ORIGINAL ARTICLE

Preventing Ventilator-Associated Pneumonia in a Pediatric Intensive Care Unit using a Modified Ventilator-Associated Pneumonia Bundle: Pre-interventional and Post-interventional Trial

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ABSTRACT

Background: Ventilator-associated pneumonia increases in-hospital stay, morbidity and mortality of ventilated pediatric patients. It prolongs time spent on the ventilator and length of Pediatric Intensive Care Unit stay.

Methods: This is a pre-interventional and post-interventional trial of 57 and 50 pediatric patients, respectively, which started in March 2011 to decrease the rate of ventilator-associated pneumonia in Pediatric Intensive Care Unit after initiation of a modified pediatric VAP bundle compared with the ventilator-associated pneumonia rate for the preceding 12 months. The study was conducted at Makassed General Hospital in Beirut, Lebanon. It included pediatric patients that were on mechanical ventilation from March 2010 to March 2012. An interdisciplinary performance improvement team was formed, who implemented a modified pediatric VAP bundle.

Results: The implementation of the pediatric VAP bundle resulted in the reduction of ventilator-associated pneumonia rates from 52% (March 2010-2011) to 6% (March 2011-2012) ($P<0.001$).Patients who had VAP had longer stay on mechanical ventilation with a mean of 11.42 ventilator-days than those who didn't develop ventilator-associated pneumonia with a mean of 5.18 ventilator-days ($P<0.0001$).

Conclusion: Implementing the modified pediatric VAP bundle significantly reduced the ventilator-associated pneumonia rate, time on mechanical ventilation and hospital length stay with potential decrease in cost.

Abbreviations:
VAP: Ventilator Associated Pneumonia
PICU: Pediatric Intensive Care Unit
CDC: Centers for Disease Control and Prevention
CXR: Chest Radiograph
SD: Standard Deviation
DTA: Deep tracheal aspirate
BAL: Bronchoalveolar lavage

INTRODUCTION

Ventilator-associated pneumonia (VAP) is defined by the Centers for Disease Control and Prevention (CDC) as an episode of pneumonia in a patient who requires a device to assist or control respiration through a tracheostomy or endotracheal tube within 48 hours before the onset of the infection [1].Health care-associated infections have a large impact on pe-

diatric morbidity, survival, hospital costs, and length of stay[2,3].VAP is a common cause and accounts for 6.8% to 50% of health care-acquired infections among pediatric patients[4-7].

Ventilator-associated pneumonia (VAP) is a potentially lethal and common problem among mechanically-ventilated patients in intensive care units. In addition to its high mortality rate compared to other nosocomial infections, VAP is associated with prolonged hospitalization and considerable medical costs [8]. Many factors predispose to acquiring VAP; infants mechanically ventilated in the pediatric intensive care unit (PICU) are at a particularly high risk of developing VAP because of poor host factors, severe underlying diseases, prolonged use of mechanical ventilation, inadequate pulmonary toilet and extensive use of invasive devices and procedures; gram-negative and gram-positive bacteria are the most common causative organisms[9].

Few data exist regarding the strategies that hospitals use to prevent VAP. Moreover, little is known about what factors influence the use of these strategies [10]. Recently, interest has focused on practice "care bundles," sets of practices implemented together[11].

Care bundle is a cohesive set of evidence-based, well-established clinical practices that, when implemented together; achieve better patient outcomes than when implemented individually. Each element, on its own, should have strong scientific support[10].

In adult, the Centers for Disease Control and Prevention (CDC) and American Thoracic Society have published guidelines for the prevention of ventilator-associated pneumonia, by using adult VAP bundles[12,13].Several studies have shown a reduction in VAP after the guidelines were implemented into a bundle of interventions that were implemented as a single intervention [14-18].

VAP bundle is scarce in the pediatric literature. Since there is evidence that implementing a VAP bundle can result in significant, sustained reductions in VAP rates, hospital length of stay and costs, we implemented a modified pediatric VAP bundle, adapted from adult VAP bundle, applicable in pediatric intensive care unit (PICU).

Therefore, we undertook this study in the beginning of March 2011 to decrease the rate of VAP in PICU after initiation of this modified pediatric VAP bundle compared with the VAP rate for the preceding 12 months (2010).

MATERIALS AND METHODS

A pre-interventional and post-interventional study was conducted in the pediatric intensive care unit (PICU) at Makassed General Hospital, Beirut, Lebanon between March 2010 and March 2012.

Study Design: In this pre-interventional and post-interventional study, that included 57 and 50 patients respectively, we compared the rates of VAP, from March 2010 to March 2011, for a 1-year period before the initiation of the modified pediatric VAP prevention bundle. This rate was compared with the VAP rates after intervention from March 2011 to March 2012 (a 1-year period).

Intervention: In addition to routine infection control protocols, a modified pediatric VAP bundle, applicable in PICU, was adapted from adults for the study.

The adult VAP bundle components, adapted from the Institute for Healthcare improvement (IHI), include the following: (1) Hand hygiene, (2) Close suction system and subglottic suctioning, (3) Peptic ulcer disease prophylaxis, (4) Maintain cuff pressures and endotracheal tube maintenance, (4) Head-of-bedelevation, (5) Sedation vacation and readiness to wean assessment and (6) Deep venous thrombosis prophylaxis[19].

From the above adult care bundle, we adapted our modified VAP bundle, which is composed of the following: (1) Hand hygiene and sterile gloves when in contact with secretions and IV intervention, (2) Close suction system,(3) Peptic ulcer prophylaxis,(4) Orogastric tube for residual volumes before feeding, (5)15-30°head-of-bed elevation, (6) Oral hygiene with antiseptic solution and (7) Readiness to wean and extubate assessment (Annexure 1).

Inclusion criteria: All pediatric patients, admitted to pediatric intensive care unit (PICU) between March 2010 and March 2012, and required mechanical ventilation for longer than 48 hours were included in the study.

Exclusion criteria: Pediatric patients who were ventilated and had pneumonia upon PICU admission, ventilated ≤ 48 hours, non-invasively ventilated or who died within 48 hours of ventilation were excluded from the study.

Measures: Two sets of measures were monitored: process and outcome measures. The process measure reflected the rate of adherence to the ventilator bundle. The outcome measure included the rate of VAP, duration of intubation, and the organism responsible for VAP. The definition of VAP was based on the CDC's National Nosocomial Infection Surveillance definitions [1].

Implementation process: Multiple steps were taken to implement the ventilator bundle and include staff education, development of an audit tool, data collection and tracking of the measures. A team approach to drive and maintain the initiative was developed and included the following: infection control professional, critical care nursing, chief residents, chairman of the infection control committee, and chairman of pediatric department.

Staff education was accomplished by multiple presentations on VAP, the importance of the VAP bundle,

and discussion on the VAP elements. After the initial educational session, a working group worked on the development of the VAP bundle checklist. The compliance with the bundle elements was recorded on daily basis using a checklist during rounds (Figure 1). Feedback was provided by chief residents on compliance with these processes to the PICU team.

Surveillance: Active VAP surveillance continued throughout the study, including full blood counts and, if indicated, chest x-ray, sputum samples and blood cultures with temperatures ≥38.5°C or <36.0°C. The bedside nurse was responsible for collecting VAP data over the 12-month period until 24 hours post extubation, discharge or death.

VAP definition: VAP was defined as pneumonia occurring >48 hours after intubation diagnosed by specific chest radiograph (CXR) changes with at least three clinical or laboratory findings. Diagnosis was based on radiological, clinical and laboratory criteria from the CDC's National Nosocomial Infection Surveillance System [1] (Table 1).

Table 1: Diagnostic criteria for VAP

Radiological + at least three clinical/laboratory criteria	
Radiological	**Clinical/laboratory**
New or progressive pulmonary infiltrates, consolidation or cavitations on chest radiograph (two or more serial chest X-rays)	- Core temperature ≥38.5°C or <36°C (no other recognized cause)
	- Leucopenia or leukocytosis (by age)
	0 days–1 week >34×10^9 L
	1 week–1 month >19.5 or <5×10^9 L
	2-5 years >17.5 or <6×10^9 L
	6-12 years >15.5 or <4.5×10^9 L
	13 to <18 years >11 or <4.5×10^9 L
	- Significant positive culture from respiratory secretions
	- Relevant culture from alternative site of infection

Radiological: VAP was suggested by new or progressive pulmonary infiltrates, consolidation or cavitation on at least two serial CXRs with gradual resolution (rapid resolution suggests non-infective etiology, e.g. pulmonary edema or atelectasis)[1].

Clinical: Core temperature ≥38.5°C or <36°C Hyper/ Hypothermia was defined as at least two consecutive abnormal readings, using standard measurement techniques, in a 24-hour period not clearly attributable to extra-pulmonary infection, the environment or blood/drug reactions[1].

Laboratory: *Leucopenia or leukocytosis* was defined by age according to the International Consensus Conference on Pediatric Sepsis statement [20].

Significant culture of respiratory secretions Microbial growth from endotracheal secretions was reported. Sensitivities were performed on any potential respiratory pathogen.

Relevant cultures from alternative site of infection Positive blood cultures of likely respiratory tract pathogens, unrelated to another source of infection, were considered in the diagnosis of VAP.

RESULTS

A total of 107 pediatric patients were enrolled into the study. The pre-interventional group was 57 patients, and the post-interventional group was 50 patients. Baseline demographic information between both groups showed no difference in sex (Table 2).

In the pre-interventional group, VAP occurred in 30 patients out of 57, a VAP rate of 52.6 cases per 100 mechanically ventilated patients, compared to 3 out of 50, a VAP rate of 6 cases per 100 mechanically ventilated patients, after implementation of VAP bundle. Thus, there was a statistically significant difference in the rate of VAP between the pre-interventional and post-interventional groups (*P*<0.0001) (Table 3).

Table 2: Baseline demographic information of patients with and without VAP

Variable	Before VAP Bundle (n=57)	After VAP Bundle (n=50)	P-value
Male	33(57.9%)	28(56%)	
Female	24(42.1%)	22(44%)	0.843

Table 3: Rates of VAP before and after implementation of Pediatric VAP bundle

Variable	Before VAP Bundle (n=57)	After VAP Bundle (n=50)	P-value
VAP	30(52.6%)	3(6%)	<0.0001
NO VAP	27(47.4%)	47(94%)	<0.0001

Table 4: Duration of ventilator-days between patients with and without VAP

Variable	VAP	Non-VAP	P-value
Number of patients	33	74	
Ventilator-days (mean)	11.42	5.18	<0.0001

Pediatric patients with VAP had longer duration on ventilation with mean duration of 11.42 ventilator-days, compared to 5.18 ventilator-days in patients who did not have VAP, with statistically significant difference (P <0.0001) (Table 4).

In the pre-interventional group, the deep tracheal aspirates (DTA) cultures of 33 cases of VAP revealed as follows: 12 cases of *Staphylococcus aerius*, 7 cases of *Pseudomonas aeruginosa*, 1 case of *E.coli*, 1 case of *Acinetobacte*r spp and 9 cases with no growth results. In the post-interventional group, the deep tracheal aspirate (DTA) cultures of 3 cases of VAP revealed 2 cases of *Pseudomonas aeruginosa* and 1 case with no growth result (Table 5).

Table 5: Microorganisms from DTA cultures in patients with VAP

Organism	DTA Culture	Before VAP Bundle	After VAP Bundle
No Organism	10(30.3%)	9(30%)	1(33.33%)
Staph aerius	12(36.36%)	12(40%)	0
Pseudomonas spp	9(27.27%)	7(23.33%)	2(66.66%)
E. coli spp	1(3.03%)	1(3.33%)	0
Acinetobacter spp	1(3.03%)	1(3.33%)	0

DISCUSSION

Few data are available on VAP rates in the PICU and reported rates vary for each study, Stover *et al* reported an overall rate of 0.9 per 1,000 ventilator days in infants [21]. Cordero *et al* found an overall rate of 18.9% among low birth weight infants [22]. Our study showed VAP rate of 52% among ventilated pediatric patients before implementation of the modified pediatric VAP bundle.

There was a strong correlation between VAP and duration of ventilator use [5, 6]. In our study, patients who had VAP had longer stay on mechanical ventilation with a mean of 11.42 ventilator-days than those who didn't develop VAP with a mean of 5.18 ventilator-days. Other potential risk factors for VAP have been examined in several large studies; the results have differed between study populations [23, 24].

Clinical interventions for monitoring and therapeutic purposes can increase infants' risk of VAP. Placement of the nasogastric tube might enhance nasopharyngeal and gastric colonization with gram-negative bacilli that could be aspirated into the lower airway, initiating VAP [25], while intravenous catheterization induced colonization as well as bloodstream dissemination of organisms [5, 6, 21]. Infants who underwent prolonged use of mechanical ventilatory support, have potentiated exposure to contaminated respiratory equipment and contact with contaminated or colonized hands of healthcare workers in the PICU [26].

There was a limitation in the sampling procedures used to obtain microbiologic specimens from the small respiratory tract in our study, in that invasive techniques to distinguish infection from colonization are not practical or feasible and may be harmful in small infants. They can impair blood-gas exchange, delay treatment, and lead to sepsis. The role of the bronchoalveolar lavage (BAL) in devising a therapeutic strategy superior to one based only on clinical evaluation has not been evaluated in infants [27-29]. Percutaneous transthoracic aspiration is a definitive diagnostic procedure but is not commonly performed [30]. Endotracheal aspirate is the simplest means of obtaining respiratory secretions from infants receiving mechanical ventilation[31].

Gram-negative bacilli comprised nearly the whole isolates from cultures of specimens obtained from endotracheal aspirate and blood. Aerobic gram-negative bacilli are implicated in a wide spectrum of nosocomial infections in the ICU. Their emergence as significant pathogens seems to be related partly to the widespread use of broad-spectrum antibiotics, and partly to their ability to develop resistance rapidly to the major groups of antibiotics [32-34]. Coagulase-negative staphylococcus was the only gram-positive organism that accounted for the etiology of VAP and was associated with central intravenous catheters [35, 36]. Multi-resistant strains of *Acinetobacter*, *Klebsiella*and *Pseudomonas* are difficult to treat and are implicated in a wide spectrum of nosocomial infections, predominantly in the ICU [37].

VAP was the most common nosocomial infection contributing to death [38]. Mortality depended on duration on ventilator and virulence of pathogen; those with longer duration on ventilator were at higher risk. VAP caused by *Pseudomonas aeruginosa*had a higher rate of mortality [39]. Fagon *et al* suggesting that in addition to the severity of underlying medical conditions and nosocomial bacteremia, VAP independently contributes to ICU patient mortality[38].

Since some clinical interventions increase the development of VAP, clinical guidelines for the prevention of VAP should be developed [40].Pediatricians should understand its epidemiology and participates in control measures, by reducing the risk of cross-contamination during mechanical ventilation, preventing colonization and aspiration, and caring for enteral tubes and central catheters in sick infants.

In the current study, we created a modified VAP bundle applicable to PICU and that resulted in a significant decrease in the VAP rate and maintained such a reduction over 12 months. In Lebanon, no studies were conducted to evaluate the rate of VAP in PICU, or to decrease its rate. In this study, we observed a high rate of VAP before implementation of VAP bundle reaching 52% of ventilated patients, and a significant reduction of VAP rate after implementing VAP bundle down to 6% of ventilated patients. We also observed reduction in the duration of mechanical ventilation that resulted in decrease of hospital length stay in PICU with potential cost avoidance, and this in turn improved the outcome and decreased the pediatric morbidity and mortality related to VAP.

CONCLUSION

In conclusion, we adopted a modified pediatric VAP bundle resulting in a marked reduction of the VAP rate. Thus, such measures are effective and require staff training and a multidisciplinary program. A well-developed and supported program will enhance the success rate of such interventions, especially if coupled with data feedback.

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Annexure:

Figure 1: Pediatric VAP Bundle