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RESEARCH ARTICLE

BURDEN, RISK FACTORS, AND OUTCOMES OF VENTILATOR-ASSOCIATED PNEUMONIA IN INDIAN INTENSIVE CARE UNITS: A SYSTEMATIC REVIEW

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Abstract

Background: Ventilator-Associated Pneumonia (VAP) is a major healthcare associated infection among patients with artificial airway management and burden of VAP varies among ICUs in India. This systematic review focuses on VAP occurring between the years 2015 to 2025 in India. Reported studies are expected to include data on Frequency, Microbiology, Risk Factors, Outcomes and Prevention of VAP. This review contains a random effects meta-analysis of prevalence for studies that included both numerator and denominator values.

Methods: The databases PubMed and Publisher were searched for a combination of terms Ventilator-Associated Pneumonia, India, Intensive Care Unit, Incidence, Risk Factors, Mortality, Microbiology, and Antimicrobial Resistance. Included studies were Indian ICU studies of adults published between 2015 to 2025 that included original VAP data. Quality of the included studies was assessed through design appropriate criteria for observational studies. Six Cohort studies including 2153 mechanically ventilated patients and 344 VAP cases were included in the prevalence random effects meta-analysis.

Results: Prevalence of individual studies ranged from 4.8% to 41.9%. With considerable heterogeneity (I^2 97.7%), pooled prevalence on the logit scale was 20.1% (95% CI 10.0–36.1%). The incidence density was reported as 11.03, 23.54, 39.59, 40.1 and 43.5 per 1000 ventilator days in the different studies. Gram-negative bacteria were the most predominant, especially Acinetobacter Baumannii, Klebsiella Pneumon iae, and Pseudomonas Aeruginosa, and were reported to be multi drug resistant. Amongst the risk factors reported, there were multiple studies where VAP was reported to increase the length of stay in ICU and hospital, and a number of studies reported an increase in mortality.

Conclusion: VAP continues to have a significant burden in Indian ICUs. High statistical heterogeneity indicates a national pooled prevalence should not be used to derive a single expected prevalence at every hospital. Priorities

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remain on the standardized surveillance and prevention bundles, as well as localized Empiric therapy and antimicrobial stewardship.

Introduction:-

Mechanical ventilation is an essential tool in critical care. However, Endotracheal Intubation enables biofilm formation on the tube and alters the host defense responses promoting micro-aspiration and impairing mucociliary clearance. Invasive Mechanical Ventilation for at least 48 hours is the accepted definition for Ventilator-Associated Pneumonia (VAP) in many clinical studies and surveillance programs. However, there are many differences, including varying case definitions, across these programs and studying VAP. These variations account for many of the differences in reported estimates and indicate the need for caution when comparing Indian studies. Beyond the infection, VAP prolongs the duration of Mechanical Ventilation, exposes patients to prolonged therapy with Broad-spectrum Antimicrobials, prolongs the hospital stay as well as the stay in ICU, and increases the financial burden and the risk of developing resistance to antimicrobials in the surrounding community.

India is a priority country for VAP surveillance because intensive care systems differ across hospitals in India. These systems differ in Microbiology, Antibiotic Resistance, Case-mix, and Staffing. Several Indian studies conducted after 2015 reported low and high percentages of intubated patients developing VAP. For example, one study reported 47 cases of VAP among 979 intubated patients while another reported 95 cases among 250 patients. Hence, comparing percentages and ignoring case definitions and diagnostic criteria is inadequate. The microbiological studies done in combination with Intensive Care Unit (ICU) empiric therapy that is continuously broadened to include the most resistant pathogens deranged the microbiology and resulted in the emergence of Multidrug Resistant (MDR) Gram-negative bacteria. These findings have direct implications for the approach to empiric therapy, and the impact of empiric Broad-spectrum Therapy will be an impetus for resistance to develop.

The rational response to this is rapid microbiology sampling, de-escalation of therapy, strengthening prevention of resistance and rational use of antibiotic therapy, and knowledge of unit-specific antibiograms.This review analyses the Burden, Risk Factors, Microbiological Profile, Antimicrobial Resistance, and Outcomes of VAP in Indian ICUs in the publications between 2015 and 2025. It also undertakes a quantitative synthesis of prevalence when corresponding numerators and denominators are available. The Aim is not to calculate a single national rate in the Indian Health Care system, which is heterogeneous. Instead, it is to estimate the burden of VAP in ICUs in India and explain why there are big differences in what has been reported.

Methods:-

Design and Reporting of this Review:-

This review has been prepared in accordance with PRISMA 2020 to ensure complete transparency of the Identification, Screening, Assessment of Eligibility, and Reporting of Studies. The following is the research question: What is The Burden, Clinical Factors, Dominant Microorganisms and Resistance Patterns, and Outcomes of VAP among adult ICU patients in India who are under Invasive Mechanical Ventilation?

Search Strategy:-

Published works between January 2015 and December 2025 were assessed using a structured search. Search components combined “Ventilator Associated Pneumonia” or “VAP” with “India,” “Intensive Care Unit,” “Incidence,” “Prevalence,” “Risk Factors,” “Mortality,” “Microbiology,” “Antimicrobial Resistance,” and “Ventilator Days.” We looked at Indexed PubMed Articles, Open Access Repositories, Publisher’s Websites, and other Supplementary Articles. Bibliographic cross-checks were done to verify DOIs of publisher and PubMed articles.

Eligibility Criteria:-

Eligible original Indian Clinical Studies investigated adults experiencing Invasive Ventilation. Studies had to report VAP Frequency, Incidence, Density, Microbiology, Mortality, and/or other Clinical Outcomes. Prospective and Retrospective Observational studies were considered. Records outside India, pediatric-only studies, narrative reviews, editorials, studies published outside 2015-2025, and reports lacking outcomes interpretable as VAP were not included for synthesis of primary evidence. Two publications reporting the same cohort were not included in the meta-analysis of prevalence. Instead, the publication without a duplicate was included and the other included the costs or other outcomes.

Study Selection and Data Extraction:-

The documented search yielded 22 records. Five records were removed for having duplicate titles or reports of the same cohort. Seventeen records were assessed for title and abstract. Eight records were removed because of being regional reviews, records from conferences only, non-primary reports or otherwise not of primary interest. Nine detailed reports or full-text records were assessed. Two records were removed from quantitative synthesis because of lacking a necessary denominator or reporting on a cohort that was overlapping. Seven records of original research were included for a qualitative synthesis and six separate cohorts reported prevalence. The following were documented: Location, Design, Sample size, Number of VAPS, Incidence Density, Method of Diagnosis, major findings of the study, Resistance, Risk Factors, Length of stay, and the Results of the case in question.

Figure 1. PRISMA-style flow of the documented study-selection process

IDENTIFICATION Records identified in documented targeted search (n = 22)
↓
IDENTIFICATION Duplicate title/cohort records removed (n = 5)
↓
SCREENING Records screened by title/abstract (n = 17)
↓
SCREENING Records excluded (n = 8)
↓
ELIGIBILITY Full texts or detailed reports assessed (n = 9)
↓
ELIGIBILITY Excluded from Quantitative Synthesis: incompatible denominator or overlapping cohort (n = 2)
↓
INCLUDED Studies included in qualitative synthesis (n = 7)
↓
INCLUDED Independent cohorts included in Prevalence Meta-analysis (n = 6)

Quality Appraisal:-

Observational studies were evaluated concerning the definition of the Population, Recruitment (Consecutive versus Representative), explicit criteria for VAP, reliable Microbiology, completeness of Outcome, Appropriate Statistics, and handling of confounding. Overall, the studies were moderate in terms of Methodology; although some studies were limited to single-center, used older recruitment, had variable reporting of ventilator days, and had Heterogeneous definitions of cases.

Statistical Analysis:-

For Meta-analysis, six studies of VAP cases and total mechanically ventilated subjects were identified: Gore et al., 36/240; Gupta et al., 47/979; Mathai et al., 95/250; Patil and Patil, 74/267; Kumar et al., 49/117; and Rekha et al., 43/300. Study proportions were converted to logits, Sampling variances were calculated from event and nonevent counts, and a Der Simonian-Laird random effects model was used due to the expected presence of considerable between-study heterogeneity. The pooled logit was converted to a Proportion. Cochran's Q and I^2 were used to

report Heterogeneity. As only six studies were included in the analysis, the emphasis was given to the test of asymmetry of the funnel plot.

Results:-

Characteristics and Burden of the Studies:-

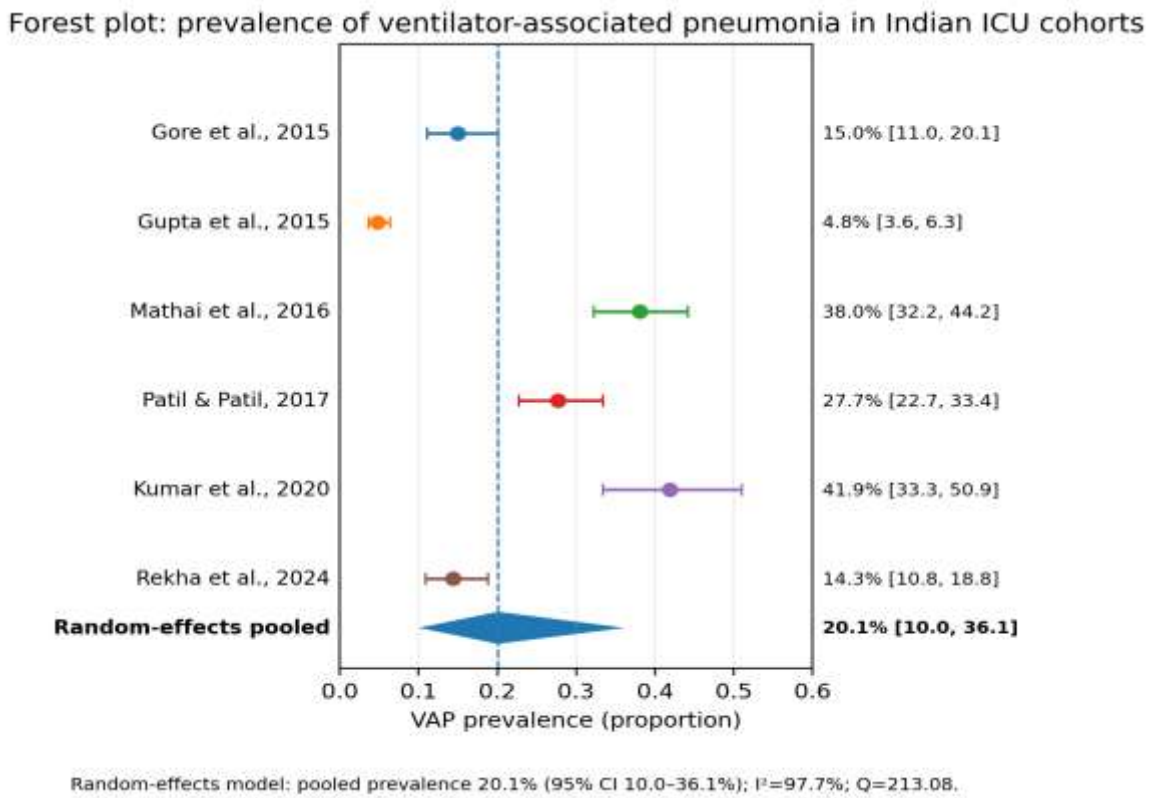
Studies including Tertiary and Secondary healthcare settings in several regions across India were varied in size of denominator. Gore et al. reported 36 cases of VAP among 240 patients on the Ventilator, with a prevalence of 15%. Gupta et al. identified 47 cases among 979 patients on the ventilator in Punjab, with a prevalence of 4.8% and an average of 11.03 cases for every 1,000 days that the Ventilator was in use. Mathai et al. reported 95 cases of VAP among 250 patients, with a prevalence of 38% and an average of 40.1 cases for every 1,000 days that the Ventilator was in use. Patil and Patil reported 74 cases of VAP among 267 patients on the Ventilator, with a prevalence of 27.7%, and an average of 39.59 cases for every 1,000 days that the Ventilator was in use. Kumar et al. reported 49 cases of VAP among 117 patients, with a prevalence of 41.9%. Rekha et al. reported 43 cases of VAP among 300 patients evaluated, with a prevalence of 14.3%.

A study in Northern India by Masih et al. reported 23.54 cases of VAP for every 1,000 days of use of a Ventilator. Stronger density of VAP episodes was reported in the medical ICU when compared to Critical care. A prospective cohort from Southwestern India reported 43.5 cases for every 1,000 days of use of a Ventilator. In different settings, it has been reported that period prevalence and incidence density estimates vary greatly.

Prevalence Meta-analysis:-

Across the six independent cohorts, 344 of 2,153 mechanically ventilated patients developed VAP. Random-effects pooled prevalence was 20.1% (95% CI 10.0–36.1%). Cochran's Q was 213.08 with five degrees of freedom and I^2 was 97.7%, indicating extreme heterogeneity. Accordingly, the pooled prevalence should be interpreted as a statistical summary of great disparities among institutions, rather than as a consistent national benchmark. The forest plot shows that individual confidence intervals do not tend to surround a common effect, and the wide random-effects interval reflects real variation across studies beyond sampling error.

Figure 2. Randomeffects forest plot of VAP prevalence in six Indian ICU cohorts.



Microbiological Profile:-
Most of the Microbiology was Gram negative. Acinetobacter species were mentioned most often. Mathai et al. reported that Acinetobacter accounted for over 50% of the isolates. The Punjab study mentioned that Acinetobacter was the first of the pathogens, followed by Pseudomonas and Klebsiella. Patil and Patil reported the presence of Klebsiella, Pseudomonas, Acinetobacter, and Staphylococcus Aureus. Kumar et al. described Acinetobacter Baumannii as the most prevalent isolate. The Southwestern cohort noted that the three most prevalent organisms were Acinetobacter, Klebsiella Pneumoniae, and Pseudomonas Aeruginosa.

The same trends are being seen in current surveillance studies. The Indian Council of Medical Research's antimicrobial resistance surveillance network reported 328 cases of VAP in 2024, with an average of 7.17 cases per 1,000 Ventilator days, in the hospitals that participated in the surveillance. Of the 499 organisms captured, Acinetobacter accounted for 43.8% of the isolates. Since the surveillance and study hospitals included in the networks are different from the individual cohort studies, the data produced by the network should not be included in the meta-analysis; however, they provide important national-level data.

Resistance:-
Mathai et al found that, with increasing onset of infection, isolates of VAP expressed a high level of Multidrug Resistance. Patil and Patil noted the presence of 55 Multidrug Resistant Isolates out of 126 bacterial isolates. In the study conducted in Punjab, Multidrug Resistance was found among isolates of Acinetobacter with a higher resistance to Cephalosporin and Ciprofloxacin with a greater tendency to fall under the group of Tigecycline and Polymyxin B. Rekha et al found a high level of Multidrug Resistance among isolates of Acinetobacter. These given studies warrant the use of local antibiograms, as therapy should be based on local resistance.

Risk Factors:-
While there were differences in some of the risk factors among the different studies, there were a few common themes. Masih et al named impaired consciousness and emergency Intubation and Tracheostomy as independent risk factors, and there were associations found with Reintubation and use of Nasogastric tubes. The Southwestern cohort named temporary organ failure and emergency Intubation and Reintubation and COPD as important factors. Gore et al named COPD and Diabetes as important factors. Mathai et al stated that men were at increased risk for development of VAP and that more severe cases resulted in worse outcomes. Most of the studies named patient related vulnerability and certain procedures as risk factors.

The risk of repeated airway manipulations is justified as there is a compromise of defensive airway function during the Reintubation process and a potential for an increase in the risk of Aspiration. Emergency Intubation may be required in a critically unstable and infected patient. Although a Tracheostomy denotes a prolonged and serious state of illness, so does Chronic Uncontrolled Inflammatory Lung Disease which may negatively impact the patient's Respiratory function. Failure of one or more vital organs, especially in patients exhibiting an elevated severity score, impacts the patient's reserve capacity. These factors should be evaluated as critical care risk factors, but should not be construed to be fully causative in all cases.

Mortality and Clinical Outcomes:-
It is well documented that VAP prolongs the length of ICU and Hospital stays. Mathai et al. reported significantly increased costs due to prolonged Hospitalization. Patil and Patil reported VAP had a case fatality rate of 29.7%, while Kumar et al. stated the rate of VAP related deaths was 36.7%. Gore et al reported a mortality rate of 55% for those diagnosed with VAP and 34% for those without. In the Southwestern cohort, the mortality rate for those in the VAP group was 31.3%, while for those without VAP it was 15.7%. Mathai et al. reported a similar finding in terms of overall mortality, but older patients and patients with a higher APACHE II score suffered the most adverse outcomes.

These results describe the challenges of estimating attributable mortality in observational studies. Patients with VAP are sicker and undergo more intensive treatment and prolonged periods of Mechanical Ventilation relative to patients who do not develop VAP. In the absence of Time-Dependent Adjustments and tools to control for competing risks, unadjusted comparisons of mortality can overestimate or underestimate the infection's direct effect.

Prevention and Infection Control:-
Preventive strategies are preferable to the total elimination of diagnostic doubt. They include reduction of Non-Therapeutic Ventilation, assessment of Extubation readiness and of Positional Support and Oral care, as well as

administration of Hand Hygiene, management of Aseptic Airway, and management of Subglottic secretions along with reduction of circuit changes and compliance with Antibiotic bundle. Evidence from a 2017 Intensive Care Infection Surgery Training Program has assessed the influence of Intensive Nursing Education on the prevention of Device-Associated Infections and has substantiated the focus on the deployment of strategies as opposed to detail in policies.

Discussion:-

The main focus of this research is to document the burden of VAP in ICUs across India and to provide an estimate of the burden. We present a random effects pooled prevalence of 1 VAP case for every 5 intubated patients as the first of its kind from India and related literature. The I^2 value, representing burden of heterogeneity, stands at 97.7% and indicates that most of the observed burden is due to context. In VAP, heterogeneity exists in the definitions of VAP, Patient Severity, ICU Specialization, Resource Availability, Staffing, Prevention Strategies, and Antibiotic exposure.

Microbiologic synthesis is more consistent in the diversity of studies compared to prevalence estimations. There is an evident large and Multidrug Resistant burden of Acinetobacter, Klebsiella and Pseudomonas. This burden carries a heavy consequence. The broad-spectrum therapy of the resistance burden is counterproductive; however, the severity of VAP mandates that effective therapy be given in a timely manner. Each individual ICU presents a situation where the prompt Respiratory Sampling, Review of Stewardship, Local Resistance Surveillance, and De-Escalation of Therapy should be undertaken in the light of the culture and clinical data suggesting the therapy should be de-escalated.

The data support that focuses on modifiable risk factors is justified. There are high risk factors that include Reintubation, Emergency Airway Interventions and prolonged time on the Ventilator. The use of prevention bundles should be assessed since although integrated systems may account for significant changes at the unit level, prevention bundles spanning multiple steps in isolation often will not.This review is limited in its analysis because of the constraints of available data. Many of the publications from 2015 to 2025 included cohorts recruited prior to 2015. Therefore, the pooled prevalence is not an accurate reflection of the current or recent practices in 2025. Most of the studies in this review were single center. Definitions differed in the CDC criteria, the Clinical Pulmonary Infection Score, and local definitions. Some studies reported Prevalence, some reported Incidence Density, and not all studies reported Ventilation days. It may be that there is publication bias, since some units that had high infection rates or a unique microbiology may be likely to publish.

The meta-analysis included only six prevalence cohorts and should not be used to rank hospitals.The ICMR surveillance network offers a greater potential for more standardized national inference. In 2024, ICMR reported a Ventilator-Associated Pneumonia rate of 7.17 cases per 1,000 Ventilator days, which is lower than many previously reported single center studies. Because many of the studies have different prevention focuses, comparisons will not be useful. Comparisons of studies with similar surfaces with surveillance foci should be made, rather than previous incomparable studies.

Future research should include the Standardization and Harmonization of definitions, inclusion of Explicit Ventilator-Days in denominators, reporting of risk-adjusted outcomes, and use of established definitions of Antimicrobial Resistance for the multicenter, prospective, surveillance studies of VAP. Research should also report on both early- and late-onset VAP. Exposure to prior antibiotics should also be reported. Adherence to the bundles should also be studied, as should the time-to-event analysis. More research is needed to address the gaps in Diagnostic and Therapeutic Stewardship Interventions. This may include rapid diagnostics and nursing staffing/education. More research may help to address the use of Rapid Diagnostics and Therapeutic Stewardship.

There is currently no definitive diagnostic test for VAP. These gaps have led to the creation of dozens of suboptimal assessment methods. These may include Fever and Leukocytosis. Changes to other diagnostic methods by different centers may also occur. These inter-center differences may be attributed more to case definitions than actual differences. Indian surveillance studies that aim to standardize Diagnostic Algorithms, reporting cultures, and/or blinding clinicians to culture results when assessing VAP will improve case definitions and help better compare surveillance studies.

Risk-adjusted benchmarking is preferred to crude comparison. For example, an ICU that manages cases of Trauma, Emergency Neurology, or other cases of Emergency, might have (VAP) Ventilator Associated Pneumonia different

from an ICU managing postoperative patients of lower clinical risk. In benchmarking studies this should be considered and other factors will impact this such as case-mix severity, the level of Ventilator use, Emergency Intubations, Reintubations, and the duration of time the patient has been ventilated. When discussing Infection Control and the Incidence of Infections, the Incidence Density (number of infections per 1,000 ventilator days) is a more appropriate metric than the Prevalence (number of infections per days a patient is on the ventilator), as the former measure adjusts for the exposure time but does not account for the complexity of the patient. For Infection Control, both measures along with their confidence intervals would be useful to clinicians.

Analogous to the description of Mortality, interpretation of the adverse outcomes would suggest that VAP could exacerbate the underlying Respiratory Failure, increase the Inflammatory response, prolong the need for Mechanical Ventilation, and perhaps Nephrotoxic and Non-nephrotoxic regimens of Antibiotics. However, with VAP, it could certainly be the case that patients are requiring prolonged Mechanical Ventilation and support. Adjustment for time-dependent effects should be included in future studies, as well as distinguishing deaths that are infection related from all cause deaths. Measures of ventilator free days, ICU free days and outcomes such as destination upon discharge, and recurrent infection episodes should be included as outcome measures.

A national reporting minimum dataset would enhance comparability. Documentation of the minimum number of patients requiring Mechanical Ventilation, the total number of days while on Mechanical Ventilation, total number of VAP cases, number of first VAP cases and number of subsequent VAP cases, the definition of VAP case, type of Specimen, Pathogen distribution, Antimicrobial susceptibility of Pathogens, prior exposure to Antibiotics, duration of Mechanical Ventilation, duration of stay in the ICU, and outcome of the patient would help define the extent and severity of the problem in the various parts of the country. Reporting the denominators would prevent the confusion between the Patient-Level Prevalence and the Event-Based Incidence Density. Standardized reports would be very useful in performing Meta-regression across Geography, ICU type, Diagnostic method, and duration of the studyacross the Indian system.

Conclusion:-

VAP is a major healthcare associated Infection in Indian ICUs. Based on 6 cohort studies reporting prevalence, using random-effects synthesis, VAP was reported in 20.1% of mechanically ventilated patients, while the extremely high Heterogeneity means this prevalence should not be used for regional surveillance. In these studies, Gram negative organisms, especially Acinetobacter, Klebsiella, and Pseudomonas, were noted and were highly resistant to multiple antibiotics. Previous Tracheal Reintubation, Emergency Tracheal Intubation, ICU stay, Organ Failure, Chronic Pulmonary Disease, and prolonged Ventilation were some of the risk factors. VAP prolongs ICU and hospital length of stay, increases mortality, and increases cost. Standardized surveillance, prevention bundle, decreased length of avoidable ventilation, decreased Airway manipulations, and increased Infection control, Microbiology, local Antibiograms, and Antimicrobial Stewardship are the most important next steps. Defining the contemporary burden of VAP in India requires high quality, multicenter, prospective studies.

Evidence Tables:-

Table 1. Characteristics and VAP burden in Cohorts contributing to the Prevalence Meta-analysis.

Study	Setting/Region	VAP cases / Ventilated	Prevalence	Incidence Density (per 1,000 ventilator-days)
Gore et al., 2015	Indian tertiary ICU	36/240	15.0%	Not consistently reported
Gupta et al., 2015	Punjab tertiary ICU	47/979	4.8%	11.03
Mathai et al., 2016	Northern India tertiary ICU	95/250	38.0%	40.1
Patil & Patil, 2017	Tertiary-care hospital	74/267	27.7%	39.59
Kumar et al., 2020	Tertiary-care ICU	49/117	41.9%	Not used because report wording is inconsistent
Rekha et al., 2024	Tertiary-care adult ICU	43/300	14.3%	Not consistently reported

Table 2. Selected Microbiological, Risk-factor, and Outcome Findings

Source	Key Finding
Mathai et al., 2016	Acinetobacter accounted for about half of reported VAP isolates; multidrug resistance was common.
Patil & Patil, 2017	Gram-negative organisms predominated; multidrug resistance was frequent among isolates.
Masih et al., 2016	Impaired consciousness, emergency intubation, and tracheostomy were important risk factors.
Rao et al., 2021	Organ failure, emergency intubation, reintubation, and COPD were associated with VAP.
Sangale et al., 2021	In a cancer ICU, Gram-negative isolates dominated and multidrug resistance was very high.
ICMR AMR Surveillance Report 2024	National surveillance documented substantial VAP incidence-density and dominance of resistant Gram-negative pathogens.

Table 3. Meta-analysis Summary

Measure	Result
Cohorts	6
VAP cases / ventilated patients	344 / 2,153
Random-effects pooled prevalence	20.1%
95% confidence interval	10.0%–36.1%
Cochran Q	213.08
I^2	97.7%
τ^2 (logit scale)	1.001

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