

Nursing in Intensive Care Unit: Exploring Factors Related to Ventilator-Associated Pneumonia

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Abstract

Background: Most patients hospitalized intensive care units require mechanical ventilation. Ventilator-associated pneumonia is the most common and severe complication of mechanical ventilation. Nursing factors are closely related to the incidence of this type of pneumonia.

Objectives: To explore nursing risk factors associated with ventilator-associated pneumonia (VAP). Committing to provide the basis for future nursing training and quality control for technical offices.

Methods: Through the quality control platform of Hebei province, questionnaires were sent to the intensive care nurses in 37 tertiary hospitals (5 hospitals were excluded due to incomplete information) in Hebei province, China, to collect the incidence of VAP and the nursing status of them from January to December 2019. All data was analyzed using an independent t-test, ANOVA, and Pearson correlation.

Results: Two central themes were derived from the data analysis: Nurse human resources and standard of nursing practice. The incidence of VAP was higher when the proportion of nurses working less than five years and the number of nurses working night shifts increased ($P = 0.000$). The incidence of VAP was lower when the sputum suction tube radius was smaller and the selected oral care solution had disinfection effect ($P = 0.000$).

Conclusions: The incidence of VAP is closely related to nursing factors. Choose different thickness of sputum suction tube and oral nursing liquid will lead to different outcomes. In addition, different nursing staff structure and scheduling mode will directly affect the incidence of VAP. Therefore, we should continue to standardize and unify nursing operation, and optimize nursing staff structure and scheduling mode.

Background

At present, mechanical ventilation is widely used in critical patients in ICUs with remarkable results. But it also has some complications, such as ventilator-associated pneumonia (VAP); this specifically refers to pneumonia developing in a mechanically ventilated patient more than 48 hours after tracheal intubation^[1, 2]. VAP is a common nosocomial infection that results in prolonged mechanical ventilation and hospital stay, as well as increased patient costs. Recent studies estimated that VAP prolongs length of mechanical ventilation by 7.6 to 11.5 days and prolongs hospitalization by 11.5 to 13.1 days compared to similar patients without VAP^[3]. The excess cost associated with VAP was estimated to be approximately \$40,000 per patient^[4]. Studies have shown that VAP occurs in 10–40% of patients who are mechanically ventilated for more than two days.

There are significant differences between different countries and ICU types^[5-7]. Reducing the burden of disease prevention is key. The study found that nursing plays a crucial role in preventing VAP^[8].

Although some studies and guidelines refer to the use of cluster management to reduce the incidence of VAP^[9], not all ICU nurses are consistent, because they are influenced by nurse factors (education level, seniority, staffing, shift, nursing operation level, etc.)^[10]. In recent years, there have been many studies on nursing and VAP^[11]. There are also studies that suggest reducing the incidence of VAP by adjusting the allocation of human resources^[12]. In addition, there are studies on patient position, cuff pressure measurement, oral care, and analysis of the influence of effective coughing on patients with VAP^[13].

In conclusion, the influence of nursing on VAP mainly comes from two aspects (nursing human resources and nursing related operations). However, previous studies did not systematically analyze from the aspect of nursing alone, and there was a lack of detailed statistics to guide clinical nursing work, leading to insufficient consideration of the advantages of nursing work. Consequently, it is important to analyze the influence on the incidence of VAP from the perspective of nursing, so as to better reduce the incidence of VAP and give patients a better prognosis. Therefore, this paper took the prevalence of VAP as the dependent variable to study the relationship between nursing and VAP as a whole.

Methods

1.1 The data source

The data used in this study were issued by the Hebei provincial quality control platform. Questionnaires were collected from 37 tertiary hospitals in Hebei Province, China, including the basic information on the hospital, the rate of VAP per month, basic information on the nurses, and related information on the nursing operation (Table 1).

Inclusion criteria: 1) Those hospitals participated in the questionnaire survey collecting variables including 21 entries in three aspects, on the accusation platform of Hebei Province from January to December 2019. The first aspect was basic information, including hospital type, total number of beds, number of ICU beds, total number of nurses, nurse-to-bed ratio, and monthly incidence of VAP. The second aspect was nursing human resources, including highest level of nursing education, the number of specialist nurses, and nurse shift arrangement. The third aspect was nursing operation status, including oral care tools, methods, frequency, the choice of oral care solution, cuff pressure detection method and frequency, the size of the endotracheal catheter, whether auscultation is performed before and after sputum aspiration, whether atomized inhalation is performed in mechanically ventilated patients, and whether gastric residual volume is routinely monitored. 2) All questionnaires were filled out by the ICU head nurse. The reported data were accurate and complete. This study was conducted in accordance with the Declaration of Helsinki and approved by the ethics committee of fourth hospital of Hebei Medical University.

During the study period, a total of 37 tertiary hospitals in Hebei Province were investigated. A total of 32 hospitals were included due to incomplete information and the elimination of special hospitals. The total number of beds was 541, the total number of nurses was 1,270, and the bed care ratio was 2.35:1. The

number of nurses with working time $n \leq 5$ years is 485, accounting for 38.18% of the total number of nurses, the number of nurses working for 5 years $< n \leq 10$ years is 526, accounting for 41.41% of the total number of nurses, and the working time $n > 10$ years There are 259 nurses, accounting for 20.39% of the total number of nurses. Educational level of nurses: 313 people have a college degree or below, accounting for 24.64% of the total number of nurses, and 957 people have a bachelor degree or above, accounting for 75.35% of the total number of nurses.

1.2 Methods

All data were statistically analyzed using the SPSS 25.0 statistical package. The measurement data were expressed as mean \pm standard deviation ($X \pm S$). Independent sample t-test and one-way analysis of variance were used. Spearman correlation analysis and multiple linear stepwise regression analysis were used to analyze the correlation between nursing related factors and the incidence of VAP. $P < 0.05$ was considered statistically significant. This study was conducted in accordance with the declaration of Helsinki. This study was conducted with approval from the Ethics Committee of the fourth hospital of Hebei Medical University, Written informed consent was obtained from all participants.

Results

1.3.1.1 The classification conditions are based on nurse shift arrangement, nursing solution selection, oral care methods, balloon pressure monitoring methods, auscultation, whether the patient is aerosolized by device ventilation, and whether the gastric residue is routinely monitored. Independent sample t test is used to determine the prevalence of VAP Compare the differences. As shown in Table 2, it can be seen that there are significant differences between the choice of nursing solution, whether to auscultate, and whether to routinely monitor the amount of gastric residue.

In terms of nurses' human resources, the results of the independent sample t-test are shown in Table 2. There was no statistical difference between nurses' shift schedules and the incidence of VAP $P=0.628$.

1.3.1.2 The prevalence of VAP is the dependent variable, and the proportion of nursing beds, the proportion of college degree and below, the proportion of bachelor degree and above, the proportion of specialist nurses, the proportion of nurses with working hours ≤ 5 years, the working hours $5 < a \leq 10$ years Proportion of nurses, working hours > 10 years, the proportion of nurses, the night shift interval of nurses, the number of nurses responsible for patients (day), the number of nurses responsible for patients (night), the frequency of oral care (times/day), and the frequency of airbag pressure monitoring (times/Day) is the independent variable. Perform correlation analysis and the results are shown in Table 3. It can be seen that the prevalence of VAP is significantly positively correlated with the proportion of nursing beds (.242**), the proportion of undergraduate education and above (.109*), the proportion of nurses working less than 5 years (.159**), and the number of nurses responsible for patients at night $.166^{**}$. The proportion of nurses with a college degree or below (-.100*), The proportion of specialist nurses (-.138**), the proportion of nurses with qualification $5 < a \leq 10$ years (-.178**), and the frequency of oral care $-.180^{**}$ showed a significant negative correlation.

The results showed that the incidence of VAP was significantly positively correlated with the proportion of nurses working less than 5 years ($P < 0.01$) and the numbers of patients that nurses were responsible for at the night ($P < 0.01$). The incidence of VAP was significantly negatively correlated with the proportion of nurses with college degrees and below ($P < 0.05$), the proportion of specialist nurses ($P < 0.01$), and the proportion of nurses working for $5 < a \leq 10$ years ($P < 0.01$) (Table 3).

1.3.2.1 In terms of nursing operation, the independent sample t -test showed that there were significant statistical differences between the incidence of VAP and nursing solution selection ($P = 0.001$), whether auscultation was conducted before sputum aspiration ($P = 0.012$), and whether gastric residue was routinely monitored ($P = 0.002$), as shown in Table 2. There was no significant difference between oral care methods, balloon pressure monitoring methods, and whether the patients with instrument ventilation received routine atomization inhalation (Table 2).

1.3.2.2

Taking the types of nursing tools and commonly used suction tubes as grouping conditions, a one-way analysis of variance was performed to compare the prevalence of VAP. There was a significant difference between the incidence of VAP and the selection of suction tube size ($P = 0.021$). There was no statistical difference with the choice of oral care tools (Table 4).

1.3.2.3 In terms of nursing operation, Spearman correlation analysis was performed on relevant factors, and the results are shown in Table 2. It can be seen that the incidence of VAP is negatively correlated with the frequency of oral care ($P < 0.01$).

1.3.3 The incidence of VAP was significantly associated with the following nine variables: the number of patients which nurses were responsible for at night, the proportion of nurses with a college education and below, the proportion of specialist nurses, the proportion of nurses working $5 < a \leq 10$ years, the frequency of oral care, the choice of oral care solution, whether auscultation was conducted before sputum suction, whether the gastric residual volume was routinely monitored, and the model of commonly used suction tube. After setting the incidence of VAP as the dependent variable, all significant variables were analyzed in the stepwise regression model. The results indicated that, in terms of human resources, the incidence of VAP increased with the increase in the proportion of nurses working for ≤ 5 years ($P = 0.000$) and the number of nurses responsible for patients at night ($P = 0.000$). In terms of nursing operations, the incidence of VAP increased with the increase in commonly used suction tube models ($P = 0.000$). The incidence of oral care solution ($P = 0.000$) with conventional disinfection is lower than that without non-sterilization (Table 5).

Discussion

Ventilator-associated pneumonia (VAP) is a potentially preventable iatrogenic disease that occurs after mechanical ventilation. Clustering is currently recommended to prevent VAP. Recent studies also confirmed the effectiveness of the VAP prophylaxis package^[14, 15]. We found that most of these

measures were related to nursing^[16]. Our survey found that nurse staffing and nursing practices affect the incidence of ventilator-associated pneumonia (Table 5). The findings are that the incidence of VAP had a positive relationship with the proportion of nurses who had worked less than 5 years and the number of patients that nurses care for on the night shift. In addition, the size of suction tube and compositions of oral care solution were associated with VAP.

A low number of nurses is associated with an increased risk of infection, and by keeping the number of staff at a high level, a significant proportion of all infections acquired in intensive care can be prevented^[17]. Dimick et al. investigated whether the ratio of nurses to patients at night had an impact on patients suffering complications after high-risk surgical procedures (liver surgery). They found that patients suffered from postoperative pulmonary complications when one nurse cares for three or more patients on the night shift in the ICU^[18]. Another study confirmed that a low nurse-to-patient ratio (<1:2) was associated with increased incidence of complications, such as pneumonia, re-intubation and sepsis, prolonged hospitalization, and increased costs^[19]. Those are consistent with our findings. However, one study found no association between high staffing levels (patient-nurse ratio < 2:1) and reduced VAP risk, based on a large group of patients receiving mechanical ventilation from 21 European ICUs. Although a patient-nurse ratio of 1:1 in a univariate analysis was associated with a lower risk of VAP, this observation was no longer important after adjusting for covariates^[20]. It is important to note that our study only focused on the relationships between nursing factors and VAP.

Our study found that the incidence of VAP increased with the number of nurses with less than 5 years of experience. In recent years, nurses with different years of experience (N0, N1, N2, N3) in Hebei Province were given stratified training and passed the corresponding certificates. This has produced remarkable results. Nurses who have worked for about 5 years (N2) are competent in almost all nursing work. Our results confirm this, to some extent. Although many studies have shown no statistically significant difference between years of nursing service and prevention of VAP^[21-23], these studies all underscore the point that nursing training directly affects the incidence of VAP. In addition, a study highlighted the importance of new undergraduate courses and training, as well as postgraduate training, in improving nurse compliance^[24]. In summary, good nursing education was associated with a lower incidence of VAP.

Ventilator-associated pneumonia is a common cause of death and morbidity in patients with endotracheal intubation, partly due to unsafe suction. The correct selection of sputum aspiration tube is an important guarantee for effective sputum aspiration^[25]. We observed that the diameter of the aspiration catheter should be less than half of the endotracheal intubation^[26]. We found that a smaller catheter can reduce the incidence of VAP, with adequate sputum aspiration. Too thick a sputum aspiration tube will cause the effective ventilation volume of the respiratory tract to be insufficient or form a dead cavity; when serious, this can cause bronchospasm or dyspnea, or even be accompanied by changes in hemodynamics. Too small a tube will affect the effect of sputum aspiration, so that the sputum cannot be completely sucked out within an effective time; this results in increased sputum times or sputum accumulation, which can easily form a sputum scab. For endotracheal intubation of a certain

diameter, the level of negative pressure delivered to the airway is determined by the size of the catheter and the suction pressure. The larger the diameter of the catheter, the smaller the reduction in suction pressure through the airway^[27]. The effect of suction pressure on lung capacity decline appears to be less than that of catheter size, and it is recommended that a smaller catheter be used whenever possible^[28]. These studies support our conclusion that the incidence of VAP increases with the size of sputum aspiration tube types in nursing practice.

Furthermore, oral care with preservatives can reduce the incidence of ventilator-associated pneumonia^[22, 29-31]. However, there are many kinds of oral care solutions at present. How to choose suitable ones is a subject for future study.

Several limitations of our study must be addressed. All the data were from Hebei Province, and the results were influenced by the region.

Conclusion

In conclusion, nursing can effectively reduce the incidence of VAP. We should continue to standardize and unify the nursing operation, as well as optimizing nursing staff structure and scheduling mode.

Relevance to clinical practice

Nurses play an important role in reducing the occurrence of VAP in intubated patients. We should improve nursing skills by setting up effective training. In addition, nursing managers need to optimize staffing. Through nursing training and integration of human resources, nurses can better participate in nursing work, thus more effectively reducing the incidence of VAP. We need to further explore the practicality of the training content and develop the content according to the needs of different levels of nurses.

Abbreviations

VAP: ventilator-associated pneumonia

Declarations

Ethics approval and consent to participate

This study was conducted in accordance with the Declaration of Helsinki and approved by the ethics committee of fourth hospital of Hebei Medical University.

Consent for publication

Not applicable.

Availability of data and materials

The dataset supporting the conclusions of this article is included within the article and additional file.

Competing interests

All of the authors had no any personal, financial, commercial, or academic conflicts of interest separately.

Found

Study on treatment status and prognostic risk factors of severe COVID-19 patients in Hebei Province, Project No. 20277707D

Authors' contributions

Yin YL, Sun MR, Chen YH conceived of the study, and Li Z and Zhang K participated in its design and coordination and Hu ZJ, Bu JJ helped to draft the manuscript. All authors read and approved the final manuscript.

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Tables

Table 1. Information and demographic characteristics of the hospital

Items	n	%
Level of hospital		
3A	24	75
3B	8	25
Total NO. of beds	541	
Total NO. of nurses	1270	
Ratio of nurses to beds	2.35:1	
Years worked in ICU		
≤5	485	38.18
5-10	526	41.41
≥10	259	20.39
Highest degree		
Junior college degree or lower	313	24.64
Bachelor degree or higher	957	75.35
Specialist nurse	188	14.8

Table 2 Nursing human resources and nursing operations

characters		n	x±s	t	p
Nurse shift schedule	8h	108	5.74±9.22	0.485	0.628
	12h	276	5.23±9.41		
Oral care solution with antiseptic effect	yes	264	3.75±5.76	3.972	<0.001
	no	120	8.94±13.76		
Oral care methods	scrub	240	5.71±10.72	1.016	0.310
	Rinse and scrub	144	4.82±6.44		
Monitoring method of cuff pressure	use instruments	372	5.33±9.44	0.561	0.575
	Use hands	12	6.87±5.84		
Auscultation before sputum suction	yes	336	5.66±9.79	2.554	0.012
	no	48	3.36±5.01		
use aerosol inhalations to treat mechanically ventilated patient	yes	216	4.83±6.46	1.201	0.231
	no	168	6.07±12.08		
Gastric residual monitoring	yes	312	5.85±10.07	3.163	0.002
	no	72	3.32±4.75		

Table 3. Correlation between VAP and related nursing factors

variables	Morbidity of VAP ‰ ‰
Ratio of nurses to beds	0.242
Proportion of highest degree	
Junior college degree or lower	-0.100*
Bachelor degree or higher	0.109
Specialist nurse	-0.138**
Years worked in ICU	
≤5	0.159**
5-10	-0.178**
≥10	0.003
Nightshift frequency	0.039
Number of patients managed by nurses	
daytime	0.075
night	0.166**
Oral care frequency	-0.180**
Monitoring frequency of Cuff pressure	0.011

Note. *P<0.05,**p< 0.01

Table 4. Oral care tools and suction tube sizes

items		n	x±s	F	p
Oral care tools	exclusive use package	312	5.36±9.72	0.006	0.994
	manual toothbrush	60	5.49±8.02		
	foam swabs	12	5.23±5.36		
suction tube sizes	10Fr	12	6.06±6.35	3.27	0.021
	12Fr	252	5.06±9.06		
	14Fr	60	3.43±6.28		
	16Fr	60	8.5±12.53		

Table 5. Nursing factors affecting the incidence of VAP

Independent variables	B	SE	β	t	p
Constant	-22.650	4.591		-4.934	0.000
Oral care solution with antiseptic effect 0=no 1=yes	-4.218	0.976	-0.209	-4.321	0.000
Number of patients managed by nurses (nightshift)	3.076	0.663	0.233	4.643	0.000
suction tube sizes 1:10,2:12,3:14,4:16	2.266	0.587	0.191	3.859	0.000
Years worked in ICU (≤ 5)	0.104	0.030	0.193	3.465	0.001

Note. Dummy variables: Oral care solution with antiseptic effect (yes=1, no=0), the sizes of suction tube (10Fr=1, 12Fr=2, 13Fr=3, 14Fr=4)