ORIGINAL ARTICLE

Incidence, Risk Factors, Microbiology and Outcomes of VAP at an NCU in India: A Prospective Observational Study

Kapil Zirpe[1], Upendra Kapse[2], Akansha Sharma[3], Atul P Kulkarni[4], Sushma Gurav[5], Anand Tiwari[6], Chaitanya Bhujbal[7], Abhijeet Deshmukh[8], Prasad Suryawanshi[9], Prajakta Pote[10], Abhaya Bhoyar[11], Kaustubh Zirpe[12], Rupali Suryawanshi[13], Rahul Sharma[14], Piyush Dhawad[15], Hrishikesh Vaidya[16]

Received on: 18 January 2025; *Accepted on:* 25 February 2025; *Published on:* 31 March 2025

Abstract

Background: Ventilator-associated pneumonia (VAP) remains a major challenge while managing ventilated critically ill patients in neurocritical care units (NCUs).

Materials and methods: This was a prospective, single-center, observational study. All adult patients admitted to our NCU requiring mechanical ventilation (MV) for >48 hours were screened for VAP as per clinical pulmonary infectious score (CPIS) criteria. The primary outcome was the incidence of VAP in the ICU. Secondary outcomes were risk factors, microbiology, percentage of MDR/XDR organisms, mortality, and length of stay (LOS) of VAP.

Results: A total of 24.94% (114 of 457) patients developed VAP. The incidence of VAP was 39.43/1000 ventilator days. Multivariate analysis of the risk factors identified, male gender, low Glasgow coma scale (GCS) of 3–8, prolonged ventilation, and diabetes mellitus as significant risk factors for the development of VAP ($p < 0.05$). *Acinetobacter baumannii* (31.58%), *Klebsiella pneumoniae* (28.95%), and *Pseudomonas aeruginosa* (13.16%) were the most common organisms responsible for VAP. Most of these isolates were multidrug resistant (MDR) (81.58%), and extensively drug-resistant (XDR) organisms (12.28%). Although VAP patients had longer ICU-LOS (26.2 ± 24.2 vs 11.8 ± 6.9 days, $p < 0.0001$), it did not affect the mortality (18.4% for VAP vs 14.3% for non-VAP, $p = 0.5$).

Conclusion: Ventilator-associated pneumonia has a high incidence of 39.43 per 1,000 ventilator days in the Indian neurocritical care setting.

Keywords: Incidence, Microbiology, Neurocritical care, Outcomes, Risk factors, Ventilator-associated pneumonia.

Indian Journal of Critical Care Medicine (2025): 10.5005/jp-journals-10071-24948

Highlights

Ventilator-associated pneumonia (VAP) is a significant challenge in neurocritical care owing to its unique population. Prospective studies addressing the exact burden of disease and its epidemiological factors are still lacking in Indian neurocritical care units (NCUs). The present study emphasizes the incidence, risk factors, microbiological profile, and outcomes of VAP in NCU.

Introduction

Ventilator-associated pneumonia remains a major challenge while managing ventilated critically ill patients in intense care units (ICU), posing substantial clinical and economic burdens worldwide. It is described as pneumonia that develops more than 48 hours after endotracheal intubation.[1] Ventilator-associated pneumonia is characterized by microbiological colonization of the lower respiratory tract facilitated by mechanical ventilation (MV), which bypasses the upper airway's natural defense mechanisms. In NCUs where patients often require prolonged MV due to various reasons, the impact of VAP is particularly pronounced.[2] The incidence of VAP varies widely across healthcare settings but consistently represents a major source of nosocomial infection, ranging from 7 to 43 per thousand days.[3] This is variability influenced by factors such as patient demographics, ICU practices, and local microbial epidemiology, highlighting the need for tailored prevention strategies based on regional data.[4]

Risk factors for VAP are multifactorial and include prolonged MV, altered level of consciousness, use of sedation and paralysis, enteral feeding, underlying chronic diseases, immunosuppression, and invasive procedures, etc.[5,6] These conditions compromise respiratory defenses, promoting the aspiration of oropharyngeal secretions and colonization by pathogenic microorganisms.

[1–3,5–12,15,16]Department of Neurotrauma, Ruby Hall Clinic, Grant Medical Foundation, Pune, Maharashtra, India

[4]Department of Critical Care Medicine, Tata Memorial Hospital, Homi Bhabha National Institute (HBNI), Mumbai, Maharashtra, India

[13]Department of Microbiology, Ruby Hall Clinic, Grant Medical Foundation, Pune, Maharashtra, India

[14]Department of Neurosurgery, Ruby Hall Clinic, Grant Medical Foundation, Pune, Maharashtra, India

Corresponding Author: Upendra Kapse, Department of Neurotrauma, Ruby Hall Clinic, Grant Medical Foundation, Pune, Maharashtra, India, Phone: +91 7798880226, e-mail: upendrakumar04@yahoo.co.in

How to cite this article: Zirpe K, Kapse U, Sharma A, Kulkarni AP, Gurav S, Tiwari A, *et al*. Incidence, Risk Factors, Microbiology and Outcomes of VAP at an NCU in India: A Prospective Observational Study. Indian J Crit Care Med 2025;29(4):308–313.

Source of support: Nil

Conflict of interest: Dr Kapil G Zirpe and Dr Atul P Kulkarni and are associated as the Editorial Board Members of this journal and this manuscript was subjected to this journal's standard review procedures, with this peer review handled independently of these Editorial Board Members and their research group.

The causative organisms of VAP are predominantly bacterial, with a high prevalence of multidrug-resistant (MDR) pathogens.[7,8] The microbiological profile is also influenced by previous antibiotic exposure, local antibiograms, and patient-related factors such as prior colonization and immunocompromised status. The emergence of MDR organisms poses a significant therapeutic challenge, necessitating the early and appropriate use of antibiotics guided by local microbiological data.

Ventilator-associated pneumonia is associated with significant morbidity, increased healthcare costs, prolonged ICU stay, and mortality making it a critical area of research and clinical focus.[9,10]

Understanding the epidemiology, risk factors, and outcomes linked with VAP is therefore essential for implementing effective preventive measures and optimizing management strategies in ICUs. There is a scarcity of prospective data related to VAP in ICUs, especially in NCUs in the Indian subcontinent.

Our objective was to examine the incidence, risk factors, microbiological profile, and outcomes such as mortality and ICU length of stay (ICU-LOS) of VAP in an Indian NCU setting.

Materials and Methods

This was a prospective observational study conducted at a tertiary care NCU, over 21 months period (September 2022–May 2024). Institutional ethics committee permission was obtained, which waived off the need for patient consent. All consecutive adult patients admitted to our NCU who required MV for more than 48 hours were included in the present study. These cases were screened for diagnosis of VAP by clinical pulmonary infectious score (CPIS) criteria.[11] Patients younger than 18 years, MV duration < 48 hours, patients already intubated or tracheostomized before admission to NCU, those admitted with diagnosed pneumonia, primary acute respiratory distress syndrome (ARDS), and pregnant patients were excluded from the study.

Data was collected in a customized case record form (CRF). Patients' demographic characteristics, acute physiological and chronic health illness (APACHE II) score, date of ICU admission, clinical history and risk factors, immunosuppression status, temperature, hemodynamic parameters, biochemistry, date of intubation, ventilatory settings, duration of MV, change in tracheal secretions, arterial blood gas analysis, chest radiography (CXR), microbiological culture reports, antibiotics treatment received, length of ICU stay (LOS) and mortality were noted. Patients were followed throughout their stay in the ICU and the standard VAP prevention bundle was followed in all cases. Appropriate empirical antibiotic therapy was initiated as per the local antibiogram.

Ventilator-associated pneumonia was diagnosed when the following clinical and microbiological criteria were met.

Clinical and Laboratory data: At least two of the following:

- New and persistent (over the past 24 hours) elevated body temperature (>38°C or 37.5°C with concurrent antipyretic medication administration).
- Change in tracheal secretions.
- White cell count (WCC): ≤4 or ≥12 cells 10^9/L for two consecutive days.
- PaO_2/FiO_2 ratio ≤300 mm Hg: deterioration in gas exchange over the past 24 hours in the absence of cardiac or other pulmonary disease.

Imaging:

- New localized or diffuse infiltrates on a single CXR (not explained by cardiac or pulmonary disease).

Microbiology:

- A positive quantitative or qualitative bacterial culture results from endotracheal aspirate or bronchoalveolar lavage (BAL). (Threshold growth of $>10^5 \times$ CFU/mL was taken as a cut-off for endotracheal aspirate and $>10^3$ CFU/mL for BAL).

The incidence rate of VAP was calculated by dividing the total number of VAP cases by the total number of MV days multiplied by 1,000.

Early VAP was defined as occurring within 48 – 96 hours, after initiation of MV, and late VAP as >96 hours of MV.[12]

Multidrug-resistant organism was defined as acquired non-susceptibility to at least one agent in three or more antimicrobial categories and extensively drug-resistant (XDR) organism was defined as non-susceptibility to at least one agent in all but two or fewer antimicrobial categories (i.e., bacterial isolates remain susceptible to only one or two categories).[13]

The primary outcome of the study was to determine the incidence of VAP in NCUs. Secondary outcomes were risk factors associated with VAP, microbiological pattern, percentage of MDR/XDR organisms, ICU mortality, and ICU-LOS.

Statistical Analysis

Statistical analysis for this study was performed using SPSS Version 25. The association between categorical variables was assessed using Chi-squared tests or Fisher's Exact test. Univariate analysis was conducted to examine the individual impact of each factor. This was followed by multivariate analysis using binary logistic regression to evaluate the combined effects. The adequacy of the regression model was confirmed using the Hosmer and Lemeshow Test for Goodness of Fit. For continuous variables, comparisons of means were performed using independent *t*-tests. *p*-values less than 0.05 were regarded as statistically significant.

Results

In our study, 24.94% (114 of 457) patients developed VAP. The percentage of early VAP was higher (59.64% vs late 40.35%) than late VAP. The overall incidence of VAP was found to be 39.43/1,000 ventilator days (Fig. 1 – Consort diagram).

More males developed VAP than females (81.6%). Several patients with hypertension and hypothyroidism were similar in

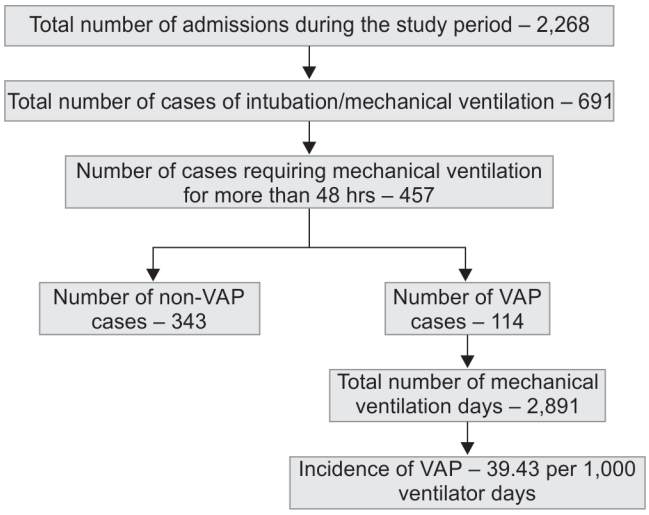

Fig. 1: Consort diagram

Table 1: Baseline characteristics of patients with VAP and those without VAP

Demographic parameter	*Non-VAP n = 343 (%)*	*VAP n = 114 (%)*	*Total*	*p*
Gender				
Female	107 (31.2%)	21 (18.40%)	128 (28%)	0.623
Male	236 (68.8%)	93 (81.6%)	329 (72%)	
Comorbidities				
Hypertension	142 (41.4%)	57 (57%)	199 (43.5%)	0.477
Hypothyroidism	22 (6.4%)	10 (8.8%)	32 (7%)	0.68
Diabetes mellitus	62 (18.1%)	40 (35.1%)	102 (22.3%)	0.002
Age distribution				
<20 years	13 (3.8%)	4 (3.5%)	17 (3.7%)	0.429
21–40 years	86 (25.1%)	18 (15.8%)	104 (22.8%)	
41–50 years	131 (38.2%)	53 (46.5%)	184 (40.3%)	
>60 years	113 (32.9%)	39 (34.2%)	152 (33.3%)	
GCS				
Mild (GCS 13–15)	79 (23%)	23 (20.2%)	102 (22.3%)	<0.001
Moderate (GCS 9–12)	165 (48.1%)	33 (28.9%)	198 (43.3%)	
Severe (GCS 3–8)	99 (28.9%)	58 (50.9%)	157 (34.4%)	
Type of cases				
Neurosurgical cases	62 (18.8%)	29 (25.4%)	91 (19.91%)	0.09
Medical conditions	281 (81.9%)	85 (74.6%)	366 (80.1%)	
Ventilation days [mean (SD)]	6.3 (3.3)	19.9 (35)	14.4 (27.9)	<0.0001
HbA1c [mean (SD)]	6.95 (1.92)	7.55 (1.87)	7.1 (1.9)	0.004
APACHE II score	17.5	18.4	17.9	0.234

GCS, Glasgow coma scale; HbA1c, glycosylated hemoglobin

Table 2: Primary diagnosis in patients who developed VAP

Diagnosis	*Number of VAP cases (number %)*
Traumatic brain injury	28 (24.56)
Acute ischemic stroke	23 (20.17)
Intracranial hemorrhage	14 (12.28)
Other CNS disorders	10 (8.7)
Malignancy/post-surgical	12 (10.52)
Septic shock	5 (4.38)
Chronic kidney disease	3 (2.63)
COPD	3 (2.63)
Cardiac disorders	3 (2.63)
Cervical spine injury	2 (1.75)
Chronic liver disease	3 (2.63)
Poisoning	2 (1.75)
Pulmonary embolism	1 (0.87)
Others	5 (4.38)

CNS, central nervous system, COPD, chronic obstructive airway disease

the VAP and non-VPA groups, however, diabetes mellitus was observed more frequently in the VAP group (35.1%). HbA1c was higher in patients who developed VAP (7.55 ± 1.87 vs 6.95 ± 1.92). Age distribution was similar between VAP and non-VAP category patients. Patients with lower glasgow coma scale (GCS) (3–8) had a significantly higher incidence of VAP. The APACHE II scores were comparable between the 2 groups (17.5 ± 7.2 for non-VAP vs 18.4 ± 6.3 for VAP, $p = 0.234$). A higher number of medical patients had VAP compared to those who had neurosurgical intervention (Table 1).

The most common primary diagnosis in patients comprised of CNS disorders (65.71%), i.e., acute ischemic stroke, traumatic brain injury, intracranial hemorrhage, and others. Other significant conditions included malignancy (10.52%) and sepsis (4.38%) (Table 2).

On performing the univariate and multivariate analysis of the risk factors linked with VAP, we identified several significant associations (Table 3). On multivariate analysis, the factors that turned out to be significant were male gender, prolonged ventilation (>7 days), severe GCS (3–8), and diabetes mellitus.

Acinetobacter baumannii (31.58%), *Klebsiella pneumoniae* (28.95%), and *Pseudomonas* (13.16%) were the most common organisms cultured from the endotracheal tube or endotracheal aspirate (Fig. 2).

Multi-drug-resistant organisms were most common (52.63%), followed by extensively drug-resistant (XDR) organisms (12.28%). A very small fraction (6.14%) of microorganisms was pan-sensitive. of the cases (Fig. 3).

Though VAP patients needed a longer period of MV (19.9 ± 35.0 vs 6.3 ± 3.3 days, $p < 0.0001$), and had longer ICU-LOS (26.2 ± 24.2 vs 11.8 ± 6.9 days, $p < 0.0001$), the mortality was similar in both groups (18.4% for VAP vs 14.3%, $p = 0.5$) for non-VAP patients (Table 4).

Discussion

We found out that around 24% of the patients developed VAP and the incidence of VAP was 39.43 per 1,000 ventilator days in our NCU. Most of these cases were of early-onset VAP (59.64%).

This is one of the largest prospective observational studies investigating VAP incidence in an Indian NCU. Our results are comparable with the recent ENIO study published in 2023 where the VAP rate was found to be 33.7/1,000 ventilator days.[2] According to a meta-analysis, the incidence of VAP amongst patients with traumatic brain injury (TBI) was approximately 36%, with a range

Table 3: Risk factors associated with VAP

		Univariate analysis			*Multivariate analysis*		
Risk factors	*Number*	*OR*	*95% CI*	*p*	*OR*	*95% CI*	*p*
Age (>60 years)	143	1.20	0.76–1.87	0.484	0.99	0.57–1.7	0.97
Male gender	329	2.01	1.18–3.39	0.008	2.1	1.1–4.1	0.03
Ventilation days (>7 days)	125	6.26	3.94–9.95	<0.001	6.9	4.1–11.9	<0.001
Diabetes mellitus	73	5.08	3.0–8.59	<0.001	6.66	3.66–11.45	<0.001
Severe GCS (3–8)	157	2.55	1.65–3.94	<0.001	2.78	1.74–5.66	<0.001
Hypertension	199	1.42	0.92–2.17	0.127	1.1	0.42–1.9	0.823
Hypothyroidism	32	1.40	0.64–3.1	0.4	1.12	0.515–3.28	0.62

CI, confidence interval, GCS, Glasgow coma scale; OR, odd's ratio

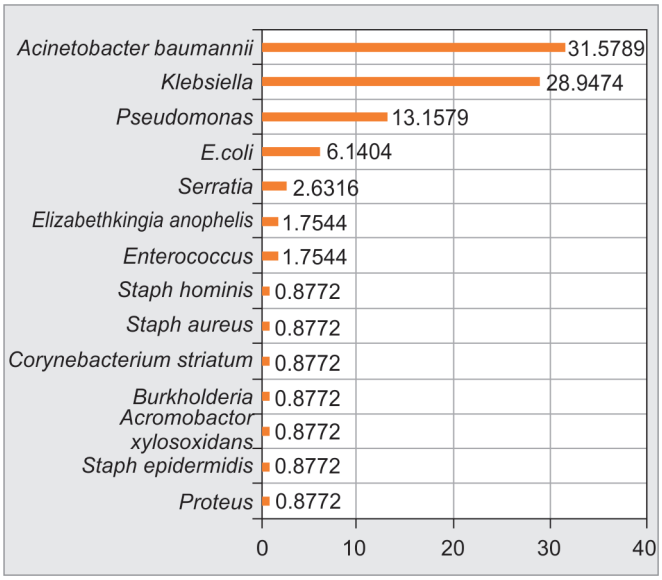

Fig. 2: Distribution of organisms cultured among the VAP cases

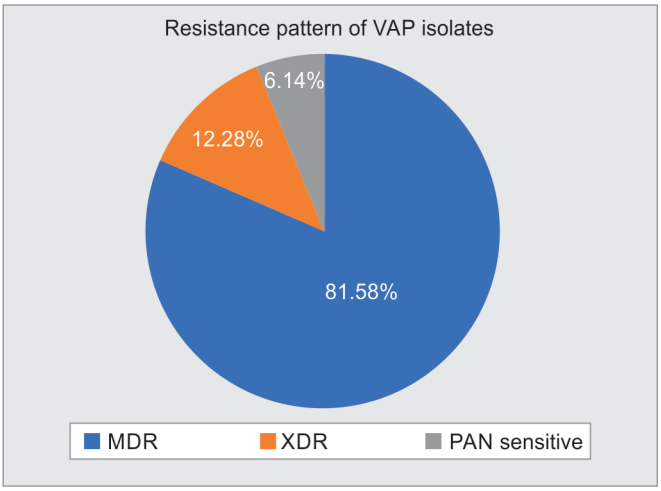

Fig. 3: Distribution of resistance pattern of bacterial isolates. MDR: Multidrug resistant, XDR: Extensively drug-resistant

reported in studies between 23 and 60% depending on the study population and methodology.[14] In another study in an Indian ICU the incidence of VAP was 57.14% with an incidence density of 31.7/1,000 ventilator days.[15]

Table 4: Outcomes of VAP and non-VAP cases

Outcome	*Non-VAP n = 343 (%)*	*VAP n = 114 (%)*	*Total*	*p*
Death	49	21	70	0.5
	14.30%	18.40%	15.30%	
Survival	294	93	387	
	85.70%	81.60%	84.70%	
Length of stay (LOS)	11.8	26.2	16.6	<0.0001
	6.9	24.2	17.5	

The incidence of VAP in neurocritical care settings varies globally due to the complex interplay of factors such as patient-specific risks (severity of illness, prolonged ventilation, Glasgow coma score at ICU admission), healthcare infrastructure (resource availability, infection control practices) and differences in ventilation practices (sedation and weaning protocols). Other contributory factors include adherence to VAP bundles, local antibiotic resistance patterns, inconsistent definitions, and reporting of VAP. Tailored prevention strategies, robust infection control measures, and standardized reporting can help to mitigate this problem.

We found that male sex, diabetes mellitus, low GCS score (3–8), and MV for >7 days were significant risk factors linked with the occurrence of VAP. Various studies have shown the male sex as an independent risk factor for the occurrence of VAP.[16–29] A recent meta-analysis of 17 articles which included 6,222 patients, showed that male gender [(OR 1.50; 95% CI: 1.29–1.75; $p < 0.001$)] is a risk factor for VAP.[21] This gender difference appears to be multifactorial, which includes favorable effects of estrogen, deleterious effects of testosterone, differences in immune function, and some behavioral factors like smoking and alcohol consumption.

Diabetes mellitus is well known to cause impaired immune response, poor glycemic control, risk of micro-aspiration due to altered swallowing mechanisms, and chronic complications like pulmonary angiopathy making it an important and commonly implicated risk factor for the development of VAP.

Results of an observational study done in Spain were similar, showing that in 7,952 admissions, the adjusted incidence rate of VAP was marginally, but significantly higher in patients with type 2 DM compared to those without diabetes [OR 36.46, (95% CI: 34.41–38.51) vs 32.57 (95% CI: 31.40–33.74)] cases per 1,00,000/inhabitants.[22] Darvishi-Khejri et al. [23] showed that the risk of VAP was greater in the diabetic population after adjusting for other factors [HR-10.12 (95% CI: 5.1–20.2); $p < 0.0001$)].[24] However another study by Vardakas et al, showed contrasting results and stated that diabetes mellitus is not associated with the development of VAP.

The GCS score indicates the level of consciousness, with a lower score (<14) indicating impaired consciousness. Impaired consciousness compromises protective airway reflexes with an increased risk of micro-aspiration, which is conducive to bacterial colonization and subsequent pneumonia. We found out that a GCS score of <7 was a significant risk factor for the development of VAP. A study from Zagazig University showed that patients who developed VAP had significantly lower GCS scores.[25]

In another study in TBI patients, a Glasgow coma score of <9 was shown to be a contributing factor for VAP caused by *Staphylococcus aureus*.[26]

Mechanical ventilation > 7 days is a key risk factor for VAP development. Tracheal intubation bypasses the natural airway mucosal defense mechanism and predisposes to VAP. Blot et al.[27] showed that MV > 2 weeks was a risk factor for VAP. A study from Egypt showed that the incidence of VAP rose from 5% (in patients receiving 1 day of MV) to 65% amongst patients on MV for 30 days.[28] However, if VAP itself causes prolonged duration of MV or MV increases the risk of VAP remains unclear.

Gram-negative organisms, *A. baumannii* (31.58%) and *K. pneumoniae* (28.95%) were the most commonly identified pathogens in our study. In very few patients gram-positive organisms were implicated. The majority of these micro-organisms were multidrug-resistant (81.58%) carbapenem-resistant *Acinetobacter baumannii* (CRAB) and carbapenem resistant enterobacteriaceae (CRE) isolates (Fig. 2). These results are similar to another Indian study where the majority of bacterial isolates were gram-negative organisms. *A. baumannii* (38.7%) was the predominant pathogen closely followed by *P. aeruginosa* (17.5%) and *K. pneumoniae* (16.6%).[29]

A recent Chinese study in NCU showed that the gram-negative bacteria, fungi, and gram-positive bacteria accounted for 86.0, 7.6, and 6.4% cases of VAP respectively; most being multi-drug-resistant. The most common pathogens identified were *A. baumannii*, *K. pneumoniae*, and *P. aeruginosa*.[30] In a pediatric ICU from Cairo, the most commonly found pathogens from VAP cases were *P. aeruginosa* (47.7%), *Acinetobacter* (18.2, and methicillin-resistant *S. aureus* (MRSA) (14.4%).[31] These findings highlight that it is mainly the Gram-negative MDR organisms that cause VAP in Asian ICUs and inform the choice of empirical antibiotics for VAP therapy.

In the current study, the mortality rates were comparable amongst patients with VAP (18.4%) and those without VAP (14.3% ($p = 0.5$), but VAP patients had longer periods duration of MV and also longer stays in ICU. Thus, the burden of morbidity is significantly increased. Our results are similar to a study by Tejerina et al.[32] which found similar mortality rates in VAP and non-VAP patients (38.1 vs 37.9%, $p = 0.95$), but prolonged duration of MV and ICU stay. Another study in cases of TBI, found that the VAP patients needed a longer duration of MV [15, IQR (10–22) days vs 8 (IQR, 5–14)], $p < 0.001$) d and extended ICU LOS [20 (IQR 14–29) vs 13 (IQR 8–21) days, $p < 0.001$]. However, VAP was not linked with higher mortality or poorer neurological outcomes.[33] A recent meta-analysis of VAP in patients with TBI showed findings similar to our study, where with prolonged MV duration [OR 5.45 (95% CI: 3.78–7.12)], ICU LOS [OR 6.85; (95% CI: 4.90–8.79)], and hospital LOS [OR 10.92; (95% CI: 9.12–12.72)] were markedly higher in cases of VAP. Again VAP was not linked with a higher risk of mortality [OR 1.28 [95% CI: 0.74–2.21)].[14]

Limitations of our study are: (1) This was a single-center study, findings of our study may not be generalizable to other neurocritical care units across the globe owing to population heterogeneity; and larger multicenter trials are warranted. (2) The criteria we used to diagnose VAP may not be similar all over the world, causing variations in the incidence of VAP in different ICU settings. (3) Lastly, we did not study key risk factors including prior antibiotic use and the antibiotic susceptibility of individual bacterial isolates.

Conclusion

We found a high incidence of VAP (39.43/1,000 ventilator days) in our NCU. Male gender, diabetes mellitus, GCS score (3–8), and MV >7 days were significant risk factors for the development of VAP. Gram-negative organisms, *A. baumannii* and *K. pneumoniae* were the most commonly identified pathogens. Although VAP resulted in significant morbidity, it did not increase mortality.

Clinical Significance

Ventilator-associated pneumonia has a high incidence of 39.43 per 1,000 ventilator days in Indian neurocritical care settings and important risk factors should be identified to understand and effectively mitigate the morbidity.

Orcid

Kapil Zirpe https://orcid.org/0000-0002-8140-727X
Upendra Kapse https://orcid.org/0000-0002-5279-4485
Akansha Sharma https://orcid.org/0000-0002-6660-1162
Atul P Kulkarni https://orcid.org/0000-0002-5172-7619
Sushma Gurav https://orcid.org/0000-0001-6875-2071
Anand Tiwari https://orcid.org/0000-0002-9791-8365
Chaitanya Bhujbal https://orcid.org/0009-0007-0778-8186
Abhijeet Deshmukh https://orcid.org/0000-0001-5602-291X
Prasad Suryawanshi https://orcid.org/0000-0001-7306-8434
Prajakta Pote https://orcid.org/0000-0002-3620-3390
Abhaya Bhoyar https://orcid.org/0000-0002-0460-3162
Kaustubh Zirpe https://orcid.org/0000-0002-6291-0670
Rupali Suryawanshi https://orcid.org/0000-0001-7954-7225
Rahul Sharma https://orcid.org/0000-0002-1614-4952
Piyush Dhawad https://orcid.org/0000-0001-7237-3963
Hrishikesh Vaidya https://orcid.org/0000-0002-8015-0898

References

1. Kalili A, Metersky M, Klompas M, Muscedere J, Sweeney DA, Palmer LB, et al. Management of adults with hospital-acquired and ventilator-associated pneumonia: 2016 clinical practice guidelines by the Infectious Diseases Society of America and the American Thoracic Society. Clin Infect Dis 2016;63(5):e61–e111. DOI: 10.1093/cid/ciw353.
2. Battaglini D, Parodi L, Cinotti R, Asehnoune K, Taccone FS, Orengo G, et al. Ventilator-associated pneumonia in neurocritically ill patients: Insights from the ENIO international prospective observational study. Respir Res 2023;24(1):146. DOI: 10.1186/s12931-023-02456-9.
3. Mumtaz H, Saqib M, Khan W, Ismail SM, Sohail H, Muneeb M, et al. Ventilator associated pneumonia in intensive care unit patients: A systematic review. Ann Med Surg (Lond) 2023;85(6):2932–2939. DOI: 10.1097/MS9.0000000000000836.
4. Papazian L, Klompas M, Luyt CE. Ventilator-associated pneumonia in adults: A narrative review. Intensive Care Med 2020;46(5):888–906. DOI: 10.1007/s00134-020-05980-0.
5. Wu D, Wu C, Zhang S, Zhong Y. Risk factors of ventilator-associated pneumonia in critically Ill patients. Front Pharmacol 2019;10:482. DOI: 10.3389/fphar.2019.00482.
6. Weinstein RA, Bonten MJ, Kollef MH, Hall JB. Risk Factors for ventilator-associated pneumonia: From epidemiology to patient management. Clin Infect Dis 2024;38(8):1141–1149. DOI: 10.1086/383039.

7. Farag AM, Tawfick MM, Abozeed MY, Shaban EA, Abo-Shadi MA. Microbiological profile of ventilator-associated pneumonia among intensive care unit patients in tertiary Egyptian hospitals. J Infect Dev Ctries 2020;14(2):153–161. DOI: 10.3855/jidc.12012.
8. Park DR. The microbiology of ventilator-associated pneumonia. Respir Care 2005;50(6):742–763; discussion 763–765.
9. Mergulhão P, Pereira JG, Fernandes AV, Krystopchuk A, Ribeiro JM, Miranda D, et al. Epidemiology and burden of ventilator-associated pneumonia among adult intensive care unit patients: A Portuguese, multicenter, retrospective study (eVAP-PT Study). Antibiotics (Basel) 2024;13(4):290. DOI: 10.3390/antibiotics13040290.
10. Vincent JL. Ventilator-associated pneumonia. J Hosp Infect 2004;57(4):272–280. DOI: 10.1016/j.jhin.2003.06.001.
11. Zilberberg MD, Shorr AF. Ventilator-associated pneumonia: The clinical pulmonary infection score as a surrogate for diagnostics and outcome. Clin Infect Dis 2010;51 Suppl 1:S131–S135. DOI: 10.1086/653062.
12. Restrepo MI, Peterson J, Fernandez JF, Qin Z, Fisher AC, Nicholson SC. Comparison of the bacterial etiology of early-onset and late-onset ventilator-associated pneumonia in subjects enrolled in 2 large clinical studies. Respir Care 2013;58(7):1220–1225. DOI: 10.4187/respcare.02173.
13. Magiorakos AP, Srinivasan A, Carey RB, Carmeli Y, Falagas ME, Giske CG, et al. Multidrug-resistant, extensively drug-resistant and pandrug-resistant bacteria: An international expert proposal for interim standard definitions for acquired resistance. Clin Microbiol Infect 2012;18(3):268–281. DOI: 10.1111/j.1469-0691.2011.03570.x.
14. Li Y, Liu C, Xiao W, Song T, Wang S. Incidence, risk factors, and outcomes of ventilator-associated pneumonia in traumatic brain injury: A meta-analysis. Neurocrit Care 2020;32(1):272–285. DOI: 10.1007/s12028-019-00773-w.
15. Ranjan N, Chaudhary U, Chaudhry D, Ranjan KP. Ventilator-associated pneumonia in a tertiary care intensive care unit: Analysis of incidence, risk factors and mortality. Indian J Crit Care Med 2014;18(4):200–204. DOI: 10.4103/0972-5229.130570.
16. Cook DJ, Kollef MH. Risk factors for ICU-acquired pneumonia. JAMA 1998;279:1605–1606. DOI: 10.1001/jama.279.20.1605.
17. Napolitano LM, Greco ME, Rodriguez A, Kufera JA, West RS, Scalea T M. Gender differences in adverse outcomes after blunt trauma. J Trauma 2001;50:274–280. DOI: 10.1097/00005373-200102000-00013.
18. Magnotti LJ, Fischer PE, Zarzaur BL, Fabian TC, Croce MA. Impact of gender on outcomes after blunt injury: A definitive analysis of more than 36,000 trauma patients. J Am Coll Surg 2008;206:984–991; discussion 991–992.
19. Sharpe JP, Magnotti LJ, Weinberg JA, Brocker JA, Schroeppel TJ, Zarzaur BL. Gender disparity in ventilator-associated pneumonia following trauma: identifying risk factors for mortality. J Trauma Acute Care Surg 2014;77:161–165. DOI: 10.1097/ta.0000000000000251.
20. Magill SS, Li Q, Gross C, Dudeck M, Allen-Bridson K, Edwards JR. Incidence and characteristics of ventilator-associated events reported to the National Healthcare Safety Network in 2014. Crit Care Med 2016;44:2154–2162. DOI: 10.1097/ccm.0000000000001871.
21. Li W, Cai J, Ding L, Chen Y, Wang X, Xu H. Incidence and risk factors of ventilator-associated pneumonia in the intensive care unit: A systematic review and meta-analysis. J Thorac Dis 2024;16(9):5518–5528. DOI: 10.21037/jtd-24-150.
22. Jiménez-Trujillo I, Jiménez-García R, de Miguel-Díez J, de Miguel-Yanes JM, Hernández-Barrera V, Méndez-Bailón M, et al. Incidence, characteristic and outcomes of ventilator-associated pneumonia among type 2 diabetes patients: An observational population-based study in Spain. Eur J Intern Med 2017;40:72–78. DOI: 10.1016/j.ejim.2017.01.019.
23. Darvishi-Khezri H, Alipour A, Emami Zeydi A, Firouzian A, Mahmudi G, Omrani-Nava M. Is type 2 diabetes mellitus in mechanically ventilated adult trauma patients potentially related to the occurrence of ventilator-associated pneumonia? J Res Med Sci. 2016;21:19. DOI: 10.4103/1735-1995.179887.
24. Vardakas KZ, Siempos II, Falagas ME. Diabetes mellitus as a risk factor for nosocomial pneumonia and associated mortality. Diabet Med 2007;24(10):1168–1171. DOI: 10.1111/j.1464-5491.2007.02234.x.
25. Chang L, Dong Y, Zhou P. Investigation on risk factors of ventilator-associated pneumonia in acute cerebral hemorrhage patients in intensive care unit. Can Respir J 2017:7272080. DOI: 10.1155/2017/7272080.
26. Rello J, Quintana E, Ausina V, Puzo C, Net A, Prats G. Risk factors for Staphylococcus aureus nosocomial pneumonia in critically ill patients. Am Rev Respir Dis 1990;142:1320–1324. DOI: 10.1164/ajrccm/142.6_Pt_1.1320.
27. Blot S, Koulenti D, Dimopoulos G, Martin C, Komnos A, Krueger WA, et al. Prevalence, risk factors, and mortality for ventilator-associated pneumonia in middle-aged, old, and very old critically ill patients. Crit Care Med 2014;42:601–609. DOI: 10.1097/01.ccm.0000435665.07446.50.
28. Abdelrazik OA, Salah Abdelazim M. Ventilator-associated pneumonia in adult intensive care unit prevalence and complications. Egypt J Crit Care Med 2017;5:61–63. DOI: 10.1016/j.ejccm.2017.06.001.
29. Sangale A, Vivek B, Kelkar R, Biswas S. Microbiology of ventilator-associated pneumonia in a tertiary care cancer hospital. Indian J Crit Care Med 2021;25(4):421–428. DOI: 10.5005/jp-journals-10071-23790.
30. Yu Z, Li X, Lv C, Tian Y, Suo J, Yan Z, et al. Epidemiological characteristics of ventilator-associated pneumonia in neurosurgery: A 10-year surveillance study in a Chinese tertiary hospital. Infect Med (Beijing) 2024;3(3):100128. DOI: 10.1016/j.imj.2024.100128.
31. Galal YS, Youssef MR, Ibrahiem SK. Ventilator-associated pneumonia: Incidence, risk factors and outcome in paediatric intensive care units at Cairo University Hospital. J Clin Diagn Res 2016;10(6):SC06–SC11. DOI: 10.7860/JCDR/2016/18570.7920.
32. Tejerina E, Frutos-Vivar F, Restrepo MI, Anzueto A, Abroug F, Palizas F, et al. Internacional Mechanical Ventilation Study Group. Incidence, risk factors, and outcome of ventilator-associated pneumonia. J Crit Care 2006;21(1):56–65. DOI: 10.1016/j.jcrc.2005.08.005.
33. Robba C, Rebora P, Banzato E, Wiegers EJA, Stocchetti N, Menon DK, et al. Collaborative European NeuroTrauma effectiveness research in traumatic brain injury participants and investigators. incidence, risk factors, and effects on outcome of ventilator-associated pneumonia in patients with traumatic brain injury: analysis of a large, multicenter, prospective, observational longitudinal study. Chest 2020;158(6):2292–2303. DOI: 10.1016/j.chest.2020.06.064.