Subject Area:

Implementation of ventilator bundle for prevention of ventilator-associated pneumonia in pediatric intensive care unit

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Abstract

Background
Ventilator-associated pneumonia (VAP) is associated with increased morbidity and mortality in pediatric intensive care unit (PICU) patients.

Objective
The aim was to examine the effect of adherence to VAP prevention bundle on the incidence of VAP in PICU.

Patients and methods
A prospective comparative study was conducted in Al-Hussein University Hospital on all patients admitted and ventilated in PICU in a year from September 2017 until September 2018. They were divided into two groups: the first group included patients admitted to PICU after implementation of the study, comprising 43 patients as cases, and the second group included patients admitted to PICU before implementation of the study, comprising 22 patients as a control group. All included ventilated children were subjected to the following:
(1) Diagnosis on admission and indication of mechanical ventilation.
(2) Full physical examination including the assessment of the following:
    (a) Anthropometric measures that were plotted on percentiles.
    (b) Vital signs: oxygen saturation and heart rate were continuously recorded.
    (c) Systemic examination and clinical evidence of sepsis and pneumonia.
(3) Ventilation mode and duration.
(4) Type of feeding whether Total parenteral nutrition (TPN) or enteral feeding.
(5) Laboratory investigations, including the following:
    (a) Complete blood count.
    (b) Quantitative C-reactive protein.
    (c) Blood chemistry and renal functions.
    (d) Arterial blood gases.
(6) Chest radiographs.
(7) Microbiological studies.

Results
The VAP rate decreased with compliance with the ventilator bundle from 50 to 14% ($P = 0.002$). Initiation of the VAP bundle is associated with a significantly reduced incidence of VAP. VAP bundle is effective in VAP reduction when compliance is maintained.

Conclusion
VAP is one of the severe complications of mechanical ventilation that significantly increases the length of PICU stay and mortality. Bundle implementation was found effective in decreasing the VAP rate in the PICU patients.

Keywords: Pediatric intensive care unit, ventilator-acquired pneumonia, ventilator bundle

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INTRODUCTION

Centers for Disease Control and Prevention had defined ventilator-acquired pneumonia (VAP) as hospital-acquired pneumonia that develops in patients who have been treated for 48 h or longer with mechanical ventilation (MV) and who had no signs or symptoms of lower respiratory infection before they were intubated and MV initiated [1].

Many published reports showed that the occurrence of VAP is 6–10% of patients who were ventilated in the pediatric intensive care unit (PICU) and the incidence of 6–13 episodes per 1000 ventilator days [2].

VAP is a major health risk for hospitalized newborns and children. It is considered as one of the top causes of hospital-acquired infections in the PICU, with a rate of 18–26% of all hospital-acquired infections in the unit, causing a mortality rate of ~10–20%. VAP is associated with elevated mortality and morbidity rates, increasing the length of hospital stay, and as a result causing high health care costs [3].

A care bundle is defined as the implementation of a group of evidence-based interventions together for a defined patient population, which when each one of them is executed individually will result in improved patient's recovery process and outcomes, but when performed all together, they providing better outcomes than implemented individually [4].

The ventilator bundle implementation has a significant reduction in VAP rates, duration of MV, antibiotic administration, length of PICU stay, and hospital costs. In conclusion, implementation of pediatric ventilator bundle is considered a practical approach for achieving better patient and clinic outcomes, with an evidence-based safe and multidisciplinary approach [5].

PATIENTS AND METHODS

Ethics committee approval was taken. Our study is a prospective comparative study. The populations included in the study are the patients admitted to PICU in Al-Hussein University Hospital and are mechanically ventilated (this study was conducted from September 2017 until September 2018).

Inclusion criteria

A total of 65 patients were included in this study and were divided into the following:
(1) First group: patients admitted to PICU after implementation of the study, comprising 43 patients.
(2) Second group: patients admitted to PICU before implementation of the study, comprising 22 patients, as a control group.

Exclusion criteria

The following were the exclusion criteria:
(1) Patients with pneumonia before ventilation.
(2) High-risk patients such as immunocompromised patients.
(3) All neonates and children less than or equal to 18 years.
(4) Children who received MV for less than 48 h.

The ventilator bundle has four key components:
(1) 30 and 45° elevation of the head of the bed (HOB).
(2) Daily sedative interruption and daily assessment of readiness to extubate.
(3) Use of sucralfate or ranitidine as a prophylaxis peptic ulcer.
(4) Deep vein thrombosis (DVT) prophylaxis will not be implemented, as DVT is not recorded in our PICU, except as complications of femoral vein sampling or cannulation.

Methods

All included ventilated children were subjected to the following:

Full physical examination, including the assessment of the following:
(1) Anthropometric measures that were plotted on percentiles.
(2) Vital signs: oxygen saturation and heart rate were continuously recorded.
(3) Systemic examination and clinical evidence of sepsis and pneumonia.

Ventilation mode and duration
Feeding whether TPN or enteral feeding

Laboratory investigations included the following:
(1) Complete blood count.
(2) Quantitative C-reactive protein.
(3) Blood chemistry and renal functions.
(4) Arterial blood gases: blood gases monitoring was carried out after starting MV, and whenever indicated.

Chest radiographs

An initial chest radiography was done for each patient once ventilation has started then whenever indicated. Comparing serial films was of utmost importance in VAP diagnosis.

Microbiological studies included the following:

Cultures for monitoring colonization and bacterial load.

Oral swabs were taken once ventilation was initiated to determine the baseline microbial status. They were repeated every 72 h until the patient was weaned off MV or died. Buccal swabs were considered before chlorhexidine gluconate (CHG) 0.12% application. They were transported to the laboratory and cultured on blood and MacConkey agar.

Cultures of the condensate in water traps were collected in sterile cups and transported to the laboratory to be cultured on blood and MacConkey agar. This was repeated every 72 h from the start of ventilation until the baby was weaned off MV or died.

Cultures of residual gastric volume before feeding were collected via a sterile syringe from the NGT once weekly to assess gastric colonization. They were transported to the laboratory to be cultured on blood and McConkey agar.

Blood cultures

They were collected on sulphonated broth media after admission and whenever there was a suspicion of bloodstream infection.

Nonbronchoscopic bronchoalveolar lavage

The patients who were clinically diagnosed as VAP were further subjected to nonbronchoscopic bronchoalveolar lavage procedure for bacteriological confirmation of the clinical diagnosis.

The strategies of a designed VAP prevention bundle included the following:

General strategy

Adherence to hand hygiene guidelines

The infection control assigned nurses conducted hand hygiene training of all staff members, especially the new ones. The six-step hand washing posters were displayed all around. In addition, the hand rub of alcohol-based solution was placed between incubators, and in the corridor between rooms to improve hand hygiene compliance.

Performance of daily assessment of MV weaning and minimizing the prescription of sedatives as tolerated by the ventilated neonate.

Encouragement of noninvasive ventilation like nasopharyngeal continuous positive airway pressure and high-flow nasal cannula was done to minimize the risks of invasive ventilation.

Strategies to prevent aspiration

The HOB was elevated to 30–45°.

Reintubations were minimized via adequately securing the ETT to prevent its dislodgement.

Monitor of residual gastric volume before enteral bolus feedings was done to avoid gastric distention and subsequent aspiration.

Strategies to reduce colonization of the oral cavity

Suctioning of the oral secretions was performed with new suction catheters each time via open suctioning system whenever indicated.

Regular oral care with CHG 0.12% antiseptic solution administered daily every 6 h was done. It was applied via a sterile gauze (2 × 2 cm) covered by 1 ml of CHG 0.12%. Areas of application were the palate, tongue, buccal mucosa, and the upper and lower gums.

Study design

An education phase (preintervention phase) was performed to discuss how to diagnose and prevent VAP. This was accomplished by multiple presentations and clinical rounds that were attended by PICU staff. An assessment phase (intervention phase) included monitoring of the VAP bundle compliance via recording on a checklist. Observations were observed and documented regularly with the help of infection control professionals in the hospital to focus on the most common practical errors – monitoring VAP rates monthly during the bundle implementation.

Results

In this study, males were 50.77% and females were 49.23% of the patients. The mean age of the patients Age SD was 18,076 months SD = AD=18,076 (median age: 10 months). The mean age of VAP positive patients was 13.24 months, SD = 16.13 (median age: 8 months). The mean age of VAP negative patients was 23.47 months, SD = 32.14 (median age: 11 months). Patients were affected with central nervous system diseases (26.15%), pulmonary diseases (60%), neuromuscular disorders (3%) and other causes (10.77%). Overall, 90% of the patients were reintubated. Supine position was used in 43.07% of the patients. Prior use of antibiotics was seen in 100% of the patients. Urinary catheter was used in 6.15% and a central venous catheter in 26.15%. Immunodeficiency diseases were seen in 7.69%, and immunosuppressant drugs were used in 4.61%. Lung failure was the main reason for ventilation (66.15%). Overall mortality rate was 46.15%. Mortality rate was higher in VAP patients (83.3%) than non-VAP patients (35.1%). The whole mean ventilation duration was 10.89 days. The overall mean length of stay was 12.77 days.

Patient demographics, possible risk factors, underlying diseases, and duration of ventilation are summarized in Table 1.

Six patients of the case-group developed VAP (14%), whereas 11 patients of the control group developed VAP (50%) ($P = 0.002$), as shown in Tables 2 and 3 and Fig. 1.

This table shows that the most significant risk factors for VAP were supine position (100% in VAP positive cases and 22.9% in VAP negative cases), reintubation (100% in VAP positive cases and 87.5% in VAP negative cases), pump failure (47.1% in VAP positive cases and 29.2% in VAP negative cases), lung failure (52.9% in VAP positive cases and 70.8% in VAP

Table 1: Demographic criteria of pediatric intensive care unit patients

Item	*n* (%)	Mean±SD	Median (range)
Demographics			
Age (months)		20.79±29.055	10.00 (2-144)
Male	33 (50.77)		
Female	32 (49.23)		
Possible risk factors			
Reintubation	58 (90.0)		
Prior use of antibiotics	65 (100)		
Central line insertion	17 (26.15)		
Urinary catheter insertion	4 (6.15)		
Immunodeficiency disease	6 (7.69)		
Immunosuppressive drugs	3 (4.61)		
Organ failure	17 (26.15)		
Underlying illness			
CNS disease	17 (26.15)		
Pulmonary disease	39 (60)		
Neuromuscular disease	2 (3)		
PICU length of stay (days)		12.77±9.384	9.00 (2-37)
Overall mortality rate	30 (46.1)		
VAP	14 (83.3)		
Non-VAP	16 (35)		
Duration of ventilation (days)		10.89±8.798	7.00 (2-37)

CNS, central nervous system; VAP, ventilator-associated pneumonia.

negative cases), neurological disease (47.1% in VAP positive cases and 20.8% in VAP negative cases) (Table 4).

The difference between early-onset and late-onset VAP regarding organisms and outcome was statistically insignificant ($P = 0.560$ and 0.515, respectively) (Table 5).

The difference in the microorganisms found in blood culture between VAP groups and a non-VAP group of patients was statistically insignificant ($P = 0.785$), with a predominance of coagulase-negative *Staphylococcus aureus*.

This table shows that the most common cause of VAP was *Pseudomonas* spp. (35.29%), *Acinetobacter* spp. (29.41%), and *Klebsiella* spp. (17.64%).

There was a statistically significant difference between VAP positive and VAP negative groups regarding all bundle compliance.

The difference between VAP positive cases and VAP negative cases according to the outcome was statistically insignificant ($P = 0.067$).

This table shows the relation between ventilator bundle compliance and outcome among cases was statistically significant ($P = 0.001$).

DISCUSSION

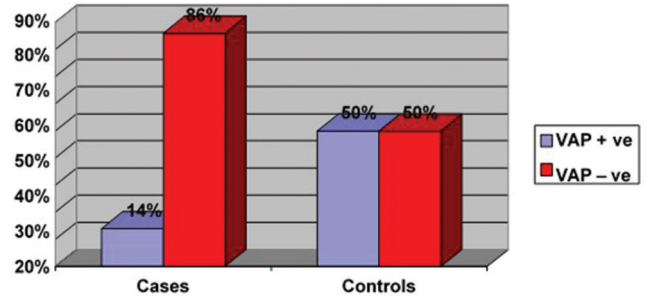Centers for Disease Control and Prevention had defined VAP as hospital-acquired pneumonia that develops in patients who

Table 2: Comparison between cases and controls regarding ventilator-associated pneumonia

	VAP positive [*n* (%)]	VAP negative [*n* (%)]
Case	6 (14)	37 (86.0)
Control	11 (50.0)	11 (50.0)

VAP, ventilator-associated pneumonia.

Figure 1: Comparing the cases and controls regarding ventilator-associated pneumonia.

Table 3: Analysis of possible risk factors predisposing to ventilator-associated pneumonia

Risk factors	VAP positive [*n* (%)]	VAP negative [*n* (%)]	P	RR
Supine position	17 (100)	11 (22.9)	0.001	
Duration of ventilation (days) (mean)	19.35	7.9	0.001	
Central line	5 (29.4)	12 (25.0)	0.754	1.176
Reintubation	17 (100)	42 (87.5)	0.327	
Urinary catheter	0 (0.0)	4 (8.3)	0.566	
Pump failure	8 (47.1)	14 (29.2)	0.236	1.737
Lung failure	9 (52.9)	34 (70.8)	0.236	0.576
Immunodeficiency diseases	0 (0.0)	6 (12.5)	0.327	
Immunosuppressive drugs	1 (5.9)	2 (4.2)	1.000	1.292
Organ failure	2 (11.8)	15 (31.3)	0.198	0.376
Sepsis	9 (52.9)	16 (33.33)	0.683	
Neurological diseases	8 (47.1)	10 (20.8)	0.042	

VAP, ventilator-associated pneumonia.

Table 4: Comparison between early-onset and late-onset ventilator-associated pneumonia regarding organisms and outcome

Items	VAP [*n* (%)]				P
	Early-onset	Late-onset	Early-onset	Late-onset	
Organisms					
Acinetobacter spp.	1	5	16.7	45.5	0.560
Pseudomonas spp.	2	3	33.3	27.3	
Klebsiella spp.	2	1	33.3	9.1	
Enterobacter spp.	1	1	16.7	9.1	
Resistant *Stenotrophomonas maltophilia*	0	1	0.00	9.1	
Total	6	11			
Outcome					
Died	6	8	100.0	72.7	0.515
Discharged	0	3	0.00	27.3	

VAP, ventilator-associated pneumonia.

have been treated for 48 h or longer with MV and who had no signs or symptoms of lower respiratory infection before they were intubated and MV initiated [1].

VAP is described as the most common nosocomial infection of intensive care and is often fatal, although attributed mortality varies [6]. The epidemiology and outcomes of VAP are well described in adults, but few data exist for pediatric patients particularly concerning risk factors, morbidity, mortality, and cost [7].

A prospective comparative study of VAP was performed in PICU of Al-Hussein University Hospital, detecting the incidence of VAP, the risk factors, and outcomes including the ventilation duration, PICU length of stay, and mortality rate. We also determined the efficacy of the ventilator bundle in

decreasing the incidence of VAP and detecting the compliance to this bundle.

The ventilator-associated pneumonia rate

Over one year, 65 patients were admitted to the PICU and matched the inclusion criteria in our study. A total of 22 patients were admitted to PICU in the first 6 months before implementation of the ventilator bundle, and 11 of them developed VAP (50.0%). Forty-three patients were admitted to the PICU in the next 6 months after implementation of the ventilator bundle approach, and six patients of them developed VAP (14.0%), as summarized in Tables 6 and 7.

In contrast to other studies not implementing ventilator bundle approach, the VAP rate ranges from 8 to 44%. Lopriore *et al.* [8], reported a VAP rate of 8.4%. Almuneef *et al.* [9], reported in their PICU in Saudi Arabia a VAP rate of 10.3%. Yuan *et al.* [10], reported in their NICU a VAP rate of 20.1%. Cravan *et al.* [11], studied about nosocomial pneumonia in 233 ICU patients requiring MV and reported that 21% of the patients expereinced VAP. Yidizdas *et al.* [12] reported a VAP rate of 44%.

On the contrary, the VAP rate in a study by Nolan *et al.* [13] implementing the VAP bundle approach was reported to be 22.72% in PICU and 9.09% in SICU, which is in contrast to VAP rate before the intervention, which was 34.78 and 33.33%, respectively. This variation in the rates of VAP might be a result of different types of patients admitted and included. Epps *et al.* [14], demonstrated that the rates of nosocomial infections including VAP differed from the kind of patients in PICU that serve mainly cardiothoracic surgery patients have lower rates than do other PICU patients. The type of patients admitted to our PICU could have influenced the rate.

Risk factors

In our study, we found that supine position ($P = 0.001$), neurological and neuromuscular diseases ($P = 0.042$), and prolonged duration of ventilation ($P = 0.001$) were independent risk factors for VAP in our PICU, as summarized in Tables 8 and 9.

Supine position appears to be important in the pathogenesis of VAP, promoting aspiration, as shown in this study and other

Table 5: Comparison of blood micro-bacterial cultures between ventilator-associated pneumonia and nonventilator-associated pneumonia patients among studied cases

Organisms	VAP [*n* (%)]	Non-VAP [*n* (%)]	*P*
Pseudomonas spp.	0 (0.00)	4 (21.05)	0.785
Candida	0 (0.00)	2 (10.52)	
CONS	3 (100.0)	13 (68.42)	
Klebseilla	0 (0.00)	0 (0.00)	
Total	3 (100.0)	19 (100.0)	

CONS, coagulase-negative *Staphylococcus aureus*;
VAP, ventilator-associated pneumonia.

Table 6: Comparison of endotracheal microbiological cultures between ventilator-associated pneumonia and nonventilator-associated pneumonia patients among studied cases

Organisms	VAP [*n* (%)]	Non-VAP [*n* (%)]	*P*
Acinetobacter spp.	5 (29.41)	2 (25.0)	0.736
Pseudomonas spp.	6 (35.29)	4 (50.0)	
Klebseilla spp.	3 (17.64)	1 (12.5)	
Enterobacter	2 (11.76)	0 (0.00)	
Resistant *Stenotrophomonas maltophilia*	1 (5.88)	1 (12.5)	
Total	17 (100.0)	8 (100.0)	

VAP, ventilator-associated pneumonia.

Table 7: Comparison between ventilator-associated pneumonia positive cases and ventilator-associated pneumonia negative cases according to compliance to ventilator bundle

Items	VAP cases		Non-VAP cases		*P*
	Mean±SD	Median (range)	Mean- SD	Median- Range	
Elevation of bed >45° compliance	58.39±3.850	58.12 (54.1-64)	97.80±8.095	100.0 (60-111)	0.001
Sedation interruption compliance	49.56±5.250	50.0 (43.2-55)	93.35±12.16	100.0 (50-105)	0.001
Spontaneous breathing compliance	40.07±4.48	40.27 (32.3-45)	84.10±24.29	91.66 (0.0-100)	0.001
Peptic ulcer prophylaxis compliance	45.80±2.74	44.72 (43.2-50)	94.96±8.365	100.0 (71.4-100)	0.001
DVT prophylaxis compliance	0	0	2.70±16.43	0.00 (0.0-100)	0.687
All bundle compliance	40.07±4.48	40.27 (32.3-45)	84.10±24.29	100.0 (0.0-100)	0.001

DVT, deep vein thrombosis; VAP, ventilator-associated pneumonia.

studies. Drakulovi *et al.* [15], found in their PICU studies that supine position was one of the risk factors for VAP development, as their study demonstrated a threefold reduction in the incidence of ICU-acquired VAP in patients kept in a semirecumbent position versus supine. Torres *et al.* [16], found that supine position was one of their risk factors for VAP in PICU. Davis *et al.* [17], found that the incidence of VAP in supine positioning as compared with the semi-recumbent positioning being significantly higher.

Neurological and neuromuscular diseases were found to be a marked risk factor in this study and other studies. Hina *et al.* [18] found that comatosed patients had a high incidence of VAP.

Prolonged duration of ventilation was found to be a significant risk factor in the present study and other studies. Ibrahim *et al.* [19] found that the risk of VAP increases with the increase in the duration of MV.

Other studies identified other several risk factors for the development of VAP as genetic syndrome, reintubation, transport out of the ICU, use of invasive procedures as central venous lines and urinary catheter, immunosuppressive diseases, immunosuppressive drugs, and sepsis. In our study, the use of gastric stress ulcer prophylaxis was not found to be independently associated with VAP.

On the contrary, Elward *et al.* [20], Foglia *et al.* [21], found in their study that genetic syndrome, transport out of the PICU, immunosuppressive drugs, and immunodeficiency diseases were all independent predictors of pediatric VAP.

Ventilator-associated pneumonia bundle significance and relations

In our study, we found a significant compliance relation between each component of the VAP bundle and prevention of VAP. The elevation of the HOB more than 45° had the most higher compliance (97.8% of the ventilation days,

$P = 0.001$); then the compliance to peptic ulcer prophylaxis among non-VAP cases, which was 94.96% of the duration of ventilation ($P = 0.001$); then the compliance to daily sedation interruption, which was 93.35% ($P = 0.001$); and then the compliance to daily assessment of spontaneous breathing and trial of extubation, which was 84.10% ($P = 0.001$). DVT prophylaxis was not done owing to nature of the patients admitted to the PICU, who had critical medical illness and were susceptible to bleeding. The compliance to all bundle together without DVT prophylaxis was 84.10% ($P = 0.001$).

Dorothy and colleagues found in their study in two SICUs over three years that compliance with HOB elevation had the most significant effect on reduction of VAP, which was initially very low in both ICUs but had the most significant improvement along the study period. DVT prophylaxis compliance, also initially poor, improved but did not affect VAP reduction. Other bundle elements had excellent compliance along the study period. HOB elevation was the single element associated with reducing VAP risk that improved during the stud period.

Resar *et al.* [22], described the effect of Institute for Healthcare Improvement (IHI) Networks experience implementing the IHI VAP bundle in a network of 61 hospitals. Greater than 95% compliance achieved by ICUs showed a reduction in VAP rates by 59%. Resar *et al.* [22], emphasized that using bundle may improve clinical outcomes, and process reliability improvement could be achieved. They consider further that the multidisciplinary teams, daily goal-setting, and increased attention to detail stimulated by bundle importantly contributed to improved clinical outcomes.

Cocanour *et al.* [23], described VAP bundle in their use, which included the IHI VAP bundle elements, in addition to various other precautions initiated. The initial VAP incidence improvements were subtle and unsustained. When they implemented an automated audit tool to calculate weekly bundle compliance data, they observed a decreased VAP rate below the 25th percentile of National Nosocomial Infections Surveillance System for the remaining months of the study. This showed the importance of the process of quality evaluation and feedback in improving bundle's clinical outcome. Nola and Berwick [13], found in their study that the use of the ventilator bundle was successful in reducing the incidence of VAP.

Table 8: Comparison between ventilator-associated pneumonia positive cases and ventilator-associated pneumonia negative cases according to the outcome

Items	VAP positive cases [*n* (%)]	VAP negative cases [*n* (%)]	*P*
Died	5 (83.3)	13 (35.1)	0.067
Discharged	1 (16.7)	24 (64.9)	
Total	6 (100.0)	37 (100.0)	

VAP, ventilator-associated pneumonia.

Table 9: The effect of ventilator bundle compliance on the outcome of cases

Items	Died cases		Discharged cases		*P*
	Mean±SD	Median (range)	Mean±SD	Median (range)	
Elevation of bed >45° compliance	83.88±19.44	96.87 (54.1-100)	98.37±8.72	100.0 (60.0-111)	0.001
Sedation interruption compliance	75.03±21.85	75.71 (43.2-100)	96.03±10.45	100.0 (50.0-106)	0.001
Spontaneous breathing compliance	56.01±27.63	60.00 (0.0-100.0)	93.76±11.98	100.0 (45.0-100)	0.001
Peptic ulcer prophylaxis compliance	78.58±22.69	82.85 (43.2-100)	94.96±12.02	100.0 (45.0-100)	0.001
DVT prophylaxis compliance	0	0	0.000±20.00	0.000 (0.00-100)	0.396
All bundle compliance	56.01±27.63	60.00 (0.0-100.0)	93.76±11.98	100.0 (45.0-100)	0.001

DVT, deep vein thrombosis.

Mortality rate

In our study, we found that there was a clinical difference between the mortality in the VAP cases (83.3%) and non-VAP cases (35.1%), although it was statistically insignificant (*P* = 0.067).

The mortality rate in our study was higher than several studies done in PICUs. In the study by Grasso *et al.* [24], mortality rate was 27% in the VAP group. In the study by Elward *et al.* [20], mortality rate was 20% in the VAP group. In the study by Yidizdas *et al.* [12], mortality rate was 22%. In the study by Lopriore *et al.* [8], mortality rate was 7.7% in VAP. This difference can be attributed to the illiteracy among parents in our hospital, so patients admitted to our PICU come in severe and complicated conditions.

Microbiological cultures

In the present study, a statistically insignificant difference was found in microorganism's cultures of tracheal aspirate between VAP group and non-VAP group of patients (*P* = 0.736) [Table 6]. Bacterial microorganisms responsible for nosocomial pneumonia in the PICU were most commonly aerobic gram-negative bacilli such as *Pseudomonas aeruginosa*, *Acinetobacter* spp., *Klebsiella pneumonia*, and *Enterobacter* spp. This predominance of aerobic gram-negative bacilli in the PICU was found to be similar to that reported by other studies in PICU patients [9,12,20,25]. On the contrary, Carvalho *et al*. [26], found a predominance of gram-positive organisms, mainly *Staphylococcus* spp.

Although viral and mycoplasma infections are thought to play an essential role in causing VAP [12], there are no sufficient data to justify routine culture for these microorganisms. Moreover, their isolation in our hospital cannot be performed.

Conclusion

(1) VAP is one of the severe complications of MV that significantly increases the length of PICU stay and mortality.
(2) The main risk factors of VAP in PICU included supine position, prolonged duration of ventilation, reintubations, and enteral feeding.
(3) Gram-negative bacilli comprised the majority of blood, nonbronchoscopic bronchoalveolar lavage, oral swabs, and residual gastric volumes cultures.
(4) Nonbronchoscopic bronchoalveolar lavage is a simple and effective technique in distal airway sampling with a minor degree of contamination and without adverse effects.
(5) Potential VAP pathogens were found to colonize the oral cavity of ventilated patients before VAP diagnosis. Therefore, implementing comprehensive oral care may reduce the incidence of VAP in PICU.
(6) Implementation of bundle was found to be effective in decreasing the VAP rate in the PICU patients.
(7) HOB elevation was the most compliant component of the bundle in the PICU.

Conflicts of interest
There are no conflicts of interest.

References

1. Control CfD, PNEU/VAP PJD-aM. Pneumonia (ventilator-associated and non-ventilator-associated pneumonia) event. 2015
2. Balasubramanian P, Tullu MS. Study of ventilator-associated pneumonia in a pediatric intensive care unit. Indian J Pediatr 2014; 81:1182–1186.
3. Casado RJ, de Mello MJ, de Aragao RC, de Albuquerque Mde F, Correia JB. Incidence and risk factors for health care-associated pneumonia in a pediatric intensive care unit. Crit Care Med 2011; 39:1968–1973.
4. Alcan AO, Korkmaz FD. Ventilatör ilişkili pnömoninin önlenmesi: Bakım paket yaklaşımı. İzmir Üniversitesi Tıp Dergisi 2015; 3:38-47.
5. Alcan AO, van Giersbergen MY, Dincarslan G, Hepcivici Z, Kaya E, Uyar M. Effect of patient position on endotracheal cuff pressure in mechanically ventilated critically ill patients. Australian Critical Care 2017; 30:267–72.
6. Klompas M. Does this patient have ventilator-associated pneumonia?. Jama 2007; 297:1583–93.
7. Niaudet P, Dudley J, Charbit M, Gagnadoux MF, Macleay K, Broyer M. Pretransplant blood transfusions with cyclosporine in pediatric renal transplantation. Pediatr Nephrol 2000; 14:451–456.
8. Lopriore E, Markhorst DG, Gemke RJ. Ventilator-associated pneumonia and upper airway colonisation with Gram negative bacilli: the role of stress ulcer prophylaxis in children. Intensive Care Med 2002; 28:763–767.
9. Almuneef M, Memish ZA, Balkhy HH, Alalem H, Abutaleb A. Ventilator-associated pneumonia in a pediatric intensive care unit in Saudi Arabia: a 30-month prospective surveillance. Infect Control Hosp Epidemiol 2004; 25:753–758.
10. Yuan TM, Chen LH, Yu HM. Risk factors and outcomes for ventilator-associated pneumonia in neonatal intensive care unit patients. J Perinat Med 2007; 35:334–338.
11. Craven DE, Steger KA. Nosocomial pneumonia in the intubated patient. New concepts on pathogenesis and prevention. Infectious Disease Clinics of North America 1989; 3:843-66.
12. Yildizdas D, Yapicioglu H, Yilmaz HL. Occurrence of ventilator-associated pneumonia in mechanically ventilated pediatric intensive care patients during stress ulcer prophylaxis with sucralfate, ranitidine, and omeprazole. J Crit Care 2002; 17:240–245.
13. Nolan TJ, Gadsby NJ, Hellyer TP, Templeton KE, McMullan R, McKenna JP, *et al*. Low-pathogenicity Mycoplasma spp. alter human monocyte and macrophage function and are highly prevalent among patients with ventilator-acquired pneumonia. Thorax 2016; 71:594–600.
14. Schwab RJ, Badr SM, Epstein LJ, Gay PC, Gozal D, Kohler M, *et al*. An official American Thoracic Society statement: continuous positive airway pressure adherence tracking systems. The optimal monitoring strategies and outcome measures in adults. Am J Respir Crit Care Med 2013; 188:613–620.
15. Drakulovic MB, Torres A, Bauer TT, Nicolas JM, Nogué S, Ferrer M. Supine body position as a risk factor for nosocomial pneumonia in mechanically ventilated patients: a randomised trial. The Lancet 1999; 354:1851–8.
16. Ewig S, Bauer T, Torres A. The pulmonary physician in critical care• 4: Nosocomial pneumonia. Thorax 2002; 57:366–71.
17. Davis Jr K, Evans SL, Campbell RS, Johannigman JA, Luchette FA, Porembka DT, *et al*. Prolonged use of heat and moisture exchangers does not affect device efficiency or frequency rate of nosocomial pneumonia. Critical Care Medicine 2000; 28:1412–8.
18. Gadani H, Vyas A, Kar AK. A study of ventilator-associated pneumonia: Incidence, outcome, risk factors and measures to be taken for prevention. Indian Journal of Anaesthesia 2010; 54:535.
19. Ibrahim EH, Mehringer L, Prentice D, Sherman G, Schaiff R, Fraser V, *et al*. Early versus late enteral feeding of mechanically ventilated patients: results of a clinical trial. JPEN J Parenter Enteral Nutr 2002; 26:174–181.

20. Elward AM, Warren DK, Fraser VJ. Ventilator-associated pneumonia in pediatric intensive care unit patients: risk factors and outcomes. Pediatrics 2002; 109:758–764.

21. Foglia E, Meier MD, Elward A. Ventilator-associated pneumonia in neonatal and pediatric intensive care unit patients. Clin Microbiol Rev 2007; 20:409–425.

22. Resar R, Pronovost P, Haraden C, Simmonds T, Rainey T, Nolan T. Using a bundle approach to improve ventilator care processes and reduce ventilator-associated pneumonia. The Joint Commission Journal on Quality and Patient Safety 2005; 31:243–8.

23. Cocanour CS, Peninger M, Domonoske BD, Li T, Wright B, Valdivia A, *et al*. Decreasing ventilator-associated pneumonia in a trauma ICU. J Trauma 2006; 61:122–129. discussion 9–30

24. Grasso F, Chidini G, Napolitano L, Calderini E. Ventilator-associated pneumonia in children: evaluation of clinical pulmonary infection score in monitoring the course of illness. Critical Care 2004; 8:209.

25. Mardganieva EA, Mironov PI, Rudnov VA. Diagnosis and treatment of ventilator-associated pneumonia in children. Anesteziol Reanimatol 2006; 1:34–38.

26. Arbique JC, Poyart C, Trieu-Cuot P, Quesne G, Carvalho Mda G, Steigerwalt AG, *et al*. Accuracy of phenotypic and genotypic testing for identification of Streptococcus pneumoniae and description of *Streptococcus pseudopneumoniae* spp. J Clin Microbiol 2004; 42:4686–4696.