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# Assessment of the Implementation of Ventilator-associated Pneumonia Preventive Bundle in Pediatric Intensive Care Unit

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***Abstract:*** ***Background****: Pneumonia associated with mechanical ventilation (VAP) is one of the important causes of nosocomial infections in pediatric intensive care units (PICU). VAP is the leading cause of morbidity and mortality in PICUs.* ***Aim:*** *To assess the compliance to ventilator bundle components: elevation of the head of bed >30, sedation interruption, spontaneous breathing trial, peptic ulcer prophylaxis and its effect on the prevention of VAP.* ***Subjects and Methods****: A case control study at PICU of Abo EL Reish El Moneira Hospital, including all mechanically ventilated patients admitted over a period of one year. The study tested the effect of implementation of this bundle as regard the rate of VAP in both group, compliance to bundle and most affecting component of it.* ***Results:*** *There was decrease incidence of VAP after implementation of the bundle, from (50%) to (14%). Development of VAP was mostly affected by being in supine position, long duration of mechanical ventilation and presence of pump failure. ($p<0.05$) The compliance to bundle components was statistically significant, $p= 0.001$.* ***Conclusion:*** *VAP rate decreased after implementation of this bundle. Elevation of the head of bed was the most compliant component of bundle in the PICU.*
***Key words:*** *Effective, Pediatric Intensive Care, Ventilator-associated pneumonia, Ventilator bundle*

## I. Introduction

Ventilator-associated pneumonia (VAP) is defined as pneumonia in mechanically ventilated patients that develops later than or at 48 hrs after the patient has been placed on mechanical ventilator and have developed abnormal chest radiography with either one of the following symptoms: fever (38 or more) with no other recognized cause, leucopenia (4,000\mm$^2$ or less), leucocytosis (13,000\mm $^2$or more). In addition, patients should have at least two changes either in the sputum character, respiratory secretions, cough or worsening of gas exchange (O2 desaturation, increased O2 requirements or increased ventilation demand). (1)

VAP is the second common hospital–acquired infection among ICU patients occurring at variable rates from 6 to 52%. (2) It is the leading cause of death in the intubated patients. Hospital mortality in ventilated patients who develop VAP is 46 %, compared to 32% for ventilated patients without VAP. (3)

The risk factors for developing VAP were found to be genetic syndromes, transport out of the PICU, re-intubation, prior antibiotic use, continuous enteral feeding, immune-suppressants, immunodeficiency, neuromuscular blockade, some medications such as steroids and H2 blockers. The most commonly isolated organisms in VAP were staphylococcus aureus and pseudomonas aeurogenosa. (4)

Because of higher incidence and costs of VAP, there are several recommendations to decrease it. The health care infection control practices advisory committee suggests using oro-tracheal tubes instead of naso-tracheal tubes when the patients require mechanical ventilation, changing breathing circuits of ventilator only if malfunction or visibly contaminated and using endo-tracheal tubes with dorsal lumen to allow respiratory secretions to drain. (5) Lately, health care infection control practices advisory committee suggested also implementing ventilator bundle which resulted in dramatic reductions in the incidence of VAP.

The ventilator bundle has four key components

- Elevation of the head of the bed to between 30 and 45 degrees.
- Daily "sedation vacation" and daily assessment of readiness for extubation.
- Peptic ulcer disease prophylaxis (unless contraindicated).
- Deep venous thrombosis (DVT) prophylaxis (unless contraindicated). (6)

We aimed to study the prevalence and risk factors of VAP in ventilated patients admitted in PICU and to assess the impact of implementing head of bed elevation, sedation vacation and peptic ulcer prophylaxis on VAP rates.

## II. Patients & Methods

This study included all patients admitted to the medical PICU of Abol Reish El Monira Hospital, Cairo University, and are mechanically ventilated, from March 2010 till March 2011.

We had two groups:
1st group: Patients admitted to PICU before implementation of the preventive bundle (from March 2010 to August 2010) and they are 22 patients: considered as control.
2nd group: Patients admitted to PICU after implementation of the preventive bundle (from September 2010 to March 2011). They are 43 patients: considered as cases.
All patients were subjected to full history and clinical examination. Routine laboratory investigations including complete blood count, C-reactive protein (CRP), eryhthrocyte sedimentation rate (ESR), arterial blood gases, liver and kidney functions, cultures and chest X-ray were done on admission and repeated as needed.
Patients were diagnosed as having VAP with:
Clinical evaluation: fever, new onset of purulent sputum, change in the character of the sputum, increased respiratory secretion or increased suction requirement, bronchial breath sounds and worsening gas exchange.
Laboratory investigation: Leucopenia or leukocytosis.
Chest radiography: Infiltrate, consolidation, cavitations and or pneumatoceles.

In this study we tested implementation of ventilator bundle suggested by Health Care Infection Control practices advisory committee in prevention of VAP in all ventilated patients upon their ventilation, by comparing VAP rate in the 1st group with VAP rate in the 2nd group after implementation of bundle components.
The ventilator bundle has four key components (but we applied the first 3 only):

a) Elevation of the head of the bed to between 30 and 45 degrees.
b) Daily "sedation vacation" and daily assessment of readiness for extubation.
c) Peptic ulcer disease prophylaxis using sucralfate or ranitidine.

Since deep venous thrombosis is not recorded in our PICU except as complications of femoral vein sampling or cannulation, prophylaxis of DVT (the 4th component) was not implemented.
Compliance to this bundle was assessed daily using a check list.
The exclusions from individual components of VAP bundle includes:
a) Sedation reviewed and, if appropriate, stopped each day.
Exclusions

- Paralyzed patient.
- Patient with brain injury, sedated with possible intra-cranial pressure problem.
- Patient who is difficult to oxygenate (Fio2> 0.7 or PEEP> 10).
- Patient who is difficult to ventilate – coughing, asynchrony.
- Patient receiving therapeutic hypothermia.
- Patient receiving palliative/terminal care.

b) Patient assessed for weaning and extubation each day.
Exclusions

- Paralyzed patient.
- Patient with brain injury, sedated with possible ICP problem.
- Patient who is difficult to ventilate – coughing, asynchrony.
- Patient who is difficult to oxygenate (Fio2 > 0.7 or PEEP > 10).
- Patient receiving therapeutic hypothermia.
- Patient receiving palliative/terminal care.

c) Avoid supine position and aim to have the head of bed elevated to at least $30^{\circ}$.
Exclusions

- Unstable, shocked patient e.g., requiring fluid challenges, high dose inotropes.
- Unstable pelvic or spinal injury (it may be possible to tilt the whole bed).

We also analyzed the association between VAP and certain risk factors as immunosuppressive diseases, immunosuppressive drugs, and invasive procedures as central venous line or urinary catheter.

## III. Statistical Analysis

Data were statistically described in terms of range, mean ± standard deviation (± SD), median, frequencies (number of cases) and percentages when appropriate. Comparison of numerical variables between the two groups was done using Mann Whitney *U* test for independent samples. For comparing categorical data, Chi square ($\chi^2$) test was performed. Exact test was used instead when the expected frequency is less than 5. For comparing categorical data, Chi square ($\chi^2$) test was performed. Yates correction equation was used instead when the expected frequency is less than 5. *P* values less than 0.05 was considered statistically significant. All statistical calculations were done using computer programs SPSS (Statistical Package for the Social Science; SPSS Inc., Chicago, IL, USA) version 15 for Microsoft Windows.

## IV. Results

A case-control study for prevention of VAP was performed in the PICU of Abo El Reesh El Monira Hospital. Sixty five patients (admitted and put on mechanical ventilation during the study period) were included. The controls were 22 patients and were not subjected to ventilator bundle approach and 43 patients were subjected to ventilator bundle approach (cases). The implementation of the bundle and the assessment of compliance were applied daily from day one to the end of the ventilation days.

Patient's demographics, underlying diseases, procedures, outcome and the reason for ventilation are summarized in Table**1**. The main reason for ventilation was lung failure (66.15%). Overall mortality was (46.15%), VAP mortality rate patients was higher (83.3%) than non-VAP patients (35.1%). The overall mean ventilation duration was 10.89 days. The overall mean length of stay was 12.77 days.

**Table (1): Pediatric intensive care unit patient's characteristics**

| | **N** | **%** | **Mean** |
|---|---|---|---|
| **Demographics** | | | |
| Male | 33 | 50.77 | |
| Female | 32 | 49.23 | |
| Age (Month) | | | 22.4 |
| **Underlying illness** | | | |
| Pulmonary disease | 39 | 60 | |
| CNS disease | 17 | 26.15 | |
| Other diseases * | 7 | 10.77 | |
| Neuromuscular disease | 2 | 3 | |
| **Possible risk Factors** | | | |
| Re-intubation | 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 | |
| **Outcome** | | | |
| PICU- LOS(days) | | | 12.77 |
| Overall Mortality rate | 30 | 46.1 | |
| VAP | 14 | 83.3 | |
| Non VAP | 16 | 35 | |
| **Duration of Ventilation(days)** | | | 10.89 |
| **Pump failure** | 43 | 66.15 | |
| **Lung failure** | 22 | 33.84 | |

CNS: central nervous system; PICU: pediatric intensive care unit; LOS: length of stay; VAP: ventilator associated pneumonia.

*Other diseases: cardiovascular, gastrointestinal, metabolic, hematologic disorders

Six patients of the case-group developed VAP (17%), while 11 patients of control group developed VAP (50%), p= 0.002 as shown in Table **2**.

**Table (2): Comparison between cases and control in relation to ventilator associated pneumonia**

| | **Cases** | **Controls** |
|---|---|---|
| **VAP + ve** | | |
| Number | 6 | 11 |
| % | 14 | 50.0 |
| **VAP – ve** | | |
| Number | 37 | 11 |
| % | 86.0 | 50.0 |
| **p value** | 0.002 | |

VAP: ventilator associated pneumonia

Univariate analysis comparing mechanically ventilated with and without VAP are summarized in Table **3**. VAP was associated with the following procedures: re-intubation and central line insertion. There was positive correlation between re-intubation and VAP, but statistically insignificant (P =0.327). The association between

VAP and central line and urinary catheter insertion was also statistically insignificant, P=0.754 and p=0.566; respectively. Relative risk (RR) of those with central line and those without in relation to VAP was 1.176.

**Table (3): Analysis of possible risk factors predisposing to ventilator associated pneumonia**

| Risk factors | VAP + ve | | VAP – ve | | P value | RR |
|---|---|---|---|---|---|---|
| | n | % | n | % | | |
| Supine position | 17 | 100 | 11 | 22.9 | 0.001 | |
| Duration of ventilation (days) | Mean 19.35 | | Mean 7.9 | | 0.0001 | |
| Central line | 5 | 29.4 | 12 | 25.0 | 0.754 | 1.176 |
| Re-intubation | 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 | 0.038 | 1.737 |
| Lung failure | 9 | 52.9 | 34 | 70.8 | 0.236 | 0.576 |
| Immunosuppressive 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 | 0.058 | |

VAP: ventilator associated pneumonia

There was a statistically significant relation between the development of VAP and duration of mechanical ventilation, p=0.0001; supine position, p=0.001; and pump failure, p=0.038.

The VAP +ve patients stayed in the PICU longer than VAP –ve patients, p=0.001. Table **4**

**Table (4): Comparison between ventilator associated pneumonia +ve and -ve patients regarding length of stay**

| | VAP – ve | VAP + ve | p value |
|---|---|---|---|
| **Length of stay (days)** | | | 0.001 |
| Mean ±SD | 9.8-6.792 | 21.00-10.92 | |
| Median-Range | 7.00-(2-36) | 18.00-(6-37) | |

VAP: ventilator associated pneumonia

The compliance to bundle components was statistically significant, p= 0.001 except for DVT prophylaxis which was not done in our study because our PICU was a medical ICU and the risk of developing DVT is very rare in our patients. Table **5**

**Table 5: The effect of ventilator bundle compliance on the outcome of cases**

| | Dead cases | | Discharged cases | | P value |
|---|---|---|---|---|---|
| | 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 |
| **All bundle compliance** | 56.01-27.63 | 60.00-(0.0-100.0) | 93.76-11.98 | 100.0-(45.0-100) | 0.001 |

## V. Discussion

Before implementation of ventilator bundle, VAP rate was 50%; and after implementation of ventilator bundle VAP rate decreased to 14%. While searching other studies we found that the VAP rate varies widely: in their PICU, **Yildizdas and colleagues 2002** (7) (44%); **Nolan and Berwick 2006** (8) **(**22.72%); **Almuneef and colleagues 2004** (9) (10.3%) and in their NICU, **Yuan and colleagues 2007** (10) (20.1 %). This variation in the

rates of VAP could be resulted from the type of patients admitted to each unit and the compliance to the bundle. Moreover, this variation indicates the difficulty that intensivists meet in the prevention of VAP due to its multifactorial predisposing factors.

Supine position, which reflects aspiration, appears to be important in the pathogenesis of VAP as demonstrate in our study and other studies. (11), (12) In this study, it was the 2nd most significant risk factor predisposing to VAP after considering the prolonged duration of mechanical ventilation. Similarly, **Ibrahim and colleagues 2001** (3) found a positive correlation between VAP and the duration of mechanical ventilation.

The presence of pump failure was found to be a significant risk factor in our study and in the study by **Hina and colleagues 2010.** (13)

In our study, there was significant relation between the compliance to each component of the VAP bundle and prevention of VAP, the most higher compliance was to elevation of the head of bed more than 45 degree (97.8 % of the ventilation days, p=0.000). **Dorothy and colleagues 2010** (14) proved that Head-of-bed elevation was the single element associated with reducing VAP in their patients**.** This is considered the simplest component of the bundle in its application, which gives intensivists hope that with some compliance, the VAP problem can be reduced.

## VI. Conclusion

The risk factors of developing VAP were prolonged duration of ventilation, supine position and neuromuscular diseases.

Bundle implementation was found effective in decreasing the VAP rate among our PICU patients. Elevation of the head of bed was the most compliant component of bundle in the PICU.

### 1. LIMITATIONS

We consider our small sample size, only 65 patients were studied, may limit its generalizability.

### 2. RECOMMENDATION

- Further evaluation of the bundle approach is needed in a wider sample scale.
- Additional studies estimating risk factors and outcome of VAP are needed in wide sample scale.

### 3. COMPETING INTEREST

There is no conflict of interest. There is no fund from any source.

### 4. AUTHOR'S CONTRIBUTION

All authors contributed to the conception and design of the survey. HR and SH analyzed the data and drafted the first version of the manuscript. NM and OA critically revised the manuscript. All authors read and approved the final manuscript.

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