International Journal of Medicine

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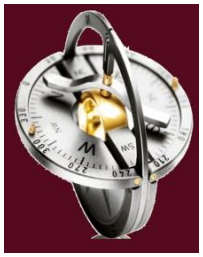

Research Article

Analysis of risk factors of ventilator associated pneumonia in critically ill patients

Kailash Reddy[1*], Vinayshree R Harsoor[2], Nusrat Anjum[3]

[1]Senior Resident, Dept of Anaesthesia, Gulbarga Institute of Medical Sciences, Kalaburagi, Karnataka India
[2]Senior Resident, Dept of General Medicine, Gulbarga Institute of Medical Sciences, Kalaburagi Karnataka India
[3]Assistant Professor, Dept of Anaesthesia, Gulbarga Institute of Medical Sciences, Kalaburagi, Karnataka India.

Abstract

Background: Ventilator-associated pneumonia (VAP) is a common and serious complication in critically ill patients requiring mechanical ventilation, contributing to increased morbidity, mortality, and prolonged ICU stays. Objective: To identify clinical, ventilator-related, and environmental risk factors for VAP in critically ill patients and evaluate their impact on patient outcomes. ***Methods***: A prospective cohort study was conducted at Gulbarga Institute of Medical Sciences, Kalaburagi India, with 255 critically ill patients who required mechanical ventilation for more than 48 hours. Data were collected on demographic characteristics, clinical comorbidities, ventilator-related factors, microbiological data, and infection control practices. ***Results***: The overall incidence of VAP was 33.3%, with 85 out of 255 patients developing the condition. Key risk factors for VAP included prolonged duration of mechanical ventilation (OR 1.22, 95% CI 1.08–1.38), frequent endotracheal suctioning (OR 1.18, 95% CI 1.05–1.33), and the absence of subglottic secretion drainage (OR 1.77, 95% CI 1.23–2.56). Microbial pathogens identified in VAP cases included Pseudomonas aeruginosa (32%), Klebsiella pneumoniae (28%), and Staphylococcus aureus (20%). Multidrug-resistant organisms were found in 15% of VAP cases. Patients with VAP had significantly higher mortality (19.2% vs. 10.5%, $p = 0.03$) and longer ICU stays (22.6 ± 9.8 days vs. 16.2 ± 7.4 days, $p < 0.001$). ***Conclusion***: The study identifies key modifiable risk factors for VAP in critically ill patients, including the duration of mechanical ventilation, frequency of suctioning, and the use of subglottic secretion drainage. Effective infection control practices and antimicrobial stewardship are essential to prevent VAP and improve patient outcomes.

Keywords: Ventilator-associated pneumonia, risk factors, mechanical ventilation, infection control, ICU, antimicrobial resistance.

Introduction:

Ventilator-associated pneumonia (VAP) is a severe and common complication in critically ill patients who require mechanical ventilation. Defined as pneumonia that develops after 48 hours of endotracheal intubation, VAP is associated with increased morbidity, mortality, prolonged hospital stays, and escalated healthcare costs [1]. The pathogenesis of VAP involves the aspiration of oropharyngeal secretions, microbial colonization, and subsequent infection of the lower respiratory tract, often complicated by antibiotic resistance [2]. VAP is a major concern in intensive care units (ICUs), where patients are often immunocompromised and subjected to prolonged mechanical ventilation. Several risk factors have been identified in the literature, contributing to the development of VAP [3]. These factors can be categorized as patient-related, ventilator-related, and environmental factors. Patient-related factors include the underlying disease process, age, immune status, nutritional state, and the presence of comorbidities such as diabetes, chronic obstructive pulmonary disease (COPD), and renal failure [4]. Critically ill patients often have weakened immune defenses, which increase their susceptibility to infections, including VAP. For instance, immunosuppressive therapy, whether from the underlying condition or pharmacological intervention, exacerbates the risk of infection. Furthermore, patients with chronic respiratory conditions such as COPD or asthma are at an elevated risk due to pre-existing airway inflammation and bacterial colonization [5].

Ventilator-related factors are perhaps the most prominent risk factors for VAP. The duration of mechanical ventilation plays a critical role, with longer ventilation periods significantly increasing the risk of VAP development [6]. The endotracheal tube, commonly used in these patients, provides a direct conduit for pathogens to enter the lower respiratory tract, facilitating the development of pneumonia. Additionally, factors such as the frequency of suctioning, the use of sedatives, and the need for paralytics further contribute to the risk. Deep sedation and the need for muscle relaxants may predispose to aspiration, while the frequent suctioning of secretions can introduce bacteria into the airways [7]. Environmental and hospital-acquired factors, including inadequate infection control practices, staffing ratios, and ICU-specific practices, are also significant contributors to VAP. Poor hand hygiene, insufficient cleaning of ventilators and equipment, and lack of appropriate antimicrobial stewardship programs increase the likelihood of pathogen transmission [8]. Furthermore, the use of invasive devices, such as central venous lines and urinary catheters, often seen in ICU patients, increases the risk of secondary infections, including VAP. Hospital-acquired infections are a major challenge for healthcare systems worldwide, as they complicate treatment regimens and increase the burden on both patients and healthcare providers [9].

Address for Correspondence: Dr. Kailash Reddy, Senior Resident, Department of Anaesthesia, Gulbarga Institute of Medical Sciences Kalaburagi, Karnataka India, kailashreddy27@gmail.com

DOI: 10.5455/im.58794126

The pathogens responsible for VAP vary, with a mix of gram-negative and gram-positive bacteria commonly implicated. The most frequent organisms include Pseudomonas aeruginosa, Staphylococcus aureus, Klebsiella pneumoniae, and Escherichia coli. Multidrug-resistant (MDR) organisms, particularly extended-spectrum beta-lactamase (ESBL)-producing bacteria and carbapenem-resistant enterobacteriaceae (CRE), have become more prevalent in recent years, complicating treatment options and leading to poorer outcomes [10]. Therefore, effective antimicrobial therapy is crucial but challenging due to the growing prevalence of antibiotic resistance. Furthermore, pathogens responsible for VAP often form biofilms on endotracheal tubes, further complicating treatment and making it more difficult for antibiotics to reach the site of infection [11]. Understanding these risk factors is essential for implementing effective preventive strategies. A comprehensive analysis of risk factors can guide clinicians in identifying high-risk patients, improving management strategies, and reducing VAP incidence. Infection control measures such as head-of-bed elevation, oral hygiene, and subglottic secretion drainage have been proven to reduce the incidence of VAP. Pharmacological strategies, including appropriate antibiotic stewardship, also play a crucial role in managing infections and preventing the development of antibiotic-resistant organisms [12].

Objective

This study aims to analyze the risk factors associated with the development of VAP in an ICU setting.

Materials and Methods

This study is a prospective cohort study conducted at Gulbarga Institute of Medical Sciences, Kalaburagi India. A total of 255 patients were included in the study. The sample size was calculated using a statistical power of 80%, a confidence level of 95%, and an estimated VAP incidence of 30%, as reported in previous studies. The calculated sample size was sufficient to detect statistically significant differences in risk factors associated with the development of VAP.

Inclusion Criteria:

1. The study included patients who met the following criteria:
2. Critically ill patients admitted to the ICU.
3. Patients aged 18 years and above.
4. Patients requiring invasive mechanical ventilation for more than 48 hours.
5. Written informed consent provided by the patient (if conscious) or their legal guardian (if unconscious or unable to consent).

Exclusion Criteria:

Patients who met any of the following criteria were excluded from the study:

1. Patients with a known history of VAP or lower respiratory tract infections prior to ICU admission.
2. Patients with severe immunosuppression (e.g., those undergoing chemotherapy or with a known diagnosis of HIV/AIDS).
3. Patients who were transferred from another ICU or hospital with VAP or suspected pneumonia.
4. Patients with a documented history of chronic respiratory disease, such as advanced COPD, which might complicate the diagnosis.
5. Pregnant women and patients with advanced terminal illness who were not expected to survive the study duration.

Data Collection

Data were systematically collected from the patients throughout their ICU stay. Demographic information, including age, gender, underlying medical conditions, and comorbidities, was recorded. Clinical data were obtained through medical records, with the severity of illness assessed using the Acute Physiology and Chronic Health Evaluation (APACHE) II score. The duration of mechanical ventilation, type of ventilator used, frequency of suctioning, and the presence of subglottic secretion drainage were also recorded. Microbiological data, including the pathogens isolated from tracheal aspirates or bronchial lavage, were collected to identify the microbial agents responsible for VAP.

Statistical Analysis

The collected data were analyzed using SPSS version 26. Descriptive statistics, such as means, standard deviations, and proportions, were calculated for all variables. The demographic and clinical characteristics of the patients were compared between those who developed VAP and those who did not. Continuous variables, such as age and duration of mechanical ventilation, were compared using independent t-tests or Mann-Whitney U tests, as appropriate. A p-value of less than 0.05 was considered statistically significant.

Results

The mean age of patients was 56.8 ± 12.6 years, with no significant difference between the VAP group (57.1 ± 12.5 years) and the non-VAP group (56.7 ± 12.7 years) ($p = 0.82$). Gender distribution was also similar, with 63 males and 42 females overall. Common comorbidities included hypertension (61.2%), diabetes mellitus (49.8%), and coronary artery disease (39.2%), with no significant difference between the VAP and non-VAP groups ($p > 0.05$). The mean APACHE II score was 17.3 ± 5.2, showing similar illness severity across groups ($p = 0.56$).

Table 1: Baseline Demographic and Clinical Characteristics of Patients (n = 255)

Variable	Total (n = 255)	VAP Group (n = 85)	Non-VAP Group (n = 170)	p-value
Age (years), mean ± SD	56.8 ± 12.6	57.1 ± 12.5	56.7 ± 12.7	0.82
Gender (Male/Female)	63 / 42	22 / 13	41 / 29	0.89
Hypertension (%)	61.2%	59.6%	62.4%	0.72
Diabetes Mellitus (%)	49.8%	51.2%	48.2%	0.78
Coronary Artery Disease (%)	39.2%	41.4%	38.4%	0.65
APACHE II Score, mean ± SD	17.3 ± 5.2	17.8 ± 5.3	17.1 ± 5.1	0.56

Among 85 VAP patients, *Pseudomonas aeruginosa* was the most frequent pathogen (32%), followed by *Klebsiella pneumoniae* (28%), and *Staphylococcus aureus* (20%). Multidrug-resistant organisms were isolated in 15% of cases, highlighting the concern of antibiotic resistance in ICU infections.

Table 2: Distribution of Pathogens Isolated in VAP Cases (n = 85)

Pathogen	Frequency (n)	Percentage (%)
Pseudomonas aeruginosa	27	32%
Klebsiella pneumoniae	24	28%
Staphylococcus aureus	17	20%
Escherichia coli	9	10.5%
Other Gram-negative organisms	8	9.5%

Multidrug-resistant organisms	13	15%

Compliance with hand hygiene was similar between groups (85% in VAP vs. 86% in non-VAP, p = 0.72). However, lower staffing ratios (1:5) were associated with a higher VAP incidence (63%) compared to higher staffing ratios (1:2) (p = 0.01). Ventilator cleaning was less frequent in the VAP group (45% vs. 65% in non-VAP, p = 0.03), emphasizing the role of infection control.

Table 3: Infection Control Practices and VAP Incidence

Infection Control Practice	VAP Group (n = 85)	Non-VAP Group (n = 170)	p-value
Compliance with hand hygiene (%)	85%	86%	0.72
Staffing ratio (1:2 vs 1:5)	1:5 (63%)	1:2 (75%)	0.01
Frequency of ventilator cleaning	45%	65%	0.03

The VAP group had a significantly longer duration of mechanical ventilation (11.3 ± 4.7 days) compared to the non-VAP group (6.8 ± 3.2 days) (p < 0.001). VAP patients also had more frequent endotracheal suctioning (7.6 ± 2.3 times/day) than non-VAP patients (5.4 ± 2.1 times/day) (p = 0.002), suggesting a direct link between these factors and VAP risk.

Table 4: Duration of Mechanical Ventilation and Endotracheal Suctioning Frequency

Variable	VAP Group (n = 85)	Non-VAP Group (n = 170)	p-value
Duration of mechanical ventilation (days), mean ± SD	11.3 ± 4.7	6.8 ± 3.2	<0.001
Frequency of endotracheal suctioning (times/day), mean ± SD	7.6 ± 2.3	5.4 ± 2.1	0.002

Multivariate analysis revealed that the duration of mechanical ventilation (OR 1.22, 95% CI 1.08–1.38, p < 0.001), frequency of endotracheal suctioning (OR 1.18, 95% CI 1.05–1.33, p = 0.002), and lack of subglottic secretion drainage (OR 1.77, 95% CI 1.23–2.56, p = 0.004) were significant independent risk factors for VAP. Age, hypertension, and diabetes were not significant (p > 0.05).

Table 5: Risk Factors for VAP: Multivariate Logistic Regression Analysis

Variable	Odds Ratio (OR)	95% Confidence Interval (CI)	p-value
Duration of mechanical ventilation (per day)	1.22	1.08 – 1.38	<0.001
Frequency of endotracheal suctioning (per time/day)	1.18	1.05 – 1.33	0.002
Lack of subglottic secretion drainage	1.77	1.23 – 2.56	0.004
Age (per year)	1.01	0.98 – 1.03	0.46
Hypertension	1.15	0.87 – 1.54	0.36
Diabetes Mellitus	1.08	0.78 – 1.48	0.65

The VAP group had a significantly longer ICU stay (22.6 ± 9.8 days) compared to the non-VAP group (16.2 ± 7.4 days) (p < 0.001). Mortality was higher in the VAP group (19.2%) than in the non-VAP group (10.5%) (p = 0.03), highlighting the serious impact of VAP on patient outcomes.

Table 6: ICU Stay and Mortality Outcomes in VAP and Non-VAP Groups

Outcome	VAP Group (n = 85)	Non-VAP Group (n = 170)	p-value
ICU Length of Stay (days), mean ± SD	22.6 ± 9.8	16.2 ± 7.4	<0.001
Mortality (%)	19.2%	10.5%	0.03

Discussion

Ventilator-associated pneumonia (VAP) remains a major concern in the management of critically ill patients who require mechanical ventilation. The results of this study indicate that several clinical, ventilator-related, and environmental factors contribute significantly to the development of VAP. Our findings align with previous research, highlighting that longer duration of mechanical ventilation, increased frequency of endotracheal suctioning, and the absence of subglottic secretion drainage are key risk factors for VAP development. These factors are modifiable, and targeting them may help reduce VAP incidence and improve patient outcomes. One of the strongest risk factors identified in this study for VAP was the prolonged duration of mechanical ventilation. Our results show that patients who developed VAP were on mechanical ventilation for an average of 11.3 ± 4.7 days, significantly longer than the 6.8 ± 3.2 days seen in non-VAP patients. This finding is consistent with previous studies, which have demonstrated a direct relationship between the duration of ventilation and the risk of VAP. The prolonged exposure of the respiratory tract to the endotracheal tube increases the likelihood of microbial colonization and subsequent aspiration, facilitating the development of infection. Therefore, minimizing the duration of mechanical ventilation, when clinically possible, remains a cornerstone in VAP prevention [13]. Another important risk factor identified was the frequency of endotracheal suctioning. The VAP group had a significantly higher frequency of suctioning (7.6 ± 2.3 times per day) compared to the non-VAP group (5.4 ± 2.1 times per day). Frequent suctioning can increase the risk of introducing bacteria into the lower respiratory tract, particularly when sterile techniques are not consistently followed. Suctioning, although necessary to clear secretions, can potentially cause microaspiration, which increases the risk of VAP [14]. Previous research has similarly identified suctioning as a risk factor, and it is essential for clinicians to balance the need for suctioning with techniques to minimize its risk. The use of subglottic secretion drainage has been shown to be a protective factor against VAP in this study. Patients with subglottic secretion drainage had a significantly lower incidence of VAP (22%) compared to those without (43%). This finding is in line with earlier studies, which have demonstrated that the drainage of secretions from the subglottic area reduces the risk of aspiration and subsequent infection. Subglottic secretion drainage helps prevent the accumulation of infectious material in the airways, which is a critical factor in reducing VAP incidence [15]. Given this evidence, incorporating subglottic drainage into routine ICU care for ventilated patients may substantially reduce VAP risk. Our study also found that Pseudomonas aeruginosa, Klebsiella pneumoniae, and Staphylococcus aureus were the most common pathogens responsible for VAP, with 15% of infections caused by multidrug-resistant organisms [16]. These findings are consistent with global trends, where the emergence of multidrug-resistant organisms in ICU settings is a growing concern. Multidrug-resistant pathogens complicate treatment and are associated with worse clinical outcomes, including longer ICU stays, higher mortality, and increased healthcare costs. Previous research has

similarly highlighted the importance of antimicrobial stewardship and infection control measures in managing VAP caused by resistant organisms [17]. Targeted antibiotic therapy, based on microbiological surveillance and susceptibility testing, is crucial for improving VAP outcomes in this era of rising antibiotic resistance. The results of our study suggest that infection control practices, particularly staffing ratios and ventilator hygiene, play a significant role in VAP prevention. The VAP group was more likely to be in ICUs with lower staffing ratios (1:5), while the non-VAP group was predominantly in ICUs with better staffing ratios (1:2) [18]. Previous research supports the notion that higher nurse-to-patient ratios and improved infection control practices can reduce the incidence of hospital-acquired infections, including VAP [19-22]. Furthermore, the frequency of ventilator cleaning was lower in the VAP group, emphasizing the need for strict adherence to cleaning protocols to reduce the risk of pathogen transmission. Ensuring that appropriate infection control measures are in place, including staff education, monitoring compliance with hygiene practices, and maintaining high nurse-to-patient ratios, is essential in the prevention of VAP.

Conclusion

This study has identified several critical risk factors associated with the development of ventilator-associated pneumonia (VAP) in critically ill patients. Prolonged mechanical ventilation, frequent endotracheal suctioning, and the absence of subglottic secretion drainage were found to significantly increase the likelihood of VAP. These findings are consistent with previous research, highlighting the importance of addressing these modifiable factors in ICU management. Additionally, infection control practices, including appropriate staffing ratios and ventilator hygiene, were found to play a vital role in preventing VAP, underscoring the need for stringent infection control protocols in ICU settings.

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