Implementation of a Ventilator Associated Pneumonia Prevention Bundle in a Single Pediatric Intensive Care Unit

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**ABSTRACT**

**Objective:** Ventilator associated pneumonia (VAP) is considered the second most frequent infection in pediatric intensive care and there is agreement on its association with higher morbidity and increased healthcare costs. The goal of this study was to apply a bundle for VAP prevention as a process for quality improvement in the Pediatric Intensive Care Unit of Hospital Italiano de Buenos Aires, Argentina, aiming to decrease baseline VAP rate by 25% every six months over a period of two years.

**Design:** Quasi-experimental uninterrupted time series.

**Setting:** Pediatric Intensive Care Unit of Hospital Italiano de Buenos Aires, Argentina.

**Patients:** All mechanical ventilated patients admitted to the unit.

**Intervention:** It consisted of the implementation of an evidence-based VAP prevention bundle adapted to our unit and using the plan – do – study – act cycle as a strategy for quality improvement. The bundle consisted of four main components: head of the bed raised more than 30 degrees, oral hygiene with chlorhexidine, a clean and dry ventilator circuit and daily interruption of sedation.

**Measurements and Main Results:** VAP prevention team meetings started in March 2012 and the VAP bundle was implemented in November 2012 after it had been developed and made operational. Baseline VAP rate for the two years before intervention was 6.3 episodes every 1000 mechanical ventilation days. VAP rate evolution by semester and during the two years was, respectively, 5.7, 3.2, 1.8 and 0.0 episodes every 1000 mechanical ventilation days. Monthly VAP rate time series summarized in a 51-point control chart showed the presence of special cause variability after intervention was implemented.

**Conclusions:** The implementation over two years of a VAP prevention bundle specifically adapted to our unit using quality improvement tools was associated with a reduction in VAP rate of 25% every six months and a nil rate in the last semester.
INTRODUCTION

Healthcare-associated infections may be harmful to hospitalized patients and there is evidence that up to 12% of patients in pediatric intensive care units (PICU) in North America may be affected. (1) Therefore, their prevention is a priority in terms of improving the quality of care and patient safety. (2, 3)

The incidence of ventilator-associated pneumonia (VAP) is not known precisely because of the variability in diagnostic criteria. Nevertheless, it is considered the second most frequent infection in PICU after central line-associated bloodstream infections, (4, 5) representing up to 22.7% of total healthcare-associated infections (3) and affecting up to 5.1% of ventilated patients. (6) Even though mortality in pediatric patients is not accurately recognized there is agreement on its association with higher morbidity and increased healthcare costs. (4, 5, 7)

Currently there is evidence in adults that demonstrates that prevention of VAP is feasible through the implementation of certain interventions together and at the same time. This strategy, known as a VAP bundle, includes four elements: (8, 9) general measures, such as hand hygiene, daily interruption of sedation and daily evaluation of readiness for mechanical ventilation discontinuation, with the aim of reducing length of exposure to the ventilator; interventions to avoid aspiration of oropharynx secretions, such as elevation of the head of the bed to more than 30° and use of endotracheal tubes with balloons; interventions to reduce oropharynx colonization, such as mouth hygiene with antiseptic solutions and interventions to reduce device contamination, such as avoiding condensation in mechanical ventilator circuit, disinfection of devices associated with mechanical ventilators and aspiration of tracheal secretions by the sterile technique.
The implementation of these measures as a bundle has been demonstrated to reduce the incidence of VAP in adults and children. (5, 10-12) With this aim we decided its application as a process for quality improvement using the plan – do – study – act cycle that has been recognized as a model able to produce rapid improvement in healthcare. (13, 14) To avoid variability in the diagnosis of VAP we followed the surveillance definition and diagnostic criteria from the Center for Disease Control and National Healthcare Safety Network. (15)

Therefore, the goal of this study was to apply a bundle for VAP prevention as a process for quality improvement in the Pediatric Intensive Care Unit of Hospital Italiano de Buenos Aires, Argentina, aiming to decrease baseline VAP rate by 25% every six months over a period of two years.

MATERIALS AND METHODS

Setting

The study was completed in the PICU of Hospital Italiano de Buenos Aires, Argentina, a general university third-level hospital. This unit has about 650 admissions a year and it provides healthcare to medical, surgical (general, cardiovascular, neurosurgeries) and transplant patients (heart, liver, kidney, small bowel and bone marrow).

About 28% of admitted patients require mechanical ventilation and the rate of ventilator use is 40% (mechanical ventilator days/patient days*100). The VAP rate (episodes of VAP adjusted to 1000 mechanical ventilator days) in the two years before intervention was 6.3 episodes of VAP/1000 mechanical ventilator days.

Population and design
The design selected was a quasi-experimental uninterrupted time series and the study population was all mechanical ventilated patients admitted to the PICU.

**Intervention**

The intervention consisted of the implementation of an evidence-based VAP prevention bundle, adapted to our PICU and using the plan – do – study – act cycle. Steps followed were as below.

1) **Multidisciplinary group formation**

Members from the Infection Control Committee (nurse and physician), Respiratory Care Service (respiratory therapist) and PICU (head nurse, staff physician, unit vice director) formed the VAP prevention team. VAP prevention team meetings started on March 2012 and the VAP bundle was initially implemented in November 2012. During these months the VAP bundle was outlined and items were developed.

2) **VAP bundle definition**

The adult VAP prevention bundle was adapted for children. The VAP prevention team reviewed the literature and agreed that the bundle would have four main components: head of the bed raised to 30 degrees, (16, 17) oral hygiene with chlorhexidine 0.12% every six to eight hours, (18, 19) a clean and dry ventilator circuit (20) and daily interruption of intravenous sedatives. (21, 22)

3) **Making the VAP bundle operational**

To position the head of the bed a 50 cm stick was designed and vertically placed in the head edge of the bed. If its superior extreme could not be seen from the opposite end of the bed, the head of the bed was deemed to be properly raised.
To provide mouth hygiene, kits containing Chlorhexidine 0.12% oral rinse were designed and made available, laryngoscope blades were sterilized, and endotracheal tube taping and oral hygiene technique were standardized through specifically produced educational videos. Prescription orders were introduced into the electronic medical record so nurses could document the oral hygiene performed.

To keep ventilator circuits clean and dry endotracheal tube aspiration techniques were standardized through a purposely designed educational video and heated ventilator circuits with less water condensate in the expiratory limb were made available, used and exchanged every week in accordance with the manufacturer's instructions. (23) Reminders of the expiry date were placed on the circuit by respiratory therapists.

Interruption of intravenous sedatives was discussed daily during bedside morning rounds and prescription orders were introduced in the electronic medical record as well. Finally, it was agreed upon that the morning shift nurses would carry out sedative interruption before noon and then register its performance.

4) Implementation of the VAP bundle

Once the items of the VAP bundle were ready to be applied, we planned interventions oriented to PICU staff education with the aim of getting the VAP prevention bundle fully incorporated into daily practice. Actions undertaken were: announcing the start of the VAP prevention program and the main components of the VAP bundle via email; formal presentation of the program by the PICU Director and the Nurse in Charge, an activity introduced in all shifts which included information about the development of the VAP bundle, their specific items, the baseline and the aimed VAP rate; design of education material to explain the VAP bundle: text documents, slide presentations, posters and videos; display of educational material in the PICU virtual campus along with the program result indicator evolution (VAP rate); exhibition of posters
in the main corridor of the unit describing the VAP bundle components, program goals and result indicator evolution; short (20 to 30 minutes) oral presentations for small groups of doctors, nurses and respiratory therapists (four to six) by VAP prevention team members to explain the bundle, the responsibilities of staff and the goals of the program; and periodical analysis of the program evolution and oral presentations every three months to reinforce components of the bundle that were difficult to implement.

5) VAP bundle compliance

Two strategies were used. First, unplanned visits were made by Infection Control Committee members from November 2012 to August 2013. During these visits the position of the head of the bed was checked, ventilated patients’ mouths were opened and examined to see if they looked clean and ventilator circuit expiry dates were reviewed. There were 20 visits completed between November and December 2012, 10 between January and February 2013, 20 between March and April 2013, 12 between May and June 2013 and 12 between July and August 2013.

From September 2013 to October 2014, a checklist was started to use daily during the morning rounds by the staff physician in charge of the PICU to verify compliance with several evidence-based practices including those mentioned above (head of the bed elevation, performance of mouth hygiene and ventilator circuit expiry date) in addition to the daily interruption of intravenous sedatives. There were 1201 observations performed during this period (one per ventilated patient per day).

Data collection
Members of the Infection Control Committee were responsible for collecting the number of mechanical ventilation days, admission days and the percentage of compliance with VAP bundle components during unplanned visits.

Members from the PICU were responsible for obtaining the percentage of compliance with VAP bundle components derived from the use of the checklist.

Definitions

There was a standard approach to VAP surveillance: every patient on mechanical ventilation for more than 48 hours who had two or more serial chest imaging test results with new or progressive and persistent infiltrates were evaluated for diagnosis of VAP. Episodes of VAP were then defined during VAP prevention team meetings by analyzing radiologic, clinical and laboratory criteria following the Center for Disease Control and National Healthcare Safety Network guidelines. (15) If there was no agreement on the definition of an episode in this setting, the Director of the Infection Control Committee made the final decision.

Indicators were constructed with data collected and episodes of VAP defined. The process indicator was the monthly percentage of compliance with each component of the VAP bundle and the result indicator was the monthly VAP rate, defined as the number of VAP episodes every 1000 ventilator days.

Statistical analysis

For descriptive statistics we used means and standard deviations, medians and interquartile ranges or proportions, depending on the characteristics and distribution of variables.
Analysis of monthly result indicator variability was performed with a control chart. A U-type control chart was used because episodes of VAP were considered a discrete variable and reported as a rate per 1000 ventilator days. (24) The control chart time interval was 51 months, beginning two years before the intervention started. Control limits were set at ± 3 standard deviations from the mean. Special cause variability patterns considered were one point beyond the control limits, six consecutive points trending up or down or eight consecutive points on either side of the mean. (24-26)

Mean VAP rates from two years before and after the intervention was initiated were compared using the t-test for independent samples. A p value of < 0.05 was considered statistically significant.

Statistical analysis was done with Stata 9.1 (Statacorp, Texas, US). A control chart was created with QI Macros SPC software for Excel.

The study protocol was approved by the institutional review board of Hospital Italiano de Buenos Aires, Argentina (protocol number 2448).

RESULTS

The population characteristics are summarized in Table 1. We report data from 2011 and 2012 before the intervention was initiated and data from 2013 and 2014 when the intervention had been implemented.

The percentages of compliance with VAP bundle components during the study period are summarized in Figure 1. Head of the bed elevation, oral hygiene and ventilator circuit were checked throughout the study period. Daily interruption of intravenous sedation was verified beginning in September 2013.
The VAP rate is reported in a 51-month control chart that shows the last nine points below the mean, a pattern consistent with special cause variability (Figure 2).

The mean VAP rate from two years before the intervention, October 2010 to October 2012, was 6.34 and it dropped to 2.38 episodes every 1000 ventilator days over the next two years from November 2012 to December 2014. This mean VAP rate difference was statistically significant (p = 0.0047).

The VAP rate evolution after the intervention was applied was 5.7 for the first semester, 3.2 for the second, 1.8 for the third and 0.0 for the fourth.

**DISCUSSION**

The process for quality improvement in the PICU of Hospital Italiano de Buenos Aires to implement a VAP prevention bundle was associated with a reduction in VAP rate from 6.34 in the two years before intervention to 2.38 episodes every 1000 ventilator days in the next two (p = 0.0047).

The objective we planned was the reduction of the VAP rate by 25% every six months. Although we were not able to achieve this goal in the first semester after implementation, we did in the following ones. The interpretation of this finding supports our working strategy consistent with the plan – do – study – act cycle, a continuous quality improvement tool recommended by many authors for introducing rapid changes in healthcare. (14, 27, 28)

Bigham and Curley reported the effectiveness of the VAP prevention bundle in decreasing the frequency of this event in the pediatric intensive care setting. (5, 11) What our study determines, besides expanding evidence on this topic, is the importance of adapting existing evidence to particular characteristics of any PICU and the effectiveness of quality improvement tools in obtaining positive changes in concrete scenarios.
The first step of this quality improvement process consisted of defining the bundle and developing the intervention. This took about seven months (March to November 2012). Although this may be considered a relatively lengthy period of time, we considered it as a basis from which we could continue developing the rest of the program. During this time we had to sort out many practical issues that could be easier or more difficult to solve depending on the PICU’s organizational characteristics and available resources. For example, to be able to recognize when the head of the bed was properly raised we evaluated three strategies: painting a line on the wall, placing a wooden triangle next to the head of the bed and locating a vertical stick in one head of the bed vertex. We decided that the last option was the most convenient option for us and started working to get the sticks ready. We went through similar processes for new ventilator circuits, designing oral hygiene kits, sterilizing laryngoscopes blades and standardizing an endotracheal tube aspiration technique.

The next steps consisted of implementing the developed bundle, continuous verification of compliance with the items and periodical evaluation of result indicators. The first process indicator used was unplanned visits from Infection Control Committee members to check compliance with all bundle components with the exception of sedatives interruption. The evolution of this indicator over the first few months showed high levels of compliance (Figure 1). Nevertheless, the VAP rate in the first semester did not reach the planned goal. For this reason we decided to reinforce education and move towards a daily process indicator by adding all VAP bundle items, including sedative interruption, to a daily checklist used in morning rounds. This daily verification was not only useful for determining the degree of compliance, but it was also seen as an opportunity for improvement and education. If any item of the bundle was not being followed, the staff physician responsible for reviewing the checklist could take the opportunity to teach and make sure that the bundle was observed. Result indicators started to improve after use of this daily process indicator began in September 2013.
The monthly VAP rate evolution is reported in a 51-point control chart (Figure 2) that shows the last nine measurements below the mean VAP rate, a pattern consistent with special cause variability. This finding suggests there was a factor that modified the common variability of the process, it was not due to chance and the most likely factor associated with this change was the intervention implemented. (25, 26)

This study has limitations. First, it was conducted in a single PICU, so its findings may not be generalizable to other units. Second, we cannot demonstrate that the reduction in VAP rate has a positive impact on other outcome measures such as mortality, mechanical ventilation days or length of stay in the unit. We decided not to use any of these outcomes because the expected number of VAP episodes would be too few to evaluate significant differences. Third, there may be a potential risk of bias in identifying VAP cases because the intervention was not blind. Nevertheless, a standard approach to VAP surveillance according to the Center for Disease Control and National Healthcare Safety Network guidelines was followed. Last, at the same time the VAP bundle was being implemented, the hospital was going through the process of international accreditation. This may have influenced results because other quality improvements measures were developed at the same time, such as hand hygiene.

CONCLUSIONS

The implementation over a period of two years of a VAP prevention bundle specifically adapted to our PICU which included head of the bed elevation, oral hygiene, daily interruption of intravenous sedatives and keeping the ventilator circuit clean and dry, using quality improvement tools was associated with a reduction in VAP rate of 25% every six months and a nil rate in the last semester.
REFERENCES


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<table>
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<th>Variable</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
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<tr>
<td>Admissions (n)</td>
<td>672</td>
<td>652</td>
<td>692</td>
<td>621</td>
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<tr>
<td>Age (median, 25-75)</td>
<td>1.3 (0.5 - 3.6)</td>
<td>1.2 (0.4 - 3.3)</td>
<td>1.3 (0.3 - 3.4)</td>
<td>1.1 (0.3 - 3.1)</td>
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<td>Sex, boys (%)</td>
<td>51</td>
<td>52</td>
<td>53</td>
<td>49</td>
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<tr>
<td>Ventilated patients (n, %)</td>
<td>170 (25.2)</td>
<td>178 (27.3)</td>
<td>200 (28.9)</td>
<td>165 (26.6)</td>
</tr>
<tr>
<td>Days of MV, median (25-75)</td>
<td>4 (1 – 6)</td>
<td>6 (2 – 12)</td>
<td>4 (2 – 6.5)</td>
<td>4 (1.5 – 9.5)</td>
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<td>Mortality, (n %) *</td>
<td>23 (3.4)</td>
<td>22 (3.4)</td>
<td>30 (4.3)</td>
<td>33 (5.3)</td>
</tr>
<tr>
<td>Use of MV (%) *</td>
<td>35</td>
<td>45</td>
<td>36</td>
<td>38</td>
</tr>
<tr>
<td>VAP Episodes (n)</td>
<td>16</td>
<td>13</td>
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<td>Ventilated patients with VAP (%)</td>
<td>9.4</td>
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<tr>
<td>VAP rate</td>
<td>7.8</td>
<td>5.4</td>
<td>3.3</td>
<td>1.2</td>
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</table>

MV: mechanical ventilation; VAP: ventilator associated pneumonia

* PICU mortality

* Number of ventilator days / number of patient days
Figure 1. Percentage of compliance to Ventilator Associated Pneumonia prevention bundle components
Figure 2. Control chart reporting monthly Ventilator Associated Pneumonia rate