OPEN ACCESS ISSN: 2835-9496 Legesse KA, Alem YD, Desimmie EA (2026): 1356-1365
DOI: 10.71010/2835-9496/ajcmr-e254

Research Article American Journal of Clinical and Medical Research

Prevalence of Ventilator-Associated Pneumonia in a Neurological Intensive Care Unit: A Systematic Review and Meta-Analysis 2026

Author:
Kalkidan Alemu Legesse[1**], Yohannes Dessie Alem[8**], Ermias Ayele Desimmie[1**]
Co-Author:
Sisima Osman[3], Minwuyelet Abie Tasew[*2], Fraol Kitil Wakoya[1*], Kedriya Abdulkadir Hussein[5], Kedir Dekebi Guduru[6], Fedawak Dejene Jirata[*1], Getahun Mihret Chane[*3], Haile Haregot Kahsay[*2], Mentewab Hailu Kebede[*3], Natnael Kidane Bereketab[4], Snit Kiros Bitew[2], Mekdelawit Birhanu Yitaferu[3], Alefe Kedame Godifey[2], Meley Tadele Atakilti[2], Karime Rodriguez Gutierrez[7]
[1]Department of Medicine, Jimma University Institute of Health, Jimma, Ethiopia
[2]Department of Medicine, College of Health Sciences, Mekelle University, Mekelle, Ethiopia.
[3]Department of Medicine, University of Gondar College of Medicine and Health Sciences, Gondar, Ethiopia.
[4]Department of Medicine, Orotta School of Medicine and Dentistry, Asmara, Eritrea
[5]Department of Medicine, Africa Medical College, Addis Ababa, Ethiopia.
[6]Department of Medicine, Wollega University, Nekemte, Oromia, Ethiopia
[7]Department of Biology, Normandale Community College, Bloomington, Minnesota, USA
[8]Department of Medicine, Debre Tabor University College of Medicine and Health Sciences, Debre Tabor, Ethiopia

***Corresponding author:** Minwuyelet Abie Tasew, Fraol Kitil Wakoya, Fedawak Dejene Jirata, Haile Haregot Kahsay, Getahun Mihret Chane and Mentewab Hailu Kebede

To cite this article: Kalkidan Alemu Legesse[1**], Yohannes Dessie Alem[8**], Ermias Ayele Desimmie[1**], Sisima Osman[3], Minwuyelet Abie Tasew[*2], Fraol Kitil Wakoya[1*], Kedriya Abdulkadir Hussein[5], Kedir Dekebi Guduru[6], Fedawak Dejene Jirata[*1], Getahun Mihret Chane[*3], Haile Haregot Kahsay[*2], Mentewab Hailu Kebede[*3], Natnael kidane Bereketab[4], Snit kiros Bitew[2], Alefe Kedame Godifey[2], Meley Tadele Atakilti[2], Karime Rodriguez Gutierrez[7] (2026) Prevalence of Ventilator-Associated Pneumonia in a Neurological Intensive Care Unit: A Systematic Review and Meta-Analysis 2026. Ann Clin Med Cas Rep Rev: AJCMR-254.

Received Date: 20 August, 2026; **Accepted Date:** 27 August, 2026; **Published Date:** 01 September, 2026

Abstract

Introduction: *Ventilator-associated pneumonia is a serious healthcare-associated infection that develops after the initiation of mechanical ventilation and results in substantial morbidity, prolonged mechanical ventilation, increased hospital length of stay, and healthcare costs. So, this study aims to estimate the prevalence of Ventilator-Associated Pneumonia in a Neurological Intensive care unit.*

Methods and materials: *This systematic review and meta-analysis was conducted and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement. A comprehensive literature search was conducted in PubMed, Embase, Scopus, Web of Science, CINAHL, Google Scholar, and Cochrane Library from database inception to August 13. The methodological quality of the included studies was independently assessed by all reviewers using an appropriate Joanna Briggs Institute critical appraisal tool. Meta-analysis was carried out using a random-effects method using the STATA™ Version 14 software.*

Result: *32 studies involving 87416 participants were included in this meta-analysis. The prevalence of ventilator associated pneumonia ranged from 0.7 to 70.0%, with the highest 39.8% (95% CI: 27.2-52.5) seen in Europe and the lowest 23.1% (95% CI: 15.0-31.2) seen in North America. The overall estimated pooled prevalence of ventilator associated pneumonia Neurological Intensive care unit with a random-effects model was 29.7% (95% CI: 26.2- 33.2).*

Conclusion: *Despite the implementation of various interventions aimed at preventing and minimizing the incidence of ventilator-associated pneumonia. VAP remains a significant problem among patients admitted to neurological intensive care units; approximately one in three mechanically ventilated neurological ICU patients develop VAP. Therefore, strengthening early recognition, and implementing evidence-based infection-control strategies is essential.*

Keywords*: Prevalence, Ventilator-Associated Pneumonia, Intensive care unit, meta-analysis.*

Introduction

Ventilator-associated pneumonia (VAP) is a serious healthcare-associated infection and remains one of the most important infectious complications encountered in intensive care units (ICUs) [1-4]. Generally, it occurs after the initiation of mechanical ventilation and results substantial morbidity, prolonged mechanical ventilation, increased hospital length of stay, and healthcare costs [5-8]. It is primarily related to the aspiration of microorganisms into the lower respiratory tract, while endotracheal intubation, impaired airway defense mechanisms, prolonged mechanical ventilation, and disruption of normal respiratory flora [9-11]. Despite advances in infection prevention practices and ventilator-care bundles [12-14], VAP continues to represent an important challenge in critical care practice.

Furthermore, patients admitted to neurological critical care units may be particularly susceptible to VAP because of the distinctive pathophysiological and clinical characteristics of acute neurological illness [15]. Acute brain injury, stroke, intracranial hemorrhage, and other neurological disorders may result in impaired consciousness, dysphagia, loss of protective airway reflexes, and ineffective cough, thereby increasing the risk of aspiration and lower respiratory tract infection [16, 17]. In addition, neurological ICU patients frequently require endotracheal intubation and prolonged mechanical ventilation,

while interventions such as sedation, tracheostomy, external ventricular drainage, intracranial pressure monitoring, and therapeutic hypothermia may further complicate their clinical course [18].

A study indicates that neurological injury-associated immune dysfunction, the frequent use of invasive devices, and other factors predispose to healthcare-associated infections like VAP [19, 20]. The burden of VAP is clinically important because neurological patients are particularly vulnerable to complications that may interfere with neurological recovery. Also, VAP can prolong mechanical ventilation and ICU admission [21].

It is assumed that accurate estimation of the prevalence of VAP in neurological ICUs is important for infection-prevention planning, allocation of resources, development of evidence-based ventilator-care protocols, and identification of risk groups. However, the available evidence remains fragmented. Therefore a comprehensive synthesis of evidence on patients managed in neurological intensive care settings is needed to provide a precise estimate of the overall burden. Therefore, this systematic review and meta-analysis aims to estimate the pooled prevalence of ventilator-associated pneumonia among patients admitted to neurological intensive care units.

Objective of the study

- ✓ To estimate the pooled prevalence of ventilator-associated pneumonia among patients admitted to neurological intensive care units.

Methods and materials

Study design, reporting, and information sources and search strategy

This systematic review and meta-analysis was reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement [22]. A comprehensive literature search was conducted in PubMed, Embase, Scopus, Web of Science, CINAHL, google scholar, and Cochrane Library from database inception to up to August 13. Additional studies were identified by manually screening the reference lists of included studies and by conducting citation tracking of key eligible articles.

The search strategy combined medical subject headings and free-text terms. Search terms include:- “ventilator-associated pneumonia,” “VAP,” “neurological intensive care,” “neuro ICU,” “neurologic intensive care unit,” “mechanical ventilation,” ”traumatic brain injury”, stroke”, ”neurological disease”, ”TBI, ”, “intracerebral hemorrhage”, “status epilepticus”, and “global”. The search terms were connected using Boolean operators, “AND” & “OR”.

Eligibility criteria

The eligibility criteria were developed according Cochrane acronym POCC (Population, Outcome, Condition, and Context) was employed to guide the retrieval of studies across different databases.

Population: - Studies conducted among patients admitted to neurological critical care units who received invasive mechanical ventilation were eligible. Patients with neurological conditions including traumatic brain injury, stroke, intracerebral hemorrhage, subarachnoid hemorrhage, status epilepticus, and other acute neurological disorders were considered eligible.

Concept: - ventilator-associated pneumonia.

Context: - Studies conducted in neurological intensive care units.

Outcome: -The prevalence of VAP among mechanically ventilated neurological ICU patients.

Design: - observational studies, including prospective or retrospective cohort studies, cross-sectional studies, surveillance studies, or other observational designs reporting primary data published in English. Whereas studies were patients receiving only non-invasive ventilation, did not report VAP as an outcome, case reports, case series, editorials, letters, commentaries, conference abstracts without sufficient data, protocols, narrative reviews, systematic reviews, or meta-analyses will be excluded from this study.

Study selection

All identified records were imported into EndNote, and duplicate records were removed. All reviewers independently screened the titles and abstracts of retrieved records against the predefined eligibility criteria. Potentially relevant articles were retrieved in full text and independently assessed. Disagreements between reviewers were resolved through discussion and consensus. When consensus could not be reached, a third reviewer resolved the disagreement.

Data extraction

A standardized data extraction form was developed before data extraction. Each reviewers independently extracted data from the included studies. The following information was extracted: First author and year of publication, Country, Study design, Sample size, and prevalence of VAP. Any disagreement during data extraction was resolved through discussion or consultation with a third reviewer.

Quality assessment of the studies

The methodological quality of the included studies was independently assessed by all reviewers using an appropriate Joanna Briggs Institute (JBI) critical appraisal tool [23]. Any discrepancy in the result was resolved through careful examination of the studies together.

Data synthesis and statistical analysis

A random-effects model was used to obtain the pooled prevalence estimate. The pooled estimates were presented with corresponding 95% confidence intervals (CIs). Statistical heterogeneity among studies was assessed using Cochran's Q test and the I^2 statistic. The I^2 statistic was interpreted approximately as 25%, 50%, and 75% representing low, moderate, and high heterogeneity, respectively [24]. Subgroup analyses were conducted to explore potential sources of heterogeneity. Sensitivity analyses, potential small-study effects and publication bias were assessed for quantitative synthesis. Funnel-plot and Egger's regression test were used to assess publication bias. All statistical analyses were conducted using Stata version 14 statistical software.

Results

Study selection

Initially, a total of 11,226 studies were retrieved from the databases and manual searching. From this, 2157 duplicates were found and removed. The remaining 9058 articles were screened by their title and abstract, and 3217 irrelevant articles were removed. Following further screening 5841, articles were

sought for retrieval, and then 5727 articles were assessed for eligibility. Out of these, 5695 of them were excluded due to the reported prevalence of specific comorbidity. Finally, a total of 32 studies fulfilled the inclusion criteria and enrolled in the study. The detailed retrieval process is shown in (Fig 1).

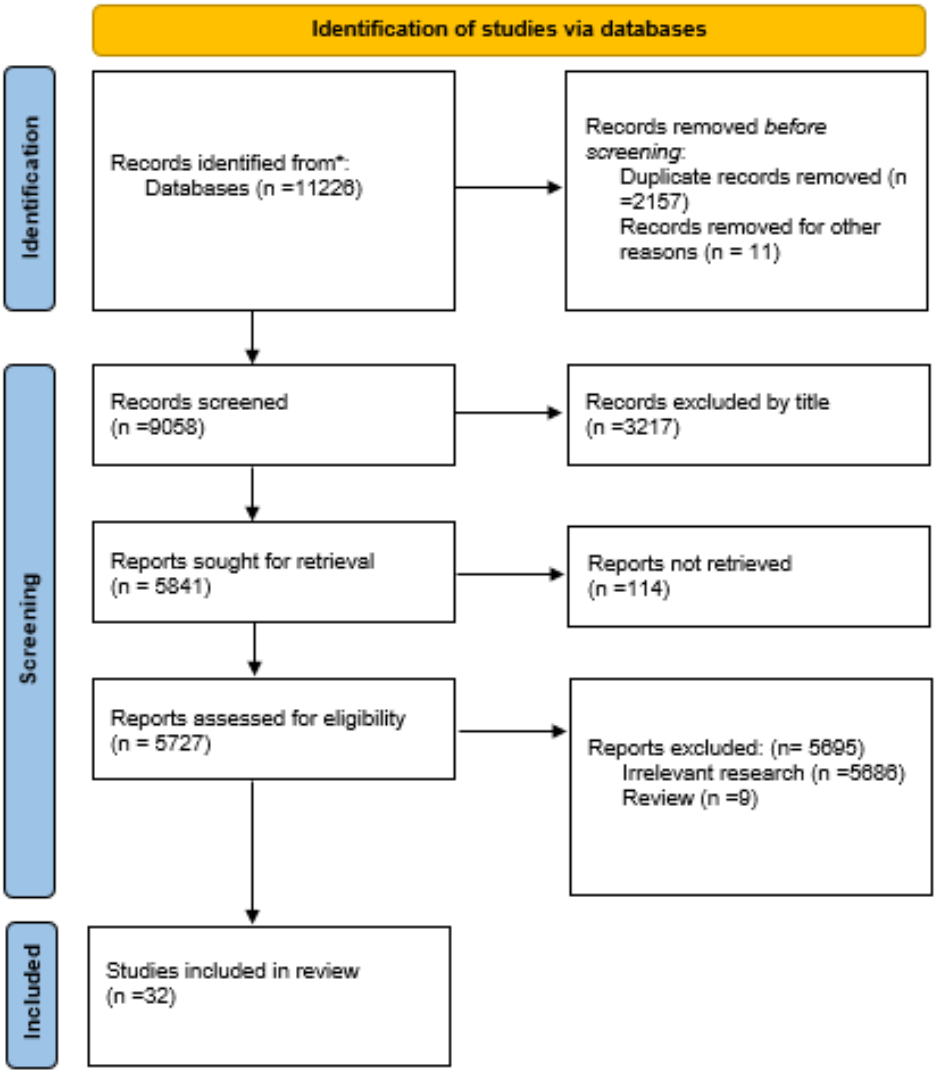

Figure 1: PRISMA flowchart diagram of the study selection.

Characteristics of study

The 32 studies [25-56] included 87416 participants. Most of studies were retrospective cohort studies. The sample size ranged from 71 [38] to 39686 [36]. Most studies were conducted in Asia. From the included studies, the prevalence of ventilator associated pneumonia ranged from 0.7[36] to 70.0 % [38] (Table 1).

Table 1: Characteristics of the included studies in the systematic review and meta-analysis.

Authors Name	Study area	Study design	Sample size	Prevalence with 95% CI
de Montmollin E, (2019)	France	Retrospective	195	40(33.1-46.8)
Kasuya Y,(2011)	USA	Retrospective	111	28(19.6-36.5)
Xu CY,(2021)	China	Retrospective	329	66.4(61.2-71.5)
Josephson SA, (2010)	USA	Retrospective	585	4.1(2.4-5.7)
Battaglini D, (2023)	Multi-center	Retrospective	1285	39.5(36.8-42.1)
Teng G, (2022)	China	Retrospective	89	44.9(34.5-55.2)
Lepelletier D, (2010)	France	Retrospective	161	21.1(14.7-27.4)
Esnault P, (2017)	France	Retrospective	175	60.6(53.3-67.8)
Gamberini L, (2019)	Italy	Cross-sectional	223	58.7(52.2-65.1)
Robba PC, (2020)	Europe	Observational study	962	20.4(17.8-22.9)
Zygun DA, (2006)	Canada	Prospective cohort	134	45(36.5-53.4)
Yu Z, (2024)	China	Retrospective	39686	0.7(0.6-0.7)

Hui X, (2013)	United States & Puerto Rico	Retrospective	24525	12.6(12.1-13.0)
Sachdeva D, (2017)	India	clinical study	71	70(59.3-80.6)
Xie J, (2018)	China	Observational study	2492	29.5(27.7-31.2)
Shrestha DK, (2019)	Nepal	Observational study	106	33(24.0-41.9)
Chang PH, (2024)	Taiwan	Retrospective	8615	5.6(5.1-6.0)
Bayrakçi S, (2025)	Turkey	Retrospective	840	24.2(21.3-27.0)
Zirpe K, (2025)	India	Observational study	457	24.9(20.9-28.8)
Kasuya Y,(2011)	USA	Observational study	622	31.3(27.6-34.9)
Elsheikh M, (2024)	Egypt	Prospective cohort	315	19.7(15.3-24.0)
Kilinc S, (2026)	Turkey	Retrospective	340	50(44.6-55.3)
Tegegne EM, (2025)	Ethiopia	Retrospective	335	31.3(26.3-36.2)
Belay CM, (2022)	Ethiopia	Retrospective	312	27.9(22.9-32.8)
Messelu MA, (2025)	Ethiopia	Retrospective	331	19.6(15.3-23.8)
Hassan ME, (2023)	Bahrain	Retrospective	155	29.7(22.5-36.8)
Elkolaly RM, (2019)	Egypt	Observational study	222	38.4(32.0-44.7)
Kanafani ZA, (2019)	Lebanon	Retrospective	386	41.9(36.9-46.8)
Ali HS, (2016)	Qatar	Retrospective	603	20.8(17.5-24.0)
Mazwi S, (2023)	South Africa	Retrospective	842	2.9(1.7-4.0)
Hayakawa K, (2023)	Vietnam	Retrospective	1,699	7.3(6.0-8.5)
Maebed AZ, (2021)	Egypt	Retrospective	213	28.1(22.0-34.1)

Prevalence of ventilator associated pneumonia

Accordingly, the overall estimated pooled prevalence of ventilator associated pneumonia Neurological Intensive care unit with a random-effects model was 29.7% (95% CI: 26.2-33.2) with heterogeneity index (I^2) of 99.7% (p = 0.000) (Fig. 2). The Eggers test yielded significant result (P < 0.001). Therefore, Duval and Tweedie's trim-and-fill method was applied to assess the potential impact of publication bias. The adjusted pooled prevalence is similar, suggesting that publication bias have no influenced the original pooled estimate.

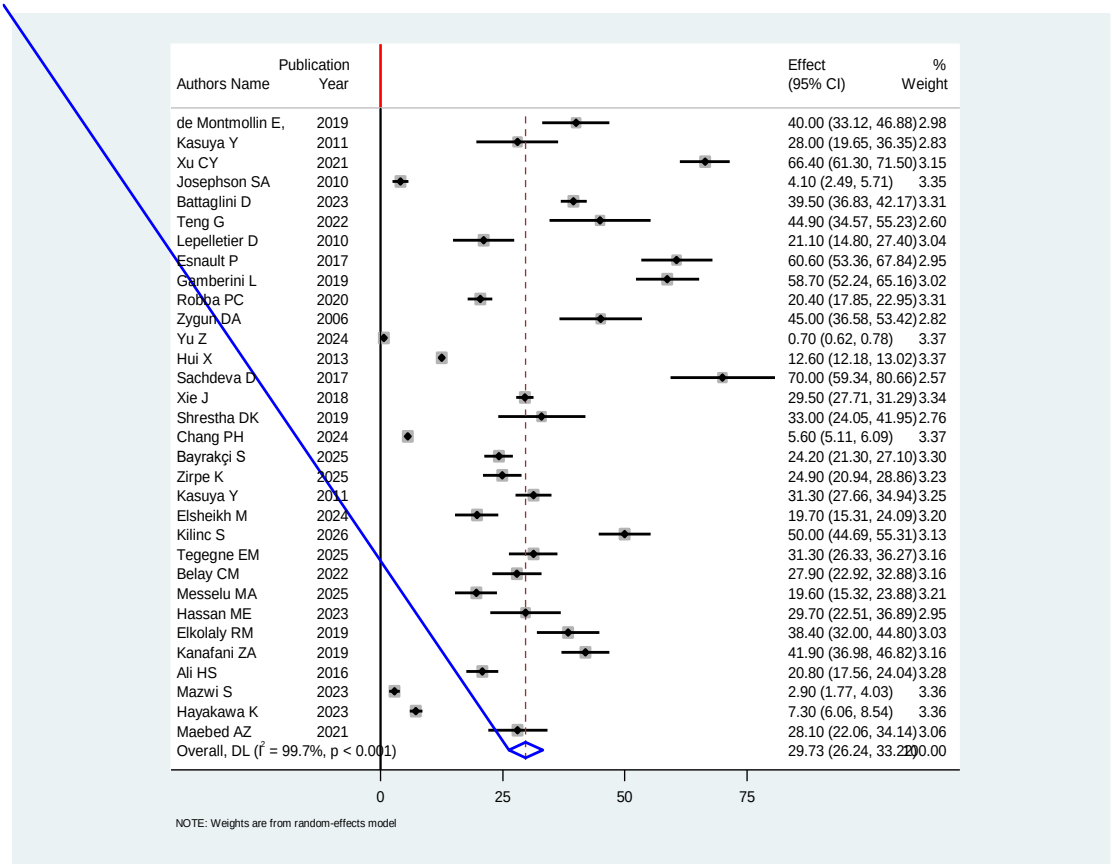

Figure 2: Forest plot showing the pooled global prevalence of Ventilator-Associated Pneumonia in a Neurological Intensive care unit.

Subgroup analysis

Four regions of the world were included in this study, based on the subgroup analysis result, the highest 39.8% (95% CI: 27.2-52.5), I^2 = 98.0%) seen in Europe and the lowest 23.1% (95% CI: 15.0-31.2), I^2 = 98.6 %) seen in North America (Fig. 3).

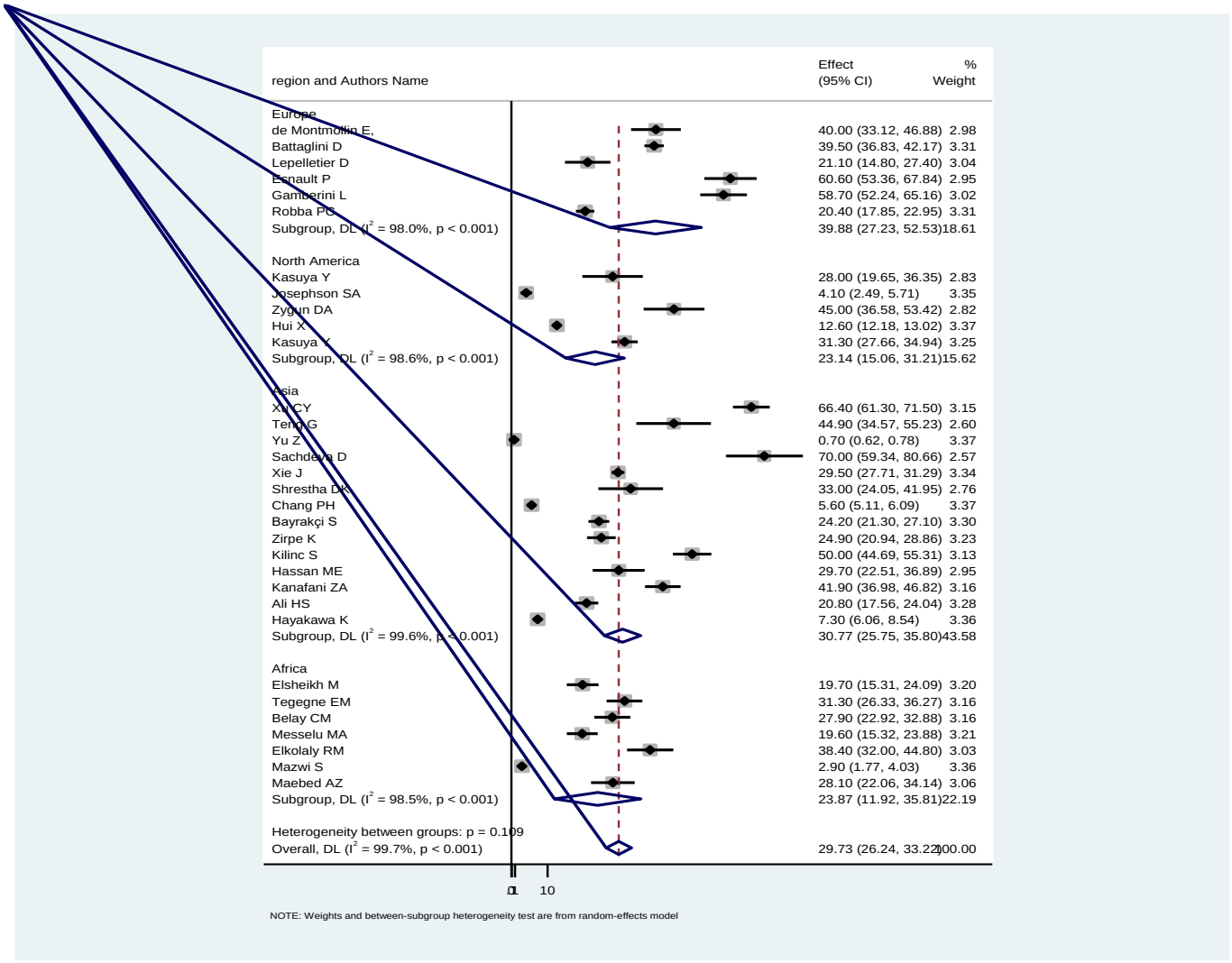

Figure 3: Subgroup analysis of pooled global prevalence of Ventilator-Associated Pneumonia in a Neurological Intensive care unit: by region.

Heterogeneity and Publication bias

Substantial between-study heterogeneity was observed (Cochran's Q = 9142.57, df = 31, P < 0.001), with a between-study variance (τ^2) of 93.917. As a result meta-regression was conducted to identify the source of heterogeneity using sample size and publication year as covariates (Table 2). It was indicated that there is no effect of sample size and year of publication year on heterogeneity between studies. The presence of publication bias was checked using Egger's test, and a graphical Funnel plot, the result of Egger's test was significant (P= 0.008). Also, visual inspection of the funnel plot indicated substantial asymmetry (Fig. 4); however, the linear trim-and-fill analysis estimated no potentially missing studies (Fig 5). But the funnel-plot remains asymmetry indicating it cannot be attributed solely to publication bias.

Table 2: Meta-regression analysis of factors affecting between-study heterogeneity.

Heterogeneity source	Coefficients	Std. Err.	P-value
Publication year	0.0212643	0.5698566	0.970
Sample size	0.0003102	0.0002053	0.142

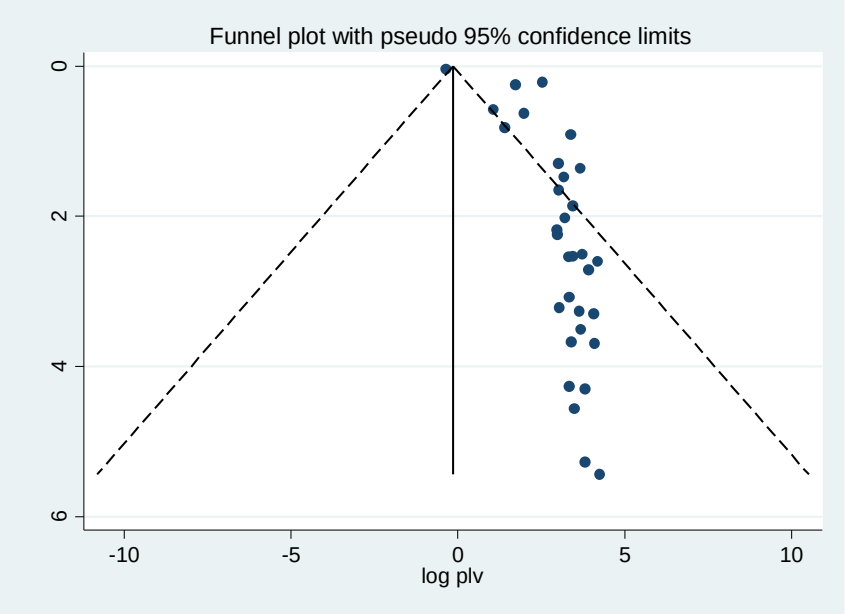

Figure 4: Funnel plot to test publication bias in 32 studies with 95% confidence limits.

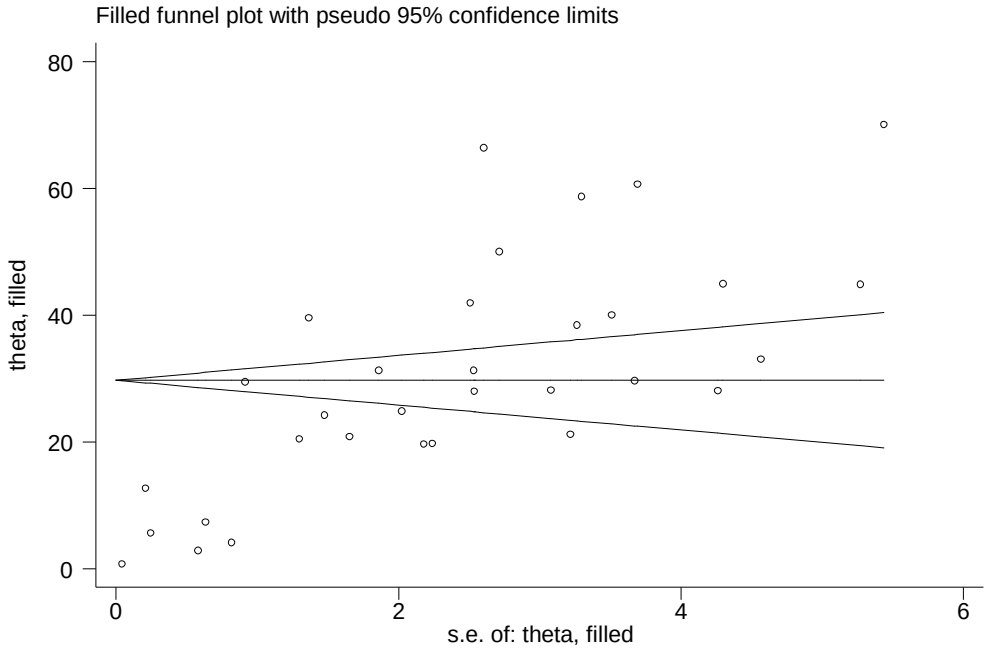

Figure 5: Funnel plot to test publication bias in 32 studies with 95% confidence limits by trim and fill analysis.

Sensitivity Analysis

Sensitivity analysis was performed to determine how various sources of uncertainty contribute to the overall uncertainty among the studies, but the results indicated that uncertainty has an insignificant influence on pooled prevalence (Fig. 6).

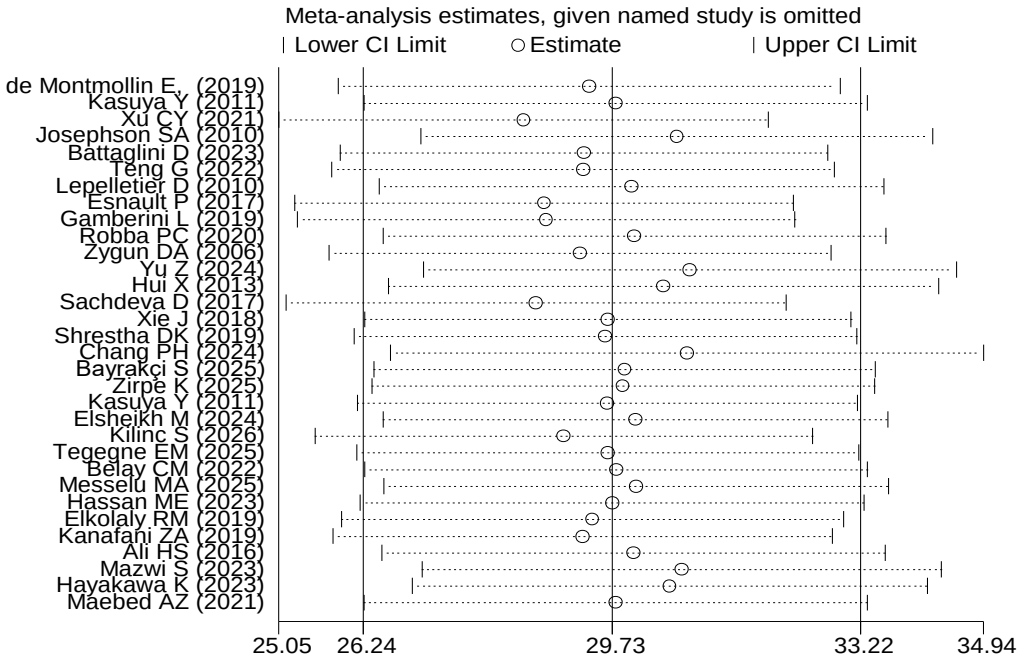

Figure 6: Sensitivity analysis of pooled global prevalence of Ventilator-Associated Pneumonia in a Neurological Intensive care unit for each study being removed one at a time.

Discussion

The present systematic review and meta-analysis found that the overall pooled prevalence of ventilator-associated pneumonia among patients admitted to neurological intensive care units was 29.7% (95% CI: 26.2–33.2). This finding indicates that approximately one in three patients in neurological intensive care who are exposed to mechanical ventilation develop VAP. The finding is consistent with evidence from general ICU populations 4.0% and 28.8% [57] and 30% [58].

This study finding is lower than a study conducted globally 42%, [59], and 36% [60]. The differences might be due to variation in the proportion of patients requiring prolonged mechanical ventilation; study designs, healthcare-system differences, and duration of follow-up can result in difference in prevalence. Moreover, improvement implementation of ventilator-care bundles, improved oral hygiene, appropriate patient positioning, aspiration-prevention measures, sedation minimization, and early assessment for ventilator liberation have increasingly been incorporated into ICU practice, this might be the reason for variation too.

Conversely, it is higher than a systematic review and meta-analysis conducted in Asia (12.7%) [61]. the higher prevalence may be attributed to the specific vulnerability of neurological ICU patients and staying of longer periods on mechanical ventilation [61].

The subgroup analysis demonstrated substantial geographical variation in the prevalence of VAP. The highest pooled prevalence was observed in Europe at 39.8% (95% CI: 27.2–52.5), whereas the lowest was observed in North America at 23.1% (95% CI: 15.0–31.2). The variation might be explained by differences in patient characteristics, neurological diagnoses, severity of illness, duration of mechanical ventilation, ICU staffing, infection-prevention practices, diagnostic criteria, and surveillance systems.

Also, a systematic review of VAP diagnostic studies demonstrated substantial variation in diagnostic approaches and highlighted the lack of a universally reliable diagnostic standard; this may result difference in prevalence too [62, 63].

Limitation of the study

This systematic review and meta-analysis have faced the following limitations. First, due to the presence of significant heterogeneity, the result should be interpreted cautiously.

Conclusion

Despite the implementation of various interventions aimed at preventing and minimizing the incidence of ventilator-associated pneumonia. On this study VAP remains a significant problem among patients admitted to neurological intensive care units; approximately one in three mechanically ventilated neurological ICU patients develops VAP. Therefore, strengthening early recognition, and implementing evidence-based infection-control strategies is essential. Future multicenter studies using standardized VAP diagnostic criteria and surveillance methods are warranted to better explain regional differences and identify modifiable risk factors for VAP in neurological ICU patients.

Declarations

Ethics approval and consent to participant

Not applicable

Consent for publication

Not applicable

Availability of data and materials

The data analyzed during the current systematic review and meta-analysis is available with reasonable request from corresponding author.

Competing interests
All the authors declare that they have no competing interests

Funding
The authors received no specific funding for this work

Acknowledgment
We would like to thank all authors of studies included in this systematic review and meta-analysis.

References

1. Kohbodi GA, Rajasurya V, Noor A. Ventilator-associated pneumonia.
2. Mathai AS, Phillips A, Isaac R. Ventilator-associated pneumonia: A persistent healthcare problem in Indian Intensive Care Units!. Lung India: official organ of Indian Chest Society. 2016 Sep;33(5):512.
3. Othman AA, Abdelazim MS. Ventilator-associated pneumonia in adult intensive care unit prevalence and complications. The Egyptian Journal of critical care medicine. 2017 Aug;5(2):61-3.
4. Morgan AJ. Ventilator Associated Pneumonia. Case Studies in Adult Intensive Care Medicine. 2017 Apr 20:265.
5. Nanao T, Ishikawa KB, Ikeda S, Yamazaki T. Clinical and economic impact of ventilator-associated pneumonia in intensive care units in Japan. Infection Prevention in Practice. 2025 Mar 1;7(1):100440.
6. Le Pape M, Besnard C, Acatrinei C, Guinard J, Boutrot M, Genève C, Boulain T, Barbier F. Clinical impact of ventilator-associated pneumonia in patients with the acute respiratory distress syndrome: a retrospective cohort study. Annals of Intensive Care. 2022 Mar 15;12(1):24.
7. Timsit JF, Esaied W, Neuville M, Bouadma L, Mourvillier B. Update on ventilator-associated pneumonia. F1000Research. 2017 Nov 29;6:2061.
8. Batra P, Mathur P, Misra MC, Kumari M, Katoch O, Hasan F. Ventilator associated pneumonia in adult patients preventive measures: a review of the recent advances. Journal of Infectiology and Epidemiology. 2018 Oct 3;1(3).
9. Howroyd F, Chacko C, MacDuff A, Gautam N, Pouchet B, Tunnicliffe B, Weblin J, Gao-Smith F, Ahmed Z, Duggal NA, Veenith T. Ventilator-associated pneumonia: pathobiological heterogeneity and diagnostic challenges. Nature communications. 2024 Jul 31;15(1):6447.
10. Ulsamer A, Bonilla S, Pérez-Fernández X, Rello J, Sabater-Riera J. The pathogenesis of ventilator-associated pneumonia: old and new mechanisms. Expert Review of Respiratory Medicine. 2025 Jul 3;19(7):655-71.
11. Safdar N, Crnich CJ, Maki DG. The pathogenesis of ventilator-associated pneumonia: its relevance to developing effective strategies for prevention. Respiratory care. 2005 Jun;50(6):725-41.
12. Alcan AO, Korkmaz FD, Uyar M. Prevention of ventilator-associated pneumonia: Use of the care bundle approach. American journal of infection control. 2016 Oct 1;44(10):e173-6.
13. Osman S, Al Talhi YM, AlDabbagh M, Baksh M, Osman M, Azzam M. The incidence of ventilator-associated pneumonia (VAP) in a tertiary-care center: comparison between pre-and post-VAP prevention bundle. Journal of infection and public health. 2020 Apr 1;13(4):552-7.
14. Klompas M, Branson R, Cawcutt K, Crist M, Eichenwald EC, Greene LR, Lee G, Maragakis LL, Powell K, Priebe GP, Speck K. Strategies to prevent ventilator-associated pneumonia, ventilator-associated events, and nonventilator hospital-acquired pneumonia in acute-care hospitals: 2022 Update. Infection Control & Hospital Epidemiology. 2022 Jun;43(6):687-713.
15. Mrozek S, Constantin JM, Geeraerts T. Brain-lung crosstalk: implications for neurocritical care patients. World journal of critical care medicine. 2015 Aug 4;4(3):163.
16. Barnett HM, Davis AP, Khot SP. Stroke and breathing. Handbook of clinical neurology. 2022 Jan 1;189:201-22.
17. Somogyi P, Babik B, Farkas E, Peták F. Lung fuction impairment following cerebral ischemic stroke: Pathophysiology, mechanisms, and clinical challenges. Respiratory Physiology & Neurobiology. 2026 Mar 24:104567.
18. Rajajee V, Riggs B, Seder DB. Emergency neurological life support: airway, ventilation, and sedation. Neurocritical care. 2017 Sep;27(Suppl 1):4-28.
19. Schefold JC, Berger D, Zürcher P, Lensch M, Perren A, Jakob SM, Parviainen I, Takala J. Dysphagia in mechanically ventilated ICU patients (DYnAMICS): a prospective observational trial. Critical care medicine. 2017 Dec;45(12):2061-9.
20. Wu D, Wu C, Zhang S, Zhong Y. Risk factors of ventilator-associated pneumonia in critically III patients. Frontiers in pharmacology. 2019 May 9;10:482.
21. Coelho L, Moniz P, Guerreiro G, Póvoa P. Airway and respiratory devices in the prevention of ventilator-associated pneumonia. Medicina. 2023 Jan 19;59(2):199.
22. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, Shamseer L, Tetzlaff JM, Akl EA, Brennan SE, Chou R. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. Bmj. 2021 Mar 29;372.
23. Munn Z, Moola S, Lisy K, Riitano D, Tufanaru C. Systematic reviews of prevalence and incidence. Joanna Briggs Institute reviewer's manual Adelaide, South Australia: The Joanna Briggs Institute. 2017:5.1-5
24. Higgins JP, Thompson SG, Deeks JJ, Altman DG. Measuring inconsistency in meta-analysis. BMJ. 2003 Sep;327(7414):557.
25. de Montmollin E, Ruckly S, Schwebel C, Philippart F, Adrie C, Mariotte E, Marcotte G, Cohen Y, Sztrymf B, da Silva D, Bruneel F. Pneumonia in acute ischemic stroke patients requiring invasive ventilation: impact on short and long-term outcomes. Journal of Infection. 2019 Sep 1;79(3):220-7.
26. Kasuya Y, Hargett JL, Lenhardt R, Heine MF, Doufas AG, Remmel KS, Ramirez JA, Akça O. Ventilator-associated pneumonia in critically ill stroke patients: frequency, risk factors, and outcomes. Journal of critical care. 2011 Jun 1;26(3):273-9.
27. Xu CY, Ye HW, Chen B, Wu YF, Cao Z, Ding Z, Yao YP, Gao Y, Li J, Zhu JJ, He S. Analysis of risk factors and prognosis of post-stroke pulmonary infection in integrated ICU. European Review for Medical & Pharmacological Sciences. 2021 Jan 15;25(2).

28. Josephson SA, Moheet AM, Gropper MA, Nichols AD, Smith WS. Ventilator-associated pneumonia in a neurologic intensive care unit does not lead to increased mortality. Neurocritical care. 2010 Apr;12(2):155-8.
29. Battaglini D, Parodi L, Cinotti R, Asehnoune K, Taccone FS, Orengo G, Zona G, Uccelli A, Ferro G, Robba M, Pelosi P. Ventilator-associated pneumonia in neurocritically ill patients: insights from the ENIO international prospective observational study. Respiratory research. 2023 May 31;24(1):146.
30. Teng G, Wang N, Nie X, Zhang L, Liu H. Analysis of risk factors for early-onset ventilator-associated pneumonia in a neurosurgical intensive care unit. BMC infectious diseases. 2022 Jan 20;22(1):66.
31. Lepelletier D, Roquilly A, Mahe PJ, Loutrel O, Champin P, Corvec S, Naux E, Pinaud M, Lejus C, Asehnoune K. Retrospective analysis of the risk factors and pathogens associated with early-onset ventilator-associated pneumonia in surgical-ICU head-trauma patients. Journal of neurosurgical anesthesiology. 2010 Jan 1;22(1):32-7.
32. Esnault P, Nguyen C, Bordes J, D'Aranda E, Montcriol A, Contargyris C, Cotte J, Goutorbe P, Joubert C, Dagain A, Boret H. Early-onset ventilator-associated pneumonia in patients with severe traumatic brain injury: incidence, risk factors, and consequences in cerebral oxygenation and outcome. Neurocritical care. 2017 Oct;27(2):187-98.
33. Gamberini L, Giugni A, Ranieri S, Meconi T, Coniglio C, Gordini G, Bardi T. Early-onset ventilator-associated pneumonia in severe traumatic brain injury: is there a relationship with prehospital airway management?. The Journal of Emergency Medicine. 2019 Jun 1;56(6):657-65.
34. Robba PC, Rebora PP, Stocchetti MN, Menon PD, Citerio MG, Åkerlund C, Nelson D, Amrein K, Nyirádi J, Andelic N, Andreassen L. 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 Dec 1;158(6):2292-303.
35. Zygun DA, Zuege DJ, Boiteau PJ, Lapland KB, Henderson EA, Kortbeek JB, Doig CJ. Ventilator-associated pneumonia in evere traumatic brain injury. Neurocritical care. 2006 Oct;5(2):108-14.
36. Yu Z, Li X, Lv C, Tian Y, Suo J, Yan Z, Bai Y, Liu B, Fang L, Du M, Yao H. Epidemiological characteristics of ventilator-associated pneumonia in neurosurgery: A 10-year surveillance study in a Chinese tertiary hospital. Infectious Medicine. 2024 Sep 1;3(3):100128.
37. Hui X, Haider AH, Hashmi ZG, Rushing AP, Dhiman N, Scott VK, Selvarajah S, Haut ER, Efron DT, Schneider EB. Increased risk of pneumonia among ventilated patients with traumatic brain injury: every day counts!. journal of surgical research. 2013 Sep 1;184(1):438-43.
38. Sachdeva D, Singh D, Loomba P, Kaur A, Tandon M, Bishnoi I. Assessment of surgical risk factors in the development of ventilator-associated pneumonia in neurosurgical intensive care unit patients: Alarming observations. Neurology India. 2017 Jul 1;65(4):779-84.
39. Xie J, Yang Y, Huang Y, Kang Y, Xu Y, Ma X, Wang X, Liu J, Wu D, Tang Y, Qin B. The current epidemiological landscape of ventilator-associated pneumonia in the intensive care unit: a multicenter prospective observational study in China. Clinical Infectious Diseases. 2018 Nov 13;67(suppl_2):S153-61.
40. Shrestha DK, Rajbhandari B, Pradhanang A, Sedain G, Shilpakar SK, Pradhan S. Ventilator-associated pneumonia in neurosurgical patients: a tertiary care center study. Journal of Institute of Medicine Nepal. 2019 Dec 4;41(2):40-4.
41. Chang PH, Lin TL, Chen YJ, Lai WH, Chen IL, Chang HC, Lin YC, Lin YH, Li WF, Liu YW, Wang CC. Risk factors, pathogens, and outcomes of Ventilator-Associated Pneumonia in Non-cardiac Surgical patients: a retrospective analysis. Microorganisms. 2024 Jul 13;12(7):1422.
42. Bayrakçi S, Şahin A, Bayrakçi O, Aslan S. Characteristics of ventilator-associated pneumonia due to Gram-negative bacteria in the intensive care unit: A single-center experience. Medicine. 2025 Jun 27;104(26):e42946.
43. Zirpe K, Kapse U, Sharma A, Kulkarni AP, Gurav S, Tiwari A, Bhujbal C, Deshmukh A, Suryawanshi P, Pote P, Bhoyar A. Incidence, risk factors, microbiology and outcomes of VAP at an NCU in India: A Prospective Observational Study. Indian Journal of Critical Care Medicine: Peer-reviewed, Official Publication of Indian Society of Critical Care Medicine. 2025 Apr;29(4):308.
44. Kasuya Y, Hargett JL, Lenhardt R, Heine MF, Doufas AG, Remmel KS, Ramirez JA, Akça O. Ventilator-associated pneumonia in critically ill stroke patients: frequency, risk factors, and outcomes. Journal of critical care. 2011 Jun 1;26(3):273-9.
45. Elsheikh M, Kuriyama A, Goto Y, Takahashi Y, Toyama M, Nishikawa Y, El Heniedy MA, Abdelraouf YM, Okada H, Nakayama T. Incidence and predictors of ventilator-associated pneumonia using a competing risk analysis: a single-center prospective cohort study in Egypt. BMC Infectious Diseases. 2024 Sep 19;24(1):1007.
46. Kilinc S, Aydogan MS, Duran M, Yucetas CS. Incidence, microbiology, and clinical impact of ventilator-associated pneumonia in traumatic brain injury: a single-center retrospective study. Brain Injury. 2026 Jun 7;40(7):614-8.
47. Tegegne EM, Chekol Gete B, Demissie DB. Prevalence of ventilator-associated pneumonia and associated factors among intubated adult patients admitted in public hospitals in Addis Ababa, Ethiopia: a facility-based retrospective study design. Frontiers in Medicine. 2025 Apr 25;12:1500901.
48. Belay CM, Zewale TA, Amlak BT, Abebe TG, Hailu G. Incidence and predictors of ventilator-associated pneumonia among adult intubated patients in Bahir Dar Specialized Hospitals, 2021: a retrospective follow-up study. International Journal of General Medicine. 2022 Nov 11;15:8173.
49. Messelu MA, Tiruneh BG, Kassie A, Aynalem BA, Gedfew M, Ayenew T. Prevalence, risk factors, and outcomes of ventilator-associated pneumonia among adults on mechanical ventilation in ICUs of specialized hospitals, Northwest Ethiopia. International Journal of Africa Nursing Sciences. 2025 Dec 25:100965.
50. Hassan ME, Al-Khawaja SA, Saeed NK, Al-Khawaja SA, Al-Awainati M, Radhi SS, Alsaffar MH, Al-Beltagi M. Causative bacteria of ventilator-associated pneumonia in intensive care unit in Bahrain: Prevalence and antibiotics

susceptibility pattern. World journal of critical care medicine. 2023 Jun 9;12(3):165.
51. Elkolaly RM, Bahr HM, El-Shafey BI, Basuoni AS, Elber EH. Incidence of ventilator-associated pneumonia: Egyptian study. Egyptian Journal of Bronchology. 2019 Jun;13(2):258-66.
52. Kanafani ZA, El Zakhem A, Zahreddine N, Ahmadieh R, Kanj SS. Ten-year surveillance study of ventilator-associated pneumonia at a tertiary care center in Lebanon. Journal of infection and public health. 2019 Jul 1;12(4):492-5.
53. Ali HS, Khan FY, George S, Shaikh N, Al-Ajmi J. Epidemiology and outcome of ventilator-associated pneumonia in a heterogeneous ICU population in Qatar. BioMed research international. 2016;2016(1):8231787.
54. Mazwi S, van Blydenstein SA, Mukansi M. Ventilator-associated pneumonia in an academic intensive care unit in Johannesburg, South Africa. African Journal of Thoracic and Critical Care Medicine. 2023 Dec 1;29(4):158-64
55. Hayakawa K, Binh NG, Co DX, Thach PT, Thuy PT, Chau NQ, Huong ML, Van Thanh D, Phuong DM, Miyoshi-Akiyama T, Nagashima M. Clinical and microbiological evaluation of ventilator-associated pneumonia in an intensive care unit in Vietnam. Infection Prevention in Practice. 2023 Dec 1;5(4):100318.
56. Maebed AZ, Gaber Y, Bakeer W, Dishisha T. Microbial etiologies of ventilator-associated pneumonia (VAP) in intensive care unit of Beni-Suef University's Hospital. Beni-Suef University journal of basic and applied sciences. 2021 Jul 29;10(1):41.
57. Al-Omari B, McMeekin P, Allen AJ, Akram AR, Graziadio S, Suklan J, Jones WS, Lendrem BC, Winter A, Cullinan M, Gray J. Systematic review of studies investigating ventilator associated pneumonia diagnostics in intensive care. BMC pulmonary medicine. 2021 Jun 9;21(1):196.
58. 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. Journal of thoracic disease. 2024 Sep 14;16(9):5518.
59. Chen S, Gao G, Xia Y, Wu Z. Incidence rate and risk factors of ventilator-associated pneumonia in patients with traumatic brain injury: a systematic review and meta-analysis of observational studies. Journal of Thoracic Disease. 2023 Apr 27;15(4):2068.
60. 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. Neurocritical care. 2020 Feb;32(1):272-85.
61. Bonell A, Azarrafiy R, Huong VT, Viet TL, Phu VD, Dat VQ, Wertheim H, van Doorn HR, Lewycka S, Nadjm B. A systematic review and meta-analysis of ventilator-associated pneumonia in adults in Asia: an analysis of national income level on incidence and etiology. Clinical Infectious Diseases. 2019 Jan 18;68(3):511-8.
62. Al-Omari B, McMeekin P, Allen AJ, Akram AR, Graziadio S, Suklan J, Jones WS, Lendrem BC, Winter A, Cullinan M, Gray J. Systematic review of studies investigating ventilator associated pneumonia diagnostics in intensive care. BMC pulmonary medicine. 2021 Jun 9;21(1):196.
63. Rea-Neto A, Youssef NC, Tuche F, Brunkhorst F, Ranieri VM, Reinhart K, Sakr Y. Diagnosis of ventilator-associated pneumonia: a systematic review of the literature. Critical care. 2008 Apr 21;12(2):R56.