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Bacterial Contamination of Ventilators in the Intensive Care Unit

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Abstract

Objectives: To investigate the level of bacterial contamination in ventilation devices after being connected to head trauma patients with confirmed ventilator-associated pneumonia.
Methods: This prospective, cross sectional study was carried out at Shahid Mohammadi hospital, Bandar-e Abbas, Iran. Samples for assessing the contamination of ventilators were obtained from expiratory and inspiratory tube insertion sites before connecting the device to the patients. The patients were then observed for the development of ventilator-associated pneumonia and were enrolled in the study if considered eligible. Sampling was repeated after disconnecting the patient. The following variables were assessed in each patient: gender, age, Glasgow Coma Scale upon hospitalization, length of stay in the intensive care unit (ICU), and mortality.
Results: A total of 33 patients, including 26 men and 7 women, were enrolled in the study. There was no significant association between ventilation contamination and time of sampling (before or after ventilation) in the evaluated sites ($P > 0.05$). However, based on McNemer's test for equality of frequencies, the prevalence of positive culture after disconnecting the device from the patients (60.6%) was not the same as the prevalence before being connected to the patients (21.2%) at inspiratory tube insertion sites ($P = 0.002$). Also, at both sites, the variety and pathogenicity of microorganisms after disconnecting the device were higher than those of microorganisms, colonized from samples which were obtained before connecting the device.
Conclusions: The findings of the present study showed that mechanical ventilation of patients with pulmonary infection leads to the contamination of ventilators. These findings suggest the need for designing and implementing new measures, which are easily available in developing and resource-deficient countries in order to reduce the contamination of ventilation devices and prevent cross-contamination.

Keywords: Ventilator-Associated Pneumonia, Equipment Contamination, Artificial Respiration

1. Background

Hospital-acquired pneumonia is the second most common pulmonary infection caused by microorganisms and is responsible for 25% of infections in intensive care units (ICUs) (1, 2). Ventilator-associated pneumonia (VAP) is defined as a nosocomial infection, occurring in patients who rely on mechanical ventilators via invasive methods. VAP is associated with considerable morbidity and mortality, increased duration of hospitalization, and significant financial burden (3-5), mainly owing to infection with antibiotic-resistant bacteria and administration of improper empirical antibiotics (6, 7). Traditionally, diagnosis of VAP includes clinical criteria indicative of an infectious process, serial radiographic changes, and microbiological confirmation (8).

Over the past few decades, various studies have concentrated on the prevention of VAP. Nevertheless, despite these contributions, the majority of questions, related to the prevention of VAP, remain unanswered and are the subject of controversy. Measures for the prevention of VAP can be classified as pharmacological and nonpharmacological. In general, ventilators are understood to be one of the major causes of nosocomial pneumonia. Therefore, strategies have been suggested for disinfection of ventilators, such as use of hydrogen peroxide and sodium hypochlorite (9); however, use of such methods for VAP prevention is financially controversial (10).

Contamination of ventilators, connected to patients with pulmonary infection, has not been assessed in previous studies. Several researchers found low bacterial colonization of anesthetic machines after ventilating patients with pulmonary infection (11-13). However, the effect of prolonged mechanical ventilation of patients with pneu-

monia on ventilator has not yet been investigated. Therefore, the current study aimed to evaluate the contamination level of ventilators after being connected to patients with VAP, who were hospitalized in the ICU.

2. Methods

After obtaining approval from the ethics committee, this prospective, cross sectional study was carried out during 2015 - 2016.

2.1. Study Population and Design

Samples for assessing the contamination of ventilators were obtained from all the machines before being connected to patients, hospitalized in the general and neurosurgical ICUs after a traumatic event. The patients were then observed for the development of pneumonia, and those (minimum age of 18 years), who underwent mechanical ventilation for more than 48 hours and were diagnosed with VAP, were enrolled in the study. The exclusion criteria included age younger than 18 years, history of smoking, history of diabetes mellitus, compromised immunity, and severe malnutrition. Also, patients who had no sign of VAP after 48 hours or died before 48 hours were eliminated from the study.

2.2. Study Procedure

Out of 95 patients who were assessed for eligibility, a total of 33 cases, including 26 men and 7 women, were enrolled in the study. The following information was collected from each patient: gender, age, diagnosis, Glasgow Coma scale (GCS) upon hospitalization, length of stay in ICU, and mortality.

Diagnosis of VAP was confirmed, based on the following criteria: (1) onset of bronchial purulent sputum; (2) body temperature > 38°C or < 35.5°C; (3) white blood cell count > 10,000/mm^3 or < 4000/mm^3; (4) chest radiograph showing new or progressive infiltrates; and (5) culture of significant respiratory secretions (tracheal aspirate > 10^6 CFU/mL, bronchoalveolar lavage > 10^4 CFU/mL, or protected catheter brush culture >10^3 CFU/mL) or blood culture coinciding with respiratory secretion culture which is quantitatively insignificant.

Ventilators in general and neurosurgical ICUs were equipped with antibacterial filters, which were routinely replaced every 96 hours or after separating each patient from the ventilator. Also, the surface of the ventilators was disinfected. Samples for assessing the contamination of ventilators were obtained right before connecting the device to the patient from 2 sites namely expiratory and inspiratory tube insertion sites. Sampling was repeated right after disconnecting the patient. All the samples were cultured in a standard medium and observed for 72 hours in the hospital laboratory.

Throughout hospitalization, identical measures for preventing nosocomial pneumonia were set for the patients, including protective barriers (hand hygiene and use of gloves and face masks) for controlling the airways, an open system of aspiration secretion with single-use disposable probes, a semi-incorporated posture of 40°, continuous enteral feeding, and administration of ranitidine for the prophylaxis of stress ulcers.

2.3. Statistical Analysis

Statistical analysis was performed, using SPSS version 21.0 (SPSS Inc., Chicago, IL, USA). Descriptive statistics were calculated for each study variable. Comparison of ventilator contamination before and after being connected to the patients was performed, and the relationship with study variables was assessed, using proper statistical tests, including Chi square test, student's t test, Fisher's exact test, and one-way analysis of variance (ANOVA) (14).

3. Results

Characteristics of the study population are presented in Table 1. The majority of the patients were younger than 30 years (75.8%). A total of 24 patients (72.7%) had GCS scores below 7 upon admission, while 9 patients had GCS scores between 7 and 12. As shown in Table 2, there was no significant difference in the contamination of ventilators (in both expiratory and inspiratory insertion sites) before and after mechanical ventilation (P = 0.550 and 0.676, respectively).

The association between device contamination and the study variables is shown in Table 3. Age was associated with the contamination of expiratory limb insertion site (P = 0.005), whereas other variables were not significantly associated with ventilator contamination (P > 0.05).

Table 4 demonstrates microorganisms grown in cultures of samples, obtained before and after connecting the ventilator to the patient. As presented in this the the variety and pathogenicity of microorganisms after disconnecting the device in both sites were greater than those of microorganisms colonized from samples obtained before connecting the device.

4. Discussion

Interest in the prevention of VAP is attributed to the high prevalence of this condition, its significant morbidity and mortality, and high economic burden. Contamination

Table 1. Patient Characteristics[a]

Variables	Frequency
Age, y	
< 30	25 (75.8)
30 - 60	8 (18.2)
> 60	2 (6.1)
Gender	
Male	26 (78.8)
Female	7 (21.2)
GCS score	
< 7	24 (72.7)
7 - 12	9 (27.3)
Length of hospital stay, days	
2 - 7	6 (18.2)
7 - 14	14 (42.4)
> 14	13 (39.4)
Outcome	
Transfer to another unit	28 (84.8)
Discharge	1 (3.0)
Death	4 (12.1)

Abbreviation: GCS: Glasgow Coma Scale.
[a]Value are expressed as N. (%).

Table 2. Contamination of the Ventilator Before and After Being Connected to the Patient[a]

Expiratory Limb Insertion Site			
	After ventilation		
	Positive	Negative	P Value
Before ventilation			
Positive	0 (0)	8 (100)	0.550[b]
Negative	4 (16.0)	21 (84.0)	
Inspiratory Limb Insertion Site			
	After ventilation		
	Positive	Negative	P Value
Before ventilation			
Positive	5 (25.0)	15 (75.0)	0.676[b]
Negative	2 (15.4)	11 (84.6)	

[a]Value are expressed as N. (%).
[b]Chi square test and Fisher's exact test.

Table 3. Association Between Device Contamination and the Study Variables

Variables	Frequency (Pos:Neg)	P Value[a]
Expiratory limb insertion site		
Age, y		0.005
< 30	3:22	
30 - 60	3:3	
> 60	2:0	
Gender		0.444
Male	7:19	
Female	1:6	
GCS score		0.626
< 7	6:18	
7 - 12	2:7	
Length of hospital stay		0.515
2 - 7	2:4	
7 - 14	2:12	
> 14	4:9	
Inspiratory limb insertion site		
Age, y		0.909
< 30	15:10	
30 - 60	4:2	
> 60	1:1	
Gender		0.256
Male	17:9	
Female	3:4	
Score		0.509
< 7	15:9	
7 - 12	5:4	
Length of hospital stay		0.375
2 - 7	5:1	
7 - 14	7:7	
> 14	8:5	

[a]Chi square test and Fisher's exact test.

of ventilators, as a source of pneumonia, is a controversial issue. The proper measure for disinfecting a ventilator is to sterilize the device before connecting it to the patient. Although this is the standard method of prevention, it is not always feasible to take such measures due to different factors. The major causes include the low capacity of central supply rooms, hospital ward overcrowding, and high patient turn-over in ICUs; such problems are more evident in developing countries.

Different solutions have been suggested for decreasing the contamination of ventilators. Application of bacterial filters in the respiratory circuit is among such measures. However, use of filters has not been shown to practically prevent VAP. In fact, the center for disease control and prevention (CDC) has not approved the use of bacterial filters

Table 4. Microorganisms Colonized in Cultures

Variables	Microorganism	Frequency
Before connecting the device		
Expiratory limb insertion site	Bacillus	4
Inspiratory limb insertion site	Bacillus	6
	Gram-neg. Enterococcus	1
After disconnecting the device		
Expiratory limb insertion site	Bacillus	3
	Gram-neg. Enterococcus	3
	Acinetobacter	1
	Coagulase-neg. Staphylococcus	1
Inspiratory limb insertion site	Bacillus	6
	Micrococcus	1
	Yeast	1
	Gram-neg. Enterococcus	4
	Coagulase-neg. Staphylococcus	2
	Acinetobacter	2
	Pseudomonas	2
	Micrococcus + coagulase-neg. Staphylococcus	1
	Diphtheroid + Candida	1

due to lack of scientific evidence. Bacterial filters have several adverse effects and vary in function relative to their location in the respiratory circuit. If located at the expiratory branch or between the Y-shaped fragment and the endotracheal tube, they lead to increased air flow resistance (15-17), thereby making the expiration more difficult causing air entrapment. Also, if situated between the Y-shaped fragment and the endotracheal tube, they cause an increase in deadspace (18).

The current study aimed to evaluate the effect of mechanical ventilation of patients with pulmonary infection on ventilator contamination. Although the association between time of sampling and culture results was not statistically significant, the frequency of contamination in both sites of expiratory and inspiratory limb insertion was higher after disconnecting the patient. Studies have been conducted on the contamination of ventilation devices after connecting the device to patients with pulmonary infections, using anesthetic machines during surgical operations where the maximum time of mechanical ventilation was 8 hours (11-13).

Moulin et al. (12) and Ping et al. (13) investigated the effect of ventilating patients with pulmonary infection on the contamination of ventilators during anesthesia. The findings of both studies were in conflict with the present results. They showed that ventilators were not contaminated after ventilating the patients with bacterial colonization of the respiratory system; even in case of contamination, microorganisms were not pathological. The discrepancy between the results of previous studies and the present research is mainly due to the fact that the time of mechanical ventilation in the mentioned studies was significantly less than the current study, where patients were enrolled if they had undergone mechanical ventilation for at least 48 hours; therefore, it can be assumed that the longer time of exposure makes contamination more eminent.

In the present study, the difference in contamination of inspiratory and expiratory tube insertion sites after disconnecting the patient from the device was not statistically significant. However, in cases with contamination of inspiratory tube insertion site, 35% showed positive cultures from the expiratory tube insertion site, whereas in cases without contamination of inspiratory tube insertion site, only 7.7% had contamination in the expiratory tube insertion site. Such findings could be suggestive of the transmission of contamination from the air input to the output and potentially to the next patient connected to the device.

In the present study, we also found a significant association between the age of ICU-admitted patients and contamination of expiratory tube insertion site. Negative cultures were reported mostly in patients younger than 30 years (88%). This finding can be interpreted by differences among various age groups in terms of sputum production.

In conclusion, the findings of this study showed that mechanical ventilation of patients with pulmonary infection leads to the contamination of ventilators. These findings suggest the need for new strategies, to reduce the contamination of ventilation devices.

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