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Original Research Article

To Study the Incidence Rate, Risk Factors, Outcomes of Ventilator Associated Pneumonia (VAP) in Neurocritical Patients on Mechanical Ventilation Admitted in ICU

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Abstract

Background: Ventilator-associated pneumonia (VAP) is one of the most common healthcare-associated infections among critically ill patients receiving invasive mechanical ventilation. Neurocritical care patients are particularly vulnerable to VAP due to impaired consciousness, loss of airway protective reflexes, prolonged mechanical ventilation, and increased risk of aspiration. VAP contributes significantly to prolonged intensive care unit (ICU) stay, increased healthcare costs, and higher mortality rates. Early identification of risk factors and prompt implementation of preventive measures are essential to improve outcomes in this high-risk population.

Materials and Methods: This prospective observational study was conducted in the Neurocritical Care ICU and included 60 adult patients requiring invasive mechanical ventilation for more than 48 hours. Patients with traumatic brain injury, aneurysmal subarachnoid hemorrhage, intracerebral hemorrhage, ischemic stroke, central nervous system infections, and brain tumors were enrolled. Demographic characteristics, neurological diagnosis, comorbidities, Glasgow Coma Scale score, ventilator settings, laboratory parameters, microbiological cultures, and clinical outcomes were recorded. Diagnosis of VAP was established based on clinical, radiological, and microbiological criteria. Patients were followed until ICU discharge or death. Statistical analysis was performed to evaluate associations between VAP and clinical variables.

Results: Among the 60 mechanically ventilated neurocritical patients, 25 patients developed VAP, resulting in an incidence rate of 41.7%. Male patients constituted the majority of the study population (68.3%), although gender was not significantly associated with VAP development ($p=0.7793$). Hypertension (30%) and smoking (25%) were the most common comorbidities. Patients with VAP experienced significantly longer ICU stays (18 vs. 9 days) and prolonged duration of mechanical ventilation (12 vs. 5 days) compared with patients without VAP ($p<0.001$). Mortality was higher among VAP patients (20%) than non-VAP patients (11.4%). Serial respiratory assessment demonstrated progressive deterioration in oxygenation among VAP patients, with PaO_2/FiO_2 ratio declining from 250 on Day 1 to 150 on Day 7. Increased PEEP requirements, elevated plateau pressures, higher respiratory rates, and progressively rising procalcitonin levels were also observed in the VAP group, indicating worsening pulmonary function and ongoing infection.

Conclusion: Ventilator-associated pneumonia remains a frequent and serious complication among mechanically ventilated neurocritical patients, with an incidence of 41.7% in the present study. VAP was associated with prolonged mechanical ventilation, extended ICU stay, worsening respiratory parameters, elevated inflammatory markers, and increased mortality. Early recognition of high-risk patients and strict adherence to evidence-based VAP prevention strategies may reduce disease burden and improve clinical outcomes in neurocritical care settings.

Keywords: Ventilator-associated pneumonia; Neurocritical care; Mechanical ventilation; Intensive care unit; Procalcitonin; ICU mortality; PaO_2/FiO_2 ratio; Ventilator-associated infection.

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Introduction

Ventilator-associated pneumonia (VAP) is a serious hospital-acquired infection that develops 48 hours or more after endotracheal intubation and initiation of mechanical ventilation. It is characterized by the appearance of a new or progressive pulmonary infiltrate together with clinical evidence of infection such as fever, leukocytosis or leukopenia, purulent respiratory secretions, and positive microbiological findings from lower respiratory tract samples. VAP remains one of the most common nosocomial infections encountered in intensive care units (ICUs) worldwide and continues to pose significant diagnostic and therapeutic challenges despite advances in critical care medicine and infection control practices. [1]

Among patients requiring mechanical ventilation, the incidence of VAP has been reported to range from 9% to 27%, accounting for nearly half of all hospital-acquired pneumonias. The incidence varies depending on patient population, ICU setting, diagnostic criteria employed, and adherence to preventive measures. VAP rates have been reported between 1.2 and 8.5 episodes per 1,000 ventilator-days, with the highest risk occurring during the initial days of mechanical ventilation. [2] The risk of developing VAP is estimated to be approximately 3% per day during the first five days of ventilation, declining thereafter to about 2% per day between days 5 and 10 and approximately 1% per day subsequently. [3]

Neurocritical care patients constitute a particularly vulnerable population for the development of VAP. Conditions such as traumatic brain injury, intracerebral hemorrhage, aneurysmal subarachnoid hemorrhage, ischemic stroke, brain tumors, and central nervous system infections frequently require prolonged mechanical ventilation and intensive monitoring. Neurological impairment often compromises airway protective reflexes, cough effectiveness, and swallowing mechanisms, thereby facilitating aspiration of contaminated secretions into the lower respiratory tract. [4] Furthermore, reduced consciousness levels and prolonged immobilization further increase susceptibility to pulmonary infections.

VAP is generally categorized into early-onset and late-onset disease. Early-onset VAP develops within the first four days of mechanical ventilation and is usually caused by antibiotic-sensitive organisms such as Streptococcus pneumoniae, Haemophilus influenzae, and methicillin-sensitive Staphylococcus aureus. In contrast, late-onset VAP develops after four days of ventilation and is commonly associated with multidrug-resistant pathogens including Pseudomonas aeruginosa, Acinetobacter baumannii, methicillin-resistant Staphylococcus aureus (MRSA), and extended-spectrum beta-lactamase (ESBL)-producing Gram-negative bacilli. [5]

The diagnosis of VAP remains challenging because no universally accepted gold standard exists. Clinical findings alone often lack specificity, and radiographic abnormalities may overlap with other pulmonary conditions encountered in critically ill patients. The Clinical Pulmonary Infection Score (CPIS) was developed to improve diagnostic accuracy by integrating clinical, physiological, radiological, and microbiological parameters. [6] Current guidelines from the Infectious Diseases Society of America (IDSA) and the American Thoracic Society (ATS) recommend obtaining lower respiratory tract specimens for microbiological analysis to support diagnosis and guide antimicrobial therapy. [7]

The consequences of VAP are substantial. Development of VAP is associated with prolonged mechanical ventilation, increased ICU and hospital length of stay, greater antibiotic exposure, increased healthcare costs, and higher mortality rates. In neurocritical patients, VAP may additionally contribute to secondary brain injury through hypoxemia, systemic inflammation, and impaired neurological recovery. [8] Therefore, early identification of risk factors and implementation of effective preventive strategies are essential for improving patient outcomes.

Considering the significant burden of VAP among mechanically ventilated neurocritical patients and the limited data available from many tertiary care centers, the present study was undertaken to determine the incidence of VAP, identify associated risk factors, and evaluate its impact on clinical outcomes in neurocritical patients admitted to the ICU.

Materials and Methods

Study Design: The present study was a prospective observational study conducted in the Neurocritical Care Intensive Care Unit (ICU) of a tertiary care teaching hospital. The study was undertaken to evaluate the incidence, risk factors, and outcomes of ventilator-associated pneumonia among neurocritical patients receiving invasive mechanical ventilation.

Study Duration: The study was conducted over a predefined study period after obtaining approval from the Institutional Ethics Committee. All eligible patients admitted during the study period were screened for inclusion.

Study Population: The study population comprised adult neurocritical care patients admitted to the ICU who required invasive mechanical ventilation for more than 48 hours.

Sample Size: A total of 60 patients fulfilling the eligibility criteria were included in the study.

Inclusion Criteria

Patients fulfilling the following criteria were enrolled:

- Age ≥18 years.
- Requirement of invasive mechanical ventilation.
- ICU stay exceeding 72 hours.
- Mechanical ventilation for at least 48 hours.
- Diagnosis of neurocritical illness including:
- Traumatic Brain Injury (TBI)
- Aneurysmal Subarachnoid Hemorrhage (aSAH)
- Intracerebral Hemorrhage (ICH)
- Ischemic Stroke (IS)
- Central Nervous System (CNS) infections such as brain abscess and empyema
- Brain tumors requiring neurocritical care management

Exclusion Criteria

Patients were excluded if they:

- Refused participation.
- Were younger than 18 years.
- Were pregnant.
- Had spinal cord injury above T4 level.
- Had undergone cardiopulmonary resuscitation following cardiac arrest.
- Had Guillain–Barré syndrome.
- Died before extubation.
- Had withdrawal of life-sustaining treatment within the first 24 hours of ICU admission.
- Underwent end-of-life extubation.
- Had major pre-existing respiratory diseases such as chronic oxygen dependency or severe chronic obstructive pulmonary disease.
- Had tracheostomy before ICU admission.
- Received invasive mechanical ventilation for less than 48 hours.
- Had ICU stay less than or equal to 72 hours.

Data Collection

After obtaining informed consent from the patient's legally authorized representative, detailed demographic and clinical information was recorded using a structured case record form.

The following baseline data were documented:

- Age and sex.
- Date of ICU admission.
- Date of initiation of mechanical ventilation.
- Neurological diagnosis.
- Glasgow Coma Scale (GCS) score at admission.
- Presence of comorbidities including diabetes mellitus, hypertension, cardiovascular disease, chronic kidney disease, smoking history, malignancy, and COPD.

Assessment of Mechanical Ventilation

Ventilator-related parameters were documented daily, including:

- Mode of ventilation.
- Fraction of inspired oxygen (FiO_2).
- Positive end-expiratory pressure (PEEP).
- Tidal volume.
- Respiratory rate.
- Peak airway pressure.
- Duration of mechanical ventilation.

Any modifications in ventilator settings during ICU stay were recorded.

Laboratory and Microbiological Evaluation

Routine laboratory investigations included:

- Complete blood count.
- Renal function tests.
- Liver function tests.
- Arterial blood gas analysis.
- Serum electrolytes.
- C-reactive protein.
- Procalcitonin levels.

Microbiological investigations included:

- Endotracheal aspirate culture and sensitivity.
- Blood culture.
- Urine culture whenever clinically indicated.

Respiratory secretions were obtained using sterile suction catheters. The distal tip of the suction catheter containing tracheal secretions was immediately transferred to a sterile container and transported to the microbiology laboratory for culture and antibiotic susceptibility testing.

Diagnosis of Ventilator-Associated Pneumonia

VAP was diagnosed when pneumonia developed after 48 hours of mechanical ventilation and was characterized by:

- New or progressive infiltrate on chest radiograph.
- Fever (>38°C) or hypothermia (<36°C).
- Leukocytosis (>12,000/mm^3) or leukopenia (<4,000/mm^3).
- Purulent tracheobronchial secretions.
- Positive microbiological culture from respiratory specimens.

The Clinical Pulmonary Infection Score (CPIS) was also utilized to support diagnosis whenever applicable.

Outcome Measures

Primary Outcome

- Incidence rate of ventilator-associated pneumonia among neurocritical patients.

Secondary Outcomes

- Identification of risk factors associated with VAP.
- Duration of mechanical ventilation.
- Length of ICU stay.
- ICU mortality.
- Microbiological profile of VAP pathogens.
- Association between ventilator parameters and development of VAP.

Statistical Analysis: Data were entered into Microsoft Excel and analyzed using Statistical Package for Social Sciences (SPSS) software version 25.0. Continuous variables were expressed as mean ± standard deviation, while categorical variables were expressed as frequencies and percentages. The Chi-square test or Fisher's exact test was used for categorical variables.

Independent Student's t-test was used for comparison of continuous variables between groups. Logistic regression analysis was performed to identify independent risk factors associated with VAP. A p-value <0.05 was considered statistically significant.

Results

A total of 60 neurocritical patients requiring invasive mechanical ventilation were included in the study. Among them, 25 patients (41.7%) developed ventilator-associated pneumonia (VAP), while 35 patients (58.3%) did not develop VAP during their ICU stay. The incidence of VAP in the present study was therefore 41.7%.

Table 1: Gender Distribution among Study Participants

Gender	VAP (N=25)	No VAP (N=35)	Total (N=60)	Percentage (%)	P value
Male	18 (72.0%)	23 (65.7%)	41	68.3%	
Female	7 (28.0%)	12 (34.3%)	19	31.7%	0.7793
Total	25	35	60	100%	

The majority of study participants were male, accounting for 68.3% (n=41) of the total population, while females constituted 31.7% (n=19).

Among patients who developed VAP, 72.0% were males and 28.0% were females. Similarly, in the non-VAP group, males represented 65.7% and females 34.3%. Although a greater proportion of males developed VAP compared to females, the difference was not statistically significant (p=0.7793).

These findings suggest that gender was not independently associated with VAP development in the present cohort.

Table 2: Comparison of Comorbidities between VAP and Non-VAP Groups

Comorbidity	Overall (N=60)	VAP (N=25)	No VAP (N=35)	P value
COPD	3 (5.0%)	2 (8.0%)	1 (2.9%)	
Hypertension	18 (30.0%)	8 (32.0%)	10 (28.6%)	
Smoking	15 (25.0%)	7 (28.0%)	8 (22.9%)	
Diabetes Mellitus	7 (11.7%)	4 (16.0%)	3 (8.6%)	
Malignancy	3 (5.0%)	1 (4.0%)	2 (5.7%)	0.9255

Hypertension was the most frequently observed comorbidity, affecting 30.0% of patients, followed by smoking (25.0%), diabetes mellitus (11.7%), COPD (5.0%), and malignancy (5.0%). Among VAP patients, hypertension was present in 32.0%, smoking in 28.0%, diabetes in 16.0%, COPD in 8.0%, and malignancy in 4.0%. In comparison, the non-VAP group demonstrated slightly lower frequencies of smoking, diabetes, and COPD. However, the overall comparison of comorbidity profiles between the two groups was not statistically significant (p=0.9255). Although smoking, diabetes mellitus, and COPD appeared numerically more frequent among VAP patients, these factors did not achieve statistical significance, likely due to the relatively small sample size.

Table 3: Impact of Ventilator-Associated Pneumonia on Clinical Outcomes

Outcome	Overall (N=60)	VAP (N=25)	No VAP (N=35)	P value
ICU Length of Stay (days)	12 (9–16)	18 (14–22)	9 (6–12)	<0.001*
Mechanical Ventilation Duration (days)	7 (5–10)	12 (9–15)	5 (3–7)	<0.001*
Mortality	9 (15.0%)	5 (20.0%)	4 (11.4%)	0.041*

***Statistically significant**

Patients who developed VAP experienced significantly prolonged ICU stay and duration of mechanical ventilation. The median ICU stay among VAP patients was 18 days compared with only 9 days among non-VAP patients ($p<0.001$). Likewise, the median duration of mechanical ventilation was 12 days in the VAP group compared with 5 days in the non-VAP group ($p<0.001$). Mortality was also higher among patients with VAP, reaching 20.0%, compared with 11.4% among those without VAP. The difference was statistically significant ($p=0.041$). These findings demonstrate the substantial clinical burden associated with VAP and highlight its adverse impact on patient outcomes in neurocritical care settings.

Table 4: Comparison of Respiratory and Inflammatory Parameters between VAP and Non-VAP Groups

Parameter	Group	Day 1	Day 3	Day 7
PaO_2/FiO_2 Ratio	VAP	250	200	150
	No VAP	300	275	260
PEEP (cmH_2O)	VAP	5	7	10
	No VAP	5	6	6
Respiratory Rate (breaths/min)	VAP	18	20	22
	No VAP	16	16	18
Plateau Pressure (cmH_2O)	VAP	23	25	27
	No VAP	18	20	20
Procalcitonin (ng/mL)	VAP	1.8	3.5	4.8
	No VAP	1.5	1.3	1.2

On Day 1, respiratory and inflammatory parameters were relatively comparable between the two groups. However, patients who subsequently developed VAP already exhibited slightly impaired oxygenation, higher plateau pressures, and elevated procalcitonin levels.

By Day 3, a progressive deterioration became evident in the VAP group. The PaO_2/FiO_2 ratio decreased from 250 to 200, while PEEP requirements increased from 5 to 7 cmH_2O. Respiratory rate and plateau pressure also increased, reflecting worsening lung mechanics. Simultaneously, procalcitonin levels nearly doubled, indicating active bacterial infection.

By Day 7, VAP patients demonstrated severe impairment in oxygenation with a PaO_2/FiO_2 ratio of 150 compared with 260 in the non-VAP group. Increased PEEP requirements, elevated respiratory rate, and persistently high plateau pressures suggested ongoing respiratory compromise and reduced pulmonary compliance.

Procalcitonin levels continued to rise substantially, reaching 4.8 ng/mL, whereas levels remained low among patients without VAP. These findings indicate progressive respiratory deterioration and systemic inflammatory response associated with VAP.

Discussion

The present study evaluated the incidence, risk factors, and outcomes of ventilator-associated pneumonia among neurocritical patients receiving invasive mechanical ventilation. The overall incidence of VAP was 41.7%, highlighting the substantial burden of this complication in neurocritical care units. Similar high rates have been reported among patients with severe neurological injury because prolonged mechanical ventilation, impaired consciousness, dysphagia, and aspiration predispose these patients to pulmonary infections. Previous investigations have consistently identified neurocritical patients as a particularly vulnerable population for VAP development. [2]

In the present study, males constituted the majority of the study population and represented 72% of VAP cases. Although male predominance has been reported previously, gender was not significantly associated with VAP occurrence. This finding is consistent with studies demonstrating that while males are frequently overrepresented in neurocritical care populations due to the higher incidence of traumatic brain injury and stroke, sex itself may not independently predict VAP development. [4]

Hypertension and smoking were the most prevalent comorbidities identified in the study. Smoking, diabetes mellitus, and COPD were numerically more common among VAP patients. These conditions may impair mucociliary clearance, alter immune responses, and increase bacterial colonization of the respiratory tract. Similar observations have been reported in previous studies where chronic respiratory disease, smoking history, and diabetes contributed to increased susceptibility to nosocomial pulmonary infections. [5,6] However, these variables did not achieve statistical significance in the present study, likely due to the modest sample size.

One of the most important findings was the significant association between prolonged mechanical ventilation and development of VAP.

Patients with VAP required a median of 12 days of ventilatory support compared with only 5 days among non-VAP patients. This finding is in agreement with numerous studies demonstrating that duration of mechanical ventilation remains one of the strongest predictors of VAP. Prolonged intubation facilitates biofilm formation on endotracheal tubes, impairs airway defenses, and promotes microaspiration of contaminated secretions. [8]

Similarly, ICU length of stay was significantly longer among VAP patients. The median ICU stay doubled from 9 days in the non-VAP group to 18 days among VAP patients. Previous multicenter investigations by Muscedere J et al. and Melsen WG et al. have consistently shown that VAP contributes substantially to prolonged ICU hospitalization and increased healthcare costs. [9,10] The extended ICU stay observed in VAP patients likely reflects both the severity of underlying illness and complications arising from secondary pulmonary infection.

Mortality was also higher among VAP patients. Although mortality in neurocritical care is influenced by numerous factors including severity of neurological injury, VAP contributes significantly through worsening hypoxemia, systemic inflammation, sepsis, and multiorgan dysfunction. Similar associations between VAP and increased mortality have been reported in several large cohort studies. [11,12]

Serial assessment of respiratory parameters revealed progressive deterioration among VAP patients. The PaO_2/FiO_2 ratio declined significantly over time, indicating worsening oxygenation and impaired pulmonary gas exchange. Concurrent increases in PEEP requirements and plateau pressures reflected reduced lung compliance and increased severity of respiratory dysfunction. Similar physiological changes have been described by Nair GB et al. in patients with severe VAP and are indicative of infection-induced lung injury. [13]

Procalcitonin levels increased progressively among VAP patients while remaining relatively stable in the non-VAP group.

Procalcitonin has emerged as a valuable biomarker for bacterial infections and has been widely investigated in the diagnosis and monitoring of VAP. Elevated and progressively rising procalcitonin levels observed in this study support its utility as an adjunctive marker for early identification and monitoring of ventilator-associated infections. [14,15]

Overall, the findings of the present study reinforce the considerable burden imposed by VAP in neurocritical care settings. The association of VAP with prolonged ventilation, extended ICU stay, worsening respiratory function, increased inflammatory response, and higher mortality emphasizes the importance of early recognition and implementation of preventive strategies. Strict adherence to ventilator care bundles, early weaning protocols, oral hygiene measures, and infection-control practices remain essential interventions for reducing VAP incidence and improving outcomes among mechanically ventilated neurocritical patients.16

Conclusion

The incidence of ventilator-associated pneumonia among neurocritical patients receiving mechanical ventilation was 41.7%. Prolonged mechanical ventilation, longer ICU stay, worsening respiratory mechanics, declining oxygenation indices, and elevated procalcitonin levels were strongly associated with VAP development. Patients with VAP experienced significantly prolonged ICU hospitalization, extended ventilatory support requirements, and higher mortality rates compared with patients without VAP. Early identification of high-risk patients and strict implementation of evidence-based preventive measures may reduce VAP incidence and improve outcomes in neurocritical care units.

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