure that the VAP diagnosis was done at least with the same criteria in both groups, which is an important positive feature of the present study. Of the four studies analyzed by Zilberberg et al. [24], only one [21] had this concern when it tried to mitigate selection bias in the way of performing VAP diagnoses. Another important strength of our study, not mentioned by the four studies analyzed by Zilberberg et al., is that the ratio of nurses, nursing technicians and physiotherapists per bed was kept unaltered during the whole period of study (1:3, 1:1 and 1:7, respectively). This also reduced bias or potential confounders, because lapses in infection control were avoided over time [25, 26]. During the whole time frame of the study, no new biomedical material with antimicrobial properties (such as, silver-coated endotracheal tube, subglottic aspiration tube) was acquired by the hospital, which could also have interfered with the outcomes of the study.

From the epidemiological point of view, we limited the case mix and tried again to minimize selection bias when we used only medical ICU patients. Regarding seasonal variations, there was neither an increased incidence in winter months, nor was the climate milder in the intervention group. Paradoxically, the highest VAP incidence was in spring–summer (September–March) 2006 in a city that has no marked differences in temperature throughout the year (Rio de Janeiro). Moreover, this was the period that motivated this study and an urgent intervention on the undesirable deviation in our VAP rates.

There was no direct financial cost involved in the implementation of VAP bundle. The components of this bundle were not based on new or expensive technologies, but represented basic care to any mechanically ventilated patient. Indeed, the major expense involved in this study was the energy invested to execute it uniformly and with discipline by the ICU team. Despite the absence of studies that involve cost analysis on the prevention of avoidable adverse events in Brazil, we suggested that these interventions were cost-saving (and also probably lifesaving).

**Limitations of the study**

Compliance with the checklist was measured only during the first month of the intervention period and reached 93%. It is not known if compliance was sustained throughout the intervention period. Data from IHI showed that when the VAP bundle compliance was >95%, reduction in VAP rates reached 61% [9]. In our study, a risk reduction of 38% was observed and perhaps it means that compliance has been lower than the expected. On the other hand, it was proven that keeping the headboard above 30° most of the time is a very hard task to accomplish, even with an electronic monitoring of the angle of the bed during 24 h [27].

The author of the study was responsible for the daily checklist use during the bedside rounds. The head of the bed was verified a second time later by another ICU leadership. However, we did not ensure that the execution has been uniformly held during holidays, weekends or absenteeism, and the sustainability of the process was difficult to assess, because compliance was not verified. In a recent article that addresses the effect of interrupting the execution of a checklist for VAP prevention during 4 months, a rebound of VAP rates was observed [28]. However, during the 2 years and a quarter after the intervention, there was no interruption in checklist use for more than a day or two at most.

It is very difficult to affirm that the whole set of interventions in this trial was solely responsible for the improvements on VAP rates. An unmeasured benefit of the primary intervention is that the ICU team was more attentive to some co-interventions and this could interfere with the results. The daily risk of gastric aspiration to the lungs was mitigated when we avoided gastric distention through regular measurement of gastric residual volume. Prophylaxis for peptic ulcer disease in ventilated patients could promote an overgrowth of Gram-negative bacteria that could be aspirated and cause VAP. So the daily reassessment for cessation of this drug was done if the mechanically ventilated patient has been hemodynamically stable and has been out of risk for acquired coagulopathies in the ICU. And finally, the cuff pressure of the endotracheal tube was checked at least twice a day and should be kept between 20 and 30 cmH₂O [29]. Probably, the ICU team was more focused on the performance of these co-interventions after the educational module and this positive attitude could have resulted in an uneven distribution between groups.

**Conclusion**

In the present study, there was a reduction in VAP incidence rates and in their mean risk of development after the implementation of an educational module on preventive measures, together with a standardized patient care through the daily use of a VAP bundle checklist and through a homogeneous oral care.
Acknowledgements

We thank Dr João Pantoja and Professor Dr Giselle F. Taboada for reviewing the manuscript.

References


