

# Use of Ventilator Bundle and Staff Education to Decrease Ventilator-Associated Pneumonia in Intensive Care Patients

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**BACKGROUND** Ventilator-associated pneumonia (VAP), one of the most common hospital-acquired infections, has a high mortality rate.

**OBJECTIVES** To evaluate the incidence of VAP in a multidisciplinary intensive care unit and to examine the effects of the implementation of ventilator bundles and staff education on its incidence.

**METHODS** A 24-month-long before/after study was conducted, divided into baseline, intervention, and postintervention periods. VAP incidence and rate, the microbiological profile, duration of mechanical ventilation, and length of stay in the intensive care unit were recorded and compared between the periods.

**RESULTS** Of 1097 patients evaluated, 362 met the inclusion criteria. The baseline VAP rate was 21.6 per 1000 ventilator days. During the postintervention period, it decreased to 11.6 per 1000 ventilator days ( $P = .01$ ). Length of stay in the intensive care unit decreased from 36 to 27 days ( $P = .04$ ), and duration of mechanical ventilation decreased from 26 to 21 days ( $P = .06$ ).

**CONCLUSIONS** VAP incidence was high in a general intensive care unit in a Greek hospital. However, implementation of a ventilator bundle and staff education has decreased both VAP incidence and length of stay in the unit. (*Critical Care Nurse*. 2016;36[5]:e1-e7)

**V**entilator-associated pneumonia (VAP) is one of the most common hospital-acquired infections. It is a form of nosocomial pneumonia that occurs in patients undergoing mechanical ventilation for longer than 48 hours.<sup>1</sup> Recently reported VAP rates range from 1 to 4 cases per 1000 ventilator days in industrialized countries and up to 13 cases per 1000 ventilator days in developing countries.<sup>2</sup> VAP is the most serious health care–associated infection and is the leading cause of morbidity and

mortality from device-associated infections, especially in the intensive care unit (ICU).<sup>1</sup> Attributable mortality rate estimates vary from 10% to 65%,<sup>3</sup> with a mean of about 30%.<sup>2</sup> Furthermore, VAP has long been recognized as a cause of prolonged ICU stays and increased hospital costs. An increase of 7 to 9 days in ICU stay has been reported for a patient with VAP,<sup>4</sup> and Kollef et al<sup>5</sup> reported in 2012 that the cost per patient increases by US\$40 000 when the patient has VAP. Finally, VAP accounts for 50% of antibiotics used in the ICU.<sup>6</sup>

The Institute for Healthcare Improvement, during its “100 000 Lives Campaign,” designated the prevention of VAP as 1 of 6 interventions that would significantly contribute to improved patient care and reduction in avoidable hospital deaths.<sup>7</sup> Evidence-based guidelines for preventing nosocomial pneumonia have been published by the Centers for Disease Control and Prevention for more than 30 years<sup>8</sup> and have contributed to a reduced incidence of VAP.<sup>9</sup> Researchers in several studies<sup>10-14</sup> have

### VAP: one of the most common hospital infections, with a high mortality rate.

reported a reduced VAP rate with the implementation

of the VAP bundle and the use of similar care bundles. However, some discordance remains regarding specific bundle components,<sup>15,16</sup> and some researchers have argued against the use of VAP bundles.<sup>17</sup>

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Among several identified sources for VAP among ICU patients, contamination of the ventilator circuit has been recognized. Such contamination can be prevented by the institution of appropriate infection control measures including use of a ventilator-specific bundle.<sup>18</sup>

In the present study, we aimed to evaluate the incidence of VAP in a general ICU and hypothesized that the implementation of a specific VAP prevention bundle together with a staff education strategy would be effective in reducing the incidence of VAP in critically ill patients. It is the first time that such a hypothesis has been applied in an ICU in Greece, a country with a very high prevalence of nosocomial multidrug-resistant pathogens.<sup>19</sup>

## Methods

### Setting and Study Design

The study took place in a closed, multidisciplinary ICU with a total capacity of 30 beds. It was staffed with board-certified intensivists and had both a residency and a fellowship program. The nurse to patient ratio during the study period was 1 to 3 during the day and up to 1 to 4 during the night. A prospective, intervention study consisting of 3 phases was conducted: phase 1 was a baseline period (14 months), phase 2 was an intervention/education period (40 days), and phase 3 was a postintervention period (8.5 months). The total duration of the study was 24 months.

For all patients included in the study, several parameters were recorded in a specific structured form, including personal medical history, demographics, and comorbid conditions. The Acute Physiology and Chronic Health Evaluation (APACHE) II severity score<sup>20</sup> and Simplified Acute Physiology Score (SAPS) III<sup>21</sup> were calculated for all patients on the day of admission. Causes of ICU admission were classified as respiratory failure, neurological disease, cardiovascular disease, neurotrauma, multiple injury, sepsis, and gastrointestinal disease. The patients were monitored until ICU discharge (due to improvement or death) or up to a maximum of 30 days.

Inclusion criteria were intubation up to 12 hours before ICU admission or within 48 hours of ICU admission. Patients who were excluded were those under 18 years of age or pregnant, those transferred from another hospital's ICU, those who had been treated in an ICU for more than 48 hours during the preceding 90 days, those with less than 48 hours in the ICU, and those with a diagnosis of brain death.

The diagnosis of VAP was made by the supervising physician according to the guidelines. Specifically, the presence of a new infiltrate on the chest radiograph and 2 of 3 clinical criteria (leukocytosis, purulent secretions, fever),<sup>22</sup> together with tracheobronchial secretions, confirmed the occurrence of VAP for the physician. Also, the Clinical Pulmonary Infection Score<sup>23</sup> was calculated, and a score greater than 6 was used to verify the diagnosis.

The study was approved by the ethics committee of Evangelismos Hospital, and written informed consent was provided by the patients' relatives.

### Baseline Period

During the baseline period, systematic recording of all VAP cases was recorded on structured forms according to the aforementioned criteria. A database of all cases was constructed with all pertinent epidemiological and clinical and laboratory parameters.

### Intervention Period

Following the baseline period, the research team focused on the intervention and education. Specifically:

- A specialized leaflet was distributed to the staff that emphasized the frequency of VAP in the ICU and the relevant risk factors. Lectures were given to the medical staff and the heads of the nursing staff, focusing on the same topics, by 2 specialized nurses, every 2 weeks for 3 months. The total number of people who attended the sessions was more than 20.
- The ICU patients' data cards were modified to include the basic VAP prevention bundle (elevation of the head of the bed, daily "sedation vacations" and assessment of readiness to extubate, peptic ulcer disease prophylaxis, and deep venous thrombosis prophylaxis).<sup>24-26</sup>
- A sodium bicarbonate-based oral hygiene protocol was implemented by using special, single-use toothbrushes twice daily for 40 days.
- Posters were placed in the ICU outlining the correct hand hygiene procedure during the staff's contact with the patients.

### Process Surveillance

An 8.5-month period followed, where the recording of VAP cases resumed. In parallel, the implementation of infection control measures was monitored, at random time intervals, at least 3 times per week. Parameters

were recorded by the investigators of the protocol. At the same time, checklists were placed in the ICU in order to monitor the implementation of the VAP bundle. These checklists were completed by medical and nursing staff of the ICU and were handed over to the protocol investigators for further processing. Adherence to the 4 elements of the basic VAP bundle was monitored during the baseline and intervention periods. A point for adherence to the VAP bundle was given if at least 3 of the 4 elements of the bundle were followed on most cases.

### Main Outcome

The main surveillance outcomes were VAP density (events per 1000 mechanical ventilator days) and ICU length of stay.

### Performance Feedback

The investigators received feedback on their performance every 2 weeks during the postintervention period. Charts showing the rates of compliance with the implementation of the basic VAP bundle were presented to the ICU doctors and head nurses. Future actions were discussed in these meetings. Staff members present during the feedback meetings were responsible for the communication of the results to all other interested parties.

### Microbiology Profile

Tracheobronchial and oropharyngeal cultures were obtained at admission, after 48 hours, and after 7 days of mechanical ventilation. Tracheobronchial samples for culture were obtained through the endotracheal tube with aspiration by inserting a sterile catheter connected to an aspiration device into the airway. The aspirated secretion was placed in a sterile container directly through the circuit of the aspiration system. These samples were used to determine the main pathogen causing the VAP.

### Statistical Analysis

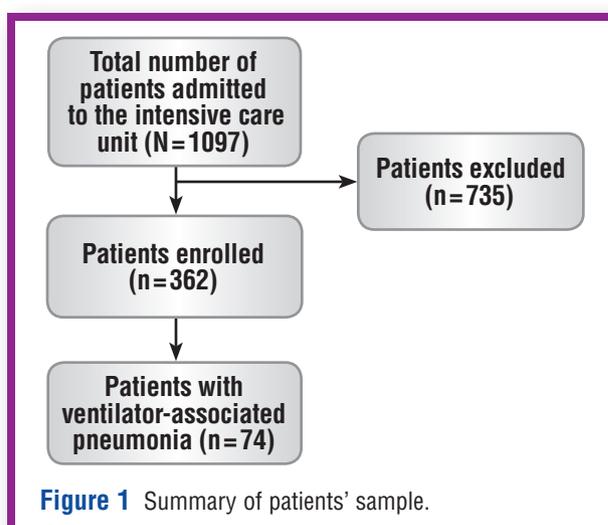
Continuous variables are presented as mean (standard deviation) or median (interquartile range), and categorical variables are presented as frequencies and proportions. All variables were tested for normal distribution. Group means of continuous variables were compared by using an independent *t* test or the Mann-Whitney test (for distributions that were not normal), and categorical variables were compared by using a  $\chi^2$  test. The effectiveness of the intervention (ventilator

bundles/staff education strategy) was assessed with a Cox hazard regression analysis model. The lowest level for statistical significance was chosen as  $P$  less than .05.

## Results

During the 2-year study period, a total of 1097 patients were admitted to the ICU and were prospectively evaluated. Of those patients, 362 met the inclusion criteria and composed the study cohort (Figure 1). The mean age of the study population was 56 (SD, 19) years, and 68% of them were male. Table 1 shows the baseline characteristics of the patients studied. The age and sex of the participants did not differ significantly from before to after the intervention. The APACHE II score was higher after the intervention, although the SAPS III did not differ from before to after the intervention. During the intervention period, the percentage of patients with neurological disease was lower. Adherence to the basic VAP bundle improved significantly from 13% to 28% after the intervention ( $P = .02$ ).

Outcome measures before and after the intervention period for the patients with VAP are presented in Table 2. The total number of VAP cases recorded was 74, and the VAP density was reduced from 21.6 to 11.6 events



**Figure 1** Summary of patients' sample.

per 1000 ventilator days ( $P = .01$ ). A decrease in VAP incidence from 23.4 to 15.4 per 100 patients was recorded. Also, there was a reduction in duration of mechanical ventilation in the postintervention period for patients with VAP. However, these last 2 differences were not statistically significant ( $P = .06$ ). The median number of days of mechanical ventilation before VAP appearance was 6 days (interquartile range, 4-15 days) before the intervention and 7 days (interquartile range,

**Table 1** Baseline characteristics of patients (n=362) before and after the intervention period

Patient data	Before intervention (n=226)	After intervention (n=136)	<i>P</i>
Age, median (interquartile range), y	59 (41-73)	58 (42-72)	.84
Male sex, No. (%) of patients	160 (71)	87 (64)	.18
APACHE II score on admission, mean (SD)	15 (7)	17 (6)	.04
SAPS III on admission, mean (SD)	58 (16)	59 (14)	.67
Mortality, %	35	41	.24
Admitted to ICU from, No. (%) of patients			.006
Emergency department	55 (24)	46 (34)	
Surgery	94 (42)	32 (24)	
Hospital general care area	68 (30)	50 (37)	
Other hospital	9 (4)	8 (6)	
Cause of ICU admission, <sup>a</sup> No. (%) of patients			
Respiratory failure	53 (23)	32 (24)	.10
Neurological disease	49 (22)	47 (35)	.007
Cardiovascular disease	28 (12)	8 (6)	.05
Neurotrauma	40 (18)	21 (15)	.60
Multiple injury	21 (9)	16 (12)	.50
Sepsis	15 (7)	4 (3)	.13
Gastrointestinal disease	22 (10)	7 (5)	.12
Meningitis	2 (1)	2 (1)	.60
Peritonitis	5 (2)	2 (1)	.60

Abbreviations: APACHE, Acute Physiology and Chronic Health Evaluation; ICU, intensive care unit; SAPS, Simplified Acute Physiology Score.

<sup>a</sup> Sum of causes is more than 100% because some patients had more than 1 cause of admission.

**Table 2** Outcome measures for the 74 patients with ventilator-associated pneumonia (VAP) before and after the intervention period

Outcome measures	Before intervention	After intervention	P
No. of VAP cases	53	21	
Days of mechanical ventilation, mean (SD)	26 (16)	21 (8)	.06
Days of mechanical ventilation before VAP, median (95% CI)	6 (3-11)	7 (4.5-9.5)	.40
VAP incidence (per 100 patients), median (95% CI)	23.4 (17.9-29)	15.4 (9.4-21.5)	.06
VAP density (events/1000 ventilator days), median (95% CI)	21.6 (16.2-28.3)	11.6 (7.2-17.8)	.01
Days in intensive care unit, mean (SD)	36 (19)	27 (14)	.04
Mortality, %	34	33	.10

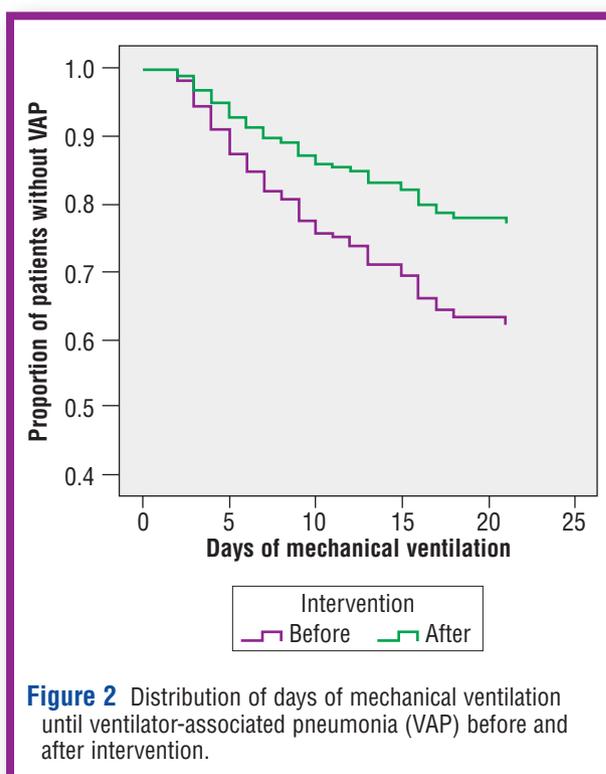
6-19 days) after the intervention ( $P = .40$ ). Finally, the mean ICU length of stay for VAP patients was 36 days (SD, 19 days) before the intervention period, and it decreased to 27 days (SD, 14 days) after the intervention ( $P = .04$ ).

Figure 2 shows the time in days until VAP before and after the intervention period. The microorganism profile of the VAP cases is presented in Table 3, based on the analysis of sputum samples taken from the patients. The microbiological profile did not differ before and after the intervention period.

## Discussion

We undertook for the first time in our hospital a prospective protocol for intervention, education, and surveillance on VAP. We have demonstrated a reduction in VAP density from 21.6 events to 11.6 events per 1000 ventilator days.

Two more positive outcomes of the present study were the statistically significant decrease ( $P = .04$ ) in the mean ICU length of stay from 36 to 27 days and the tendency for a reduction in the mean duration of mechanical ventilation from 26 to 21 days. These 2 parameters are important both for patients and financially because both are associated with an increased number of complications and higher mortality rates. On the other hand, a considerable cost is associated with extended ICU stay and the development of VAP. The implementation of a VAP-specific bundle can also contribute to an overall decrease in patients' costs. Researchers have estimated that the mean extra cost for a hospital-acquired infection was between US\$2255 and US\$5000, making it a very important financial factor.<sup>27,28</sup> As with other studies,<sup>29</sup> no difference in mortality was apparent after the intervention.



**Figure 2** Distribution of days of mechanical ventilation until ventilator-associated pneumonia (VAP) before and after intervention.

**Table 3** Microorganism profile of ventilator-associated pneumonia in the participating intensive care units by number of isolated pathogens

Isolated microorganisms	No. of isolated pathogens
<i>Acinetobacter baumannii</i>	40
<i>Pseudomonas aeruginosa</i>	7
<i>Staphylococcus aureus</i>	10
<i>Klebsiella pneumoniae</i>	16
<i>Candida albicans</i>	24
<i>Escherichia coli</i>	1
<b>Total</b>	<b>98</b>

In order to induce pneumonia, the potentially pathogenic microorganisms must reach the lower part of the respiratory system. The most probable cause of such infection is aspiration from the oral cavity.<sup>30</sup> Hospitalized patients have high concentrations of oropharyngeal and tracheobroncheal colonization from gram-negative bacilli.<sup>30</sup> Subglottic concentrations of these secretions, together with leakage around the cuff, are the principal entrance points for pathogens.<sup>31</sup> Another source of infection is colonization of gastric tubes and transfer of microbes through microaspiration.<sup>30</sup>

In the light of these considerations, it is not surprising that the most important risk factor for VAP that has emerged in several studies is intubation itself.<sup>32</sup> Mechanical ventilation increases the risk of pneumonia 6 to 21 times.<sup>32</sup> Risk factors for the occurrence of VAP are multiple and variable, including prolonged intubation, enteral

### Implementation of a ventilator bundle and a staff education protocol was successful.

feeding, supine position, low endotracheal tube pressure, ventilator circuit contamination, male sex, age more than 60 years, tracheostomy, neurosurgery, acute respiratory distress syndrome, multiorgan failure, coma, and reintubation.<sup>33</sup>

Regular monitoring for the appropriate implementation of a bundle is necessary. This requires continuous education for the participating medical and nursing staff and a dedicated person from the infection control team who would be available for the monitoring of compliance. Such monitoring would raise the staff's awareness and would increase their VAP prevention performance.<sup>34,35</sup>

On the epidemiology level, we found a strong prevalence of *Acinetobacter baumannii*. It is stated in literature that there is no significant difference in prognosis, mortality, and eradication of VAP caused by *Acinetobacter* species compared with VAP caused by other pathogens.<sup>36</sup> However, *Acinetobacter* infection is associated with prolonged ventilation, sedation, and nasogastric intubation<sup>37</sup> and with hemodynamic impairment, which is a predictive of poor outcome.<sup>38</sup>

### Limitations

Contrary to the other components that were implemented during the entire period of the study, the oral hygiene protocol was applied for a limited number of days because of financial constraints. Numerous studies<sup>39-41</sup>

indicate that this measure is effective, so we suggest that it be performed on a regular basis.

A relatively small chance of a Hawthorne effect is also possible, as the study was unblinded. However, the staff was informed of the study during the observation period as well as during the intervention period, thus minimizing the probability of a Hawthorne effect.

### Conclusion

The positive results from the VAP bundle implementation in our institution led to the continuation of this strategy in our unit. The bundle strategy was relatively easy to implement and did not require the purchase of expensive technologies. Several improvements are considered for the near future such as the addition of even more prevention measures in the basic VAP bundle that have been shown to be effective.<sup>42-44</sup> CCN

#### Financial Disclosures

None reported.

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