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High Mortality and Pathogen Burden of Ventilator-Associated Pneumonia in Al Jouf, Saudi Arabia: A Retrospective ICU Study

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Abstract

Ventilator-associated pneumonia (VAP) remains a critical challenge in intensive care units (ICUs), particularly in settings with limited infection control infrastructure. While global data exist, there is a striking lack of contemporary evidence from northern regions of Saudi Arabia, where healthcare delivery and microbial resistance patterns may differ significantly from metropolitan centers.

Objective:

To assess the incidence, microbiological profile, and outcome predictors of VAP in a resource-limited ICU in Al Jouf, Saudi Arabia—an underreported region in current literature.

Methods:

This retrospective observational study included adult ICU patients diagnosed with VAP between January 2021 and December 2023 at Prince Mutaib Bin Abdulaziz Hospital. Demographic, clinical, and microbiological data were collected. Multivariable logistic regression was used to identify independent predictors of ICU mortality.

Results:

Of 270 ICU patients, 70 (26%) developed VAP. The most common pathogens were *Acinetobacter baumannii* (37.1%) and *Klebsiella pneumoniae* (21.4%). ICU mortality was 74.3%, with age ≥65 years (OR 3.47) and female sex (OR 8.00) independently associated with death. MDR organisms were identified even in early-onset VAP, challenging traditional classifications.

Conclusion:

This study highlights the high burden of VAP and associated mortality in a northern Saudi ICU, where antimicrobial resistance patterns and resource constraints amplify the clinical risk. The findings call for region-specific infection control strategies and stewardship programs tailored to non-tertiary healthcare settings..

Introduction

Patients in Intensive Care Units (ICUs) are particularly vulnerable to nosocomial infections due to a multifactorial interplay of pathogen-related factors—such as virulence and antimicrobial resistance—host-related conditions including chronic comorbidities, and treatment-related exposures such as invasive procedures, immunosuppressive therapy, and antibiotic pressure. Among these infections, **ventilator-associated pneumonia (VAP)** is one of the most frequent and severe, affecting 9% to 27% of mechanically ventilated patients, particularly during the early phase of ventilation [2,3]. VAP accounts for up to 86% of all ICU-acquired pneumonias and is associated with substantial morbidity, mortality, and healthcare costs [1,4].

In Saudi Arabia, surveillance data report a national VAP incidence of 2.97 per 1,000 ventilator-days in Ministry of Health facilities [4]. In the United States, the financial burden of VAP is estimated at $1.45 billion annually [6]. Mortality associated with VAP ranges from 33% to 50%, depending on host factors, pathogen resistance, and timing of infection onset [5,8,31].

The microbial landscape of VAP is predominantly composed of Gram-negative bacilli, especially members of the Enterobacteriaceae family. Of increasing concern are multidrug-resistant (MDR) organisms such as *Acinetobacter baumannii* and *Klebsiella pneumoniae*, which significantly complicate management—particularly in settings with limited diagnostic support and the

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absence of structured antimicrobial stewardship programs [5,7,19–21].

While numerous studies have explored VAP epidemiology and outcomes in Saudi Arabia, most are based in tertiary care centers located in Riyadh, Jeddah, and other major cities [10,20]. Very limited data exist for secondary hospitals in northern regions such as Al Jouf, which differ in patient demographics, ICU staffing, antimicrobial practices, and resource availability. This lack of geographic representation poses a challenge to national infection control policies and may mask local risk profiles.

To address this gap, the present study aimed to assess the epidemiological characteristics, microbiological profiles, and clinical outcomes of patients diagnosed with VAP in the adult ICU of Prince Mutaib Bin Abdulaziz Hospital in Sakaka, Al Jouf. The study also sought to:

- Determine the incidence of VAP among mechanically ventilated ICU patients,
- Identify the predominant pathogens responsible for VAP in this setting, and
- Analyze clinical outcomes, particularly factors associated with ICU mortality.

Methodology:

This retrospective cross-sectional observational study was conducted in the adult Intensive Care Unit (ICU) of Prince Mutaib Bin Abdulaziz Hospital, a secondary-level healthcare facility in Sakaka, Al Jouf, Saudi Arabia. The study included all eligible adult ICU patients diagnosed with ventilator-associated pneumonia (VAP) between January 1, 2021, and December 31, 2023.

Data were retrieved from the hospital's electronic medical records using a standardized data collection form. Variables included patient demographics, comorbidities, timing of VAP onset (early vs. late), microbiological findings, relevant laboratory parameters, and clinical outcomes. In cases where patients experienced multiple VAP episodes, only the first episode was included to avoid duplication.

VAP was defined as a new or progressive pulmonary infiltrate visible on chest radiography, occurring ≥48 hours after endotracheal intubation, in combination with at least two of the following: fever (>38°C), leukocytosis or leukopenia, and purulent or malodorous tracheal secretions. VAP diagnosed within seven days of intubation was classified as early-onset, while cases arising thereafter were defined as late-onset.

Inclusion criteria were adult patients (≥18 years) admitted to the ICU who met the diagnostic criteria for VAP. Patients were excluded if they were under 18 years of age, referred from another facility with a pre-existing VAP diagnosis, or had respiratory cultures yielding only *Candida* species, normal flora, or no growth.

Descriptive statistics were used to summarize the data. Categorical variables were reported as frequencies and percentages, while continuous variables were presented as medians with interquartile ranges (IQRs). Associations between variables and ICU mortality were assessed using binary logistic regression. A P-value <0.05 was considered statistically significant. Data analysis was performed using SPSS version 29 (IBM Corp., Armonk, NY, USA).

This study was reviewed and approved by the Research Ethics Committee of the Al Jouf Health Cluster, Sakaka, Saudi Arabia (Approval No. 2024-94). Patient data were anonymized to ensure confidentiality.

Results:

During the study period, 270 adult patients were admitted to the ICU, of whom 70 (25.9%) developed ventilator-associated pneumonia (VAP). The median age of affected patients was 69 years (interquartile range [IQR]: 47.3–82.5), with a male-to-female ratio of approximately 1.6:1. More than half (55.7%) of the VAP cases occurred in patients aged 65 years or older. The median ICU stay prior to VAP diagnosis was 11 days (IQR: 5–28.5), with a post-diagnosis median stay of 8.5 days (IQR: 2.8–24.3).

Comorbidities were present in 42.9% of patients, most commonly stroke (21.4%), diabetes mellitus (18.6%), and systemic hypertension (17.1%). Less frequent conditions included chronic obstructive pulmonary disease (4.3%), asthma (2.9%), chronic liver disease (1.4%), and chronic kidney disease (1.4%). Although 60% of patients with comorbidities were aged 65 years or older, the association between age and comorbidity was not statistically significant (P = 0.53). The distribution of comorbidities is shown in Figure 1.

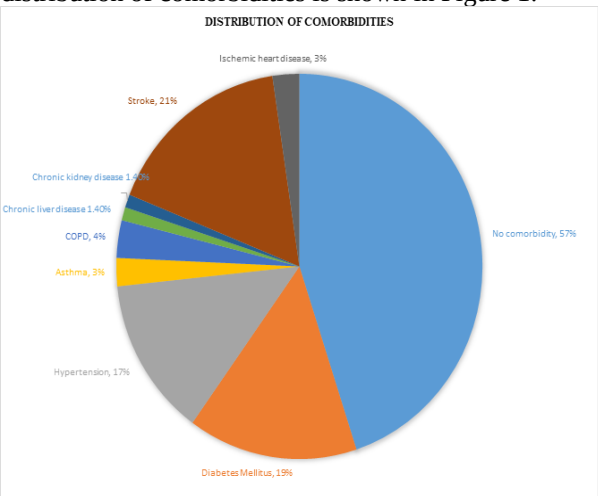

Figure 1. Distribution of comorbidities among VAP patients.

All patients exhibited new or progressive pulmonary infiltrates on chest radiography. Leukocytosis was observed in 65.7% of cases, while fever was documented in only 24.3%. Laboratory findings included elevated international normalized ratio (INR) in 47.1% and thrombocytopenia in 40.0% of patients.

Microbiological analysis identified *Acinetobacter baumannii* as the most frequently isolated pathogen (37.1%), followed by *Klebsiella pneumoniae* (21.4%). Other pathogens included *Proteus mirabilis*, *Pseudomonas aeruginosa*, *Providencia stuartii*, *Escherichia coli*, *Proteus vulgaris*, and *Enterococcus faecalis*. Notably, *E. coli*, *E. faecalis*, *P. vulgaris*, and *P. stuartii* were exclusively isolated in late-onset VAP.

Although greater pathogen diversity was observed in late-onset cases, the distribution difference was not statistically significant (P = 0.10). Figure 2 displays the distribution of pathogens by VAP onset.

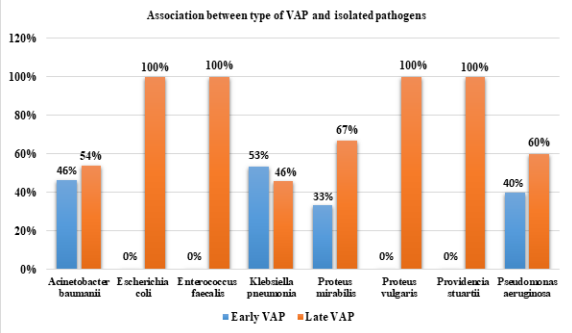

Figure 2. Pathogen distribution by VAP type. Late-onset VAP showed greater diversity, with *E. coli*, *E. faecalis*, *P. vulgaris*, and *P. stuartii* isolated exclusively in this group. *A. baumannii* and *P. aeruginosa* were more frequent in late VAP.

The overall ICU mortality rate among VAP patients was 74.3% (52/70), with 82.7% of deaths occurring within 30 days of diagnosis. The median time to death was 8.5 days (IQR: 2.0–24.8). Mortality was slightly higher in late-onset VAP (76.7%) compared to early-onset VAP (70.4%), but this was not statistically significant (P = 0.70). Mortality varied by pathogen: E. coli, E. faecalis, and P. stuartii were associated with 100% mortality; P. mirabilis and P. aeruginosa showed lower mortality rates of 33% and 50%, respectively; while A. baumannii and K. pneumoniae showed high mortality at 77% and 80%, respectively. No deaths occurred in patients with P. vulgaris infection (Figure 3).

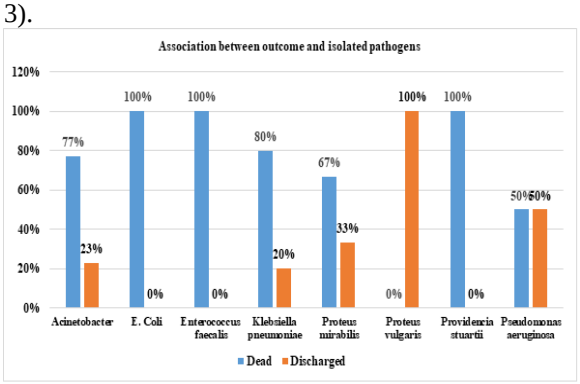

Figure 3: Association between isolated pathogens and patient outcomes. *E. coli*, *E. faecalis*, and *P. stuartii* were associated with 100% mortality. *K. pneumoniae* and *A. baumannii* also showed high mortality rates. In contrast, *P. aeruginosa* and *P. mirabilis* had better survival profiles.

Multivariable logistic regression identified age ≥65 years (OR 3.47; 95% CI: 1.12–10.76; P = 0.03) and female sex (OR 8.00; 95% CI: 1.67–38.34; P < 0.001) as independent predictors of mortality. Elevated INR showed a marginal association with mortality (OR 3.03; 95% CI: 0.94–9.74; P = 0.052). Other variables, including leukocytosis, thrombocytopenia, fever, comorbidity status, and timing of VAP onset, were not statistically significant. Complete statistical analyses are detailed in Table 1 (univariate analysis), Table 2 (mortality by ICU stay and pathogen), and Table 3 (multivariable regression).

Table 1: Association between 30-day ICU mortality and clinical variables in patients with ventilator-associated pneumonia. Mortality was significantly associated with age ≥65 years, female sex, diabetes mellitus, thrombocytopenia, and coagulopathy (elevated INR). No significant associations were found with comorbidity status, VAP onset timing, or fever presence.

	30-days outcome			
Variables	**Dead**	**Discharged**	**Total**	**P value**
Age group				
< 65	15 (60.0%)	10 (40.0%)	25 (100%)	*0.02
≥ 65	28 (87.5%)	4 (12.5%)	32 (100%)	
Total	43 (75.4%)	14 (24.6%)	57 (100%)	
Sex				
Male	21 (60.0%)	14 (40.0%)	35 (100%)	*< 0.001
Female	22 (100%)	0 (0.0%)	22 (100%)	
Total	43 (75.4%)	14 (24.6%)	57 (100%)	
Diabetes mellitus				
Yes	12 (100%)	0 (0.0%)	12 (100%)	
No	31 (68.9%)	14 (31.1%)	45 (100%)	*0.03
Total	43 (75.4%)	14 (24.6%)	57 (100%)	
COPD				
Yes	3 (100%)	0 (0.0%)	3 (100%)	
No	40 (74.1%)	14 (25.9%)	54 (100%)	0.31
Total	43 (75.4%)	14 (24.6%)	57 (100%)	
Asthma				
Yes	1 (50.0%)	1 (50.0%)	2 (100%)	
No	42 (76.4%)	13 (23.6%)	55 (100%)	0.39
Total	43 (75.4%)	14 (24.6%)	57 (100%)	
Stroke				
Yes	10 (76.9%)	3 (23.1%)	13 (100%)	
No	33 (75.0%)	11 (75.0%)	44 (100%)	0.89
Total	43 (75.4%)	14 (24.6%)	57 (100%)	
Systemic hypertension				
Yes	10 (90.9%)	1 (9.1%)	11 (100%)	
No	33 (71.7%)	13 (28.3%)	46 (100%)	0.18
Total	43 (75.4%)	14 (24.6%)	57 (100%)	
Chronic kidney disease				
Yes	1 (100%)	0 (0.0%)	1 (100%)	
No	42 (75.0%)	14 (25.0%)	56 (100%)	0.56
Total	43 (75.4%)	14 (24.6%)	57 (100%)	
Chronic liver disease				
Yes	1 (100%)	0 (0.0%)	1 (100%)	
No	42 (75.0%)	14 (25.0%)	56 (100%)	0.56
Total	43 (75.4%)	14 (24.6%)	57 (100%)	
Comorbidity				
Yes	24 (85.7%)	4 (14.3%)	28 (100%)	
No	19 (65.5%)	10 (34.5%)	29 (100%)	0.07
Total	43 (75.4%)	14 (24.6%)	57 (100%)	
Time of diagnosis of VAP				
Early VAP	13 (72.2%)	5 (27.8%)	18 (100%)	
Late VAP	30 (76.9%)	9 (23.1%)	39 (100%)	0.70
Total	43 (75.4%)	14 (24.6%)	57 (100%)	
Fever				
Afebrile	33 (75.0%)	11 (25.0%)	44 (100%)	0.89
Febrile	10 (76.9%)	3 (23.1%)	13 (100%)	
Total	43 (75.4%)	14 (24.6%)	57 (100%)	
WBC				
Leucopenia	3 (100%)	0 (0.0%)	3 (100%)	
Normal	15 (93.8%)	1 (6.3%)	16 (100%)	0.06
Leucocytosis	25 (65.8%)	13 (34.2%)	38 (100%)	
Total	43 (75.4%)	14 (24.6%)	57 (100%)	
Platelets				
Thrombocytopenia	22 (88.0%)	3 (12.0%)	25 (100%)	*0.05
Normal	20 (69.0%)	9 (31.0%)	29 (100%)	
Thrombocytosis	1 (33.3%)	2 (66.7%)	3 (100%)	
Total	43 (75.4%)	14 (24.6%)	57 (100%)	

INR				
Normal	18 (64.3%)	10 (35.7%)	28 (100%)	*0.05
Coagulopathy	25 (86.2%)	4 (13.8%)	29 (100%)	
Total	43 (75.4%)	14 (24.6%)	57 (100%)	

Table 2: Association between length of ICU stay before death, isolated pathogens, type of VAP

	Duration of ICU stays before death			
Isolated pathogen	**30 days and below**	**More than 30 days**	**Total**	**P value**
Acinetobacter baumanii	19 (95.0%)	1 (5.0%)	20 (100%)	0.12
Escherichia coli	1 (33.3%)	2 (66.7%)	3 (100%)	
Enterococcus faecalis	1 (100%)	0 (0.0%)	1 (100%)	
Klebsiella pneumoniae	9 (75.0%)	3 (25.0%)	11 (100%)	
Proteus mirabilis	4 (66.7%)	2 (33.3%)	6 (100%)	
Providencia stuartii	5 (100%)	0 (0.0%)	5 (100%)	
Pseudomonas aeruginosa	4 (80.0%)	1 (20.0%)	5 (100%)	
Total	43 (82.7%)	9 (17.3%)	52 (100%)	
Type of VAP				
Early VAP	15 (78.9%)	4 (21.1%)	19 (100%)	0.59
Late VAP	28 (84.8%)	5 (15.2%)	33 (100%)	
Total	43 (82.7%)	9 (17.3%)	52 (100%)	

Table 3: Odds ratio and confidence intervals for variables associated with mortality

				(95% CI)	
Variables	**Subtypes**	**P value**	**Odds ratio**	**Lower**	**Upper**
Age (years)	Less than 65 years 65 years and above	*0.03	3.47	1.12	10.76
WBC count	Normal Leukocytopenia Leucocytosis	0.31	2.90	0.74	11.41
INR	No coagulopathy Coagulopathy	0.052	3.03	0.94	9.74
Temperature	Afebrile Febrile	0.29	0.54	0.16	1.75
Comorbidity	No Yes	0.13	2.41	0.75	7.73
Platelets count	Normal Thrombocytosis Thrombocytopenia	0.18	1.49	0.82	2.71
Sex	Male Female	*< 0.001	8.00	1.67	38.34
Type of VAP	Early VAP Late VAP	0.55	1.39	0.47	4.12
Length of ICU stay	30 days and below More than 30 days	0.64	0.73	0.19	
Temperature	Afebrile febrile	0.29	0.54	0.16	1.75
Stroke	No Yes	0.92	0.94	0.26	3.43
Diabetes mellitus	No Yes	0.09	5.10	0.61	42.38
Hypertension	No Yes	0.43	1.90	0.37	9.66
Ischaemic heart disease	No Yes	0.42	0.33	0.02	5.62
COPD	No Yes	0.29	0.73	0.63	0.85

Discussion:

This study provides a comprehensive characterization of the epidemiological patterns, microbial profiles, and clinical outcomes of ventilator-associated pneumonia (VAP) in a secondary hospital ICU in the Al Jouf region of Saudi Arabia—a

medically underserved setting with limited prior research. The observed VAP prevalence of 26% aligns with previous findings from Saudi tertiary hospitals, where rates of 15.4% to 35.4% have been reported [1,10].

A multi-country ICU surveillance study conducted between 2008 and 2013 in Gulf nations, including Saudi Arabia, revealed VAP rates exceeding those reported in U.S. hospitals participating in the National Health Safety Network (NHSN) [9]. This disparity underscores the need for enhanced infection control efforts and consistent implementation of prevention bundles across Gulf healthcare systems.

Male patients comprised the majority of VAP cases, consistent with prior literature [3,11–13]. Although the reasons are unclear, Dananché et al. identified male sex as a nonmodifiable VAP risk factor across age groups [14]. In contrast to reports suggesting lower VAP incidence in older adults [14,18], our findings showed that patients aged 65 years and above represented the largest affected group and experienced the highest mortality. This aligns with studies attributing poorer outcomes in the elderly to immunosenescence and a higher burden of comorbidities [5,7,18,39].

Interestingly, despite their lower incidence, female patients exhibited significantly higher mortality—an observation supported by prior studies and potentially attributable to sex-specific immune or treatment response differences [11,13,39]. Stroke and diabetes mellitus were the most common comorbidities; however, they were not significantly associated with mortality in this cohort, possibly due to sample size constraints.

Acinetobacter baumannii emerged as the most frequent pathogen, especially in late-onset VAP—mirroring findings from ICUs in Hail, Qassim, and Riyadh [20,24,25]. A global review identified the Middle East as having the highest rates of *Acinetobacter*-associated VAP [22]. Similarly, studies conducted across Gulf Cooperation Council (GCC) countries—including Saudi Arabia, the United Arab Emirates, and Kuwait—have consistently reported *A. baumannii* as a dominant VAP pathogen in ICU settings [23].

Unlike reports from other regions, our cohort showed no Gram-positive organisms. This may reflect local differences in ICU flora, antibiotic practices, or diagnostic protocols [26,27]. Both early- and late-onset groups exhibited multidrug-resistant (MDR) and extensively drug-resistant pathogens, including carbapenem-resistant strains. Though MDR has traditionally been linked to late-onset VAP [28,29], recent findings—including ours—suggest increasing MDR presence in early-onset cases [30]. Notably, resistance patterns did not significantly predict mortality, reinforcing that host-related factors may outweigh microbial characteristics in clinical outcomes [31–33].

Mortality did not differ significantly between early- and late-onset VAP in our study, consistent with findings by Giantsou et al., Ibrahim et al., and Hedrick et al. [32–34]. However, other studies have reported higher late-onset mortality, attributing this to diagnostic delays, longer ICU stays, and fewer tracheostomies [27,35,36].

Although elevated INR and thrombocytopenia were common, neither showed a statistically significant association with mortality. Previous research has pointed to other markers—such as hypoalbuminemia, lymphopenia, and elevated C-reactive protein—as stronger mortality predictors [37,38], suggesting the need for broader biomarker profiling in future research.

Overall, our findings reinforce the complex, multifactorial nature of VAP. They highlight the importance of strengthening infection prevention, improving regional microbial surveillance, and implementing antimicrobial stewardship, especially in resource-limited ICUs. The combination of a high MDR burden and elevated mortality among older and female patients underscores the urgency of targeted clinical interventions.

Conclusion:

This study presents novel epidemiological insight into ventilator-associated pneumonia (VAP) in the Al Jouf region of Saudi Arabia, where data have been historically limited. Rather than pathogen type or onset timing, host-related factors—particularly advanced age and female sex—were significantly associated with mortality. These findings highlight the need for individualized risk assessment and region-specific clinical protocols. Future research should focus on strengthening surveillance and evaluating interventions aimed at reducing mortality in high-risk subgroups.

Limitations

The retrospective design and single-center scope limit the generalizability of the findings. Additionally, missing data on illness severity and resistance patterns restricted deeper analysis. Nonetheless, this study contributes foundational data for a region with limited ICU-focused infection research and underscores the urgency for broader multicenter studies in similar settings.

Reference:

1. Abdelrazik Othman, A. & Salah Abdelazim, M. Ventilator-associated pneumonia in adult intensive care unit prevalence and complications. The Egyptian Journal of Critical Care Medicine 5, 61–63 (2017).

2. Dasgupta, S., Das, S., Chawan, N. S. & Hazra, A. Nosocomial infections in the intensive care unit: Incidence, risk factors, outcome and associated pathogens in a public tertiary teaching hospital of Eastern India. Indian J Crit Care Med 19, 14–20 (2015).
3. Luo, W., Xing, R. & Wang, C. The effect of ventilator-associated pneumonia on the prognosis of intensive care unit patients within 90 days and 180 days. BMC Infect Dis 21, 1–7 (2021).
4. Humayun, T. et al. Rates of Ventilator Associated Pneumonia in Saudi Ministry of Health Hospitals; A Two-year Multi-Center Study. American Journal of Infectious Diseases and Microbiology, Vol. 9, 2021, Pages 25-31 9, 25–31 (2021).
5. He, Q. et al. The epidemiology and clinical outcomes of ventilator-associated events among 20,769 mechanically ventilated patients at intensive care units: an observational study. Crit Care 25, (2021).
6. Ladbrook, E., Khaw, D., Bouchoucha, S. & Hutchinson, A. A systematic scoping review of the cost-impact of ventilator-associated pneumonia (VAP) intervention bundles in intensive care. Am J Infect Control 49, 928–936 (2021).
7. Kang, Y. et al. Clinical outcomes and risk factors for mortality from ventilator-associated events: A registry-based cohort study among 30,830 intensive care unit patients. Infect Control Hosp Epidemiol 43, 48–55 (2022).
8. Kalanuria, A. A., Zai, W. & Mirski, M. Ventilator-associated pneumonia in the ICU. Crit Care 18, 1–8 (2014).
9. El-Saed, A. et al. Ventilator-associated pneumonia rates in critical care units in 3 Arabian Gulf countries: A 6-year surveillance study. Am J Infect Control 44, 794–798 (2016).
10. Al-Dorzi, H. M. et al. The results of a 6-year epidemiologic surveillance for ventilator-associated pneumonia at a tertiary care intensive care unit in Saudi Arabia. Am J Infect Control 40, 794–799 (2012).
11. Sharpe, J. P. et al. Gender disparity in ventilator-associated pneumonia following trauma: Identifying risk factors for mortality. Journal of Trauma and Acute Care Surgery 77, 161–165 (2014).
12. Mumtaz, H. et al. Ventilator associated pneumonia in intensive care unit patients: a systematic review. Annals of Medicine & Surgery 85, 2932–2939 (2023).
13. López-de-Andrés, A. et al. Gender differences in incidence and in-hospital outcomes of community-acquired, ventilator-associated and nonventilator hospital-acquired pneumonia in Spain. Int J Clin Pract 75, e13762 (2021).
14. Dananché, C. et al. Trends of Incidence and Risk Factors of Ventilator-Associated Pneumonia in Elderly Patients Admitted to French ICUs Between 2007 and 2014. Crit Care Med 46, 869–877 (2018).
15. Jiménez-Trujillo, I. 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 40, 72–78 (2017).
16. Kasuya, Y. et al. Ventilator-associated pneumonia in critically ill stroke patients: Frequency, risk factors, and outcomes. J Crit Care 26, 273–279 (2011).
17. Kózka, M., Sega, A., Wojnar-Gruszka, K., Tarnawska, A. & Gniadek, A. Risk Factors of Pneumonia Associated with Mechanical Ventilation. International Journal of Environmental Research and Public Health 2020, Vol. 17, Page 656 17, 656 (2020).
18. Blot, S. et al. Prevalence, risk factors, and mortality for ventilator-Associated pneumonia in middle-Aged, Old, and very old critically ill patients. Crit Care Med 42, 601–609 (2014).
19. Patel, R. V., Shah, J. S., Revathi, G., Siika, W. & Shah, R. Acinetobacter infections: a retrospective study to determine inhospital mortality rate and clinical factors associated with mortality. Infection Prevention in Practice 1, 100010 (2019).
20. Saleem, M. et al. Pathogen Burden Among ICU Patients in a Tertiary Care Hospital in Hail Saudi Arabia with Particular Reference to β-Lactamases Profile. Infect Drug Resist 16, 769–778 (2023).
21. Sci-Hub | Drug-resistant ventilator associated pneumonia in a tertiary care hospital in Saudi Arabia. Annals of Thoracic Medicine, 9(2), 104 | 10.4103/1817-1737.128858. https://sci-hub.se/10.4103/1817-1737.128858.
22. Hurley, J. C. World-wide variation in incidence of Acinetobacter associated ventilator associated pneumonia: A meta-regression. BMC Infect Dis 16, 1–12 (2016).
23. Abdalla, J. S. et al. Narrative Review of the Epidemiology of Hospital-Acquired Pneumonia and Ventilator-Associated Pneumonia in Gulf Cooperation Council Countries. Infect Dis Ther 12, 1741–1773 (2023).
24. Elbrolosy, A. M., Labeeb, A. Z. & Hassan, D. M. New Delhi metallo-β-lactamase-producing Acinetobacter isolates among late-onset VAP patients: multidrug-resistant pathogen and poor outcome. Infect Drug Resist 12, 373 (2019).
25. El-Saed, A. et al. Acinetobacter is the most common pathogen associated with late-onset and recurrent ventilator-associated pneumonia

in an adult intensive care unit in Saudi Arabia. Int J Infect Dis 17, (2013).
26. Hashmi, S. et al. Pathogenic and Non-Pathogenic Microbial Presence in Ventilator Associated Pneumonia Patients in Intensive Care Unit and Safety Protocols Under Surveillance of Healthcare Provider: A Research Study. Journal of Advanced Zoology 44, 939–946 (2023).
27. Khan, R. et al. The impact of onset time on the isolated pathogens and outcomes in ventilator associated pneumonia. J Infect Public Health 9, 161–171 (2016).
28. Golia, S., Sangeetha, K. T. & Vasudha, C. L. Microbial Profile of Early and Late Onset Ventilator Associated Pneumonia in The Intensive Care Unit of A Tertiary Care Hospital in Bangalore, India. J Clin Diagn Res 7, 2462 (2013).
29. Dey, A. & Bairy, I. Incidence of multidrug-resistant organisms causing ventilator-associated pneumonia in a tertiary care hospital: a nine months' prospective study. Ann Thorac Med 2, 52–57 (2007).
30. Arayasukawat, P. et al. Microorganisms and clinical outcomes of early- and late-onset ventilator-associated pneumonia at Srinagarind Hospital, a tertiary center in Northeastern Thailand. BMC Pulm Med 21, 1–8 (2021).
31. Sci-Hub | The impact of multidrug resistance on outcomes in ventilator-associated pneumonia. American Journal of Infection Control, 42(5), 542–545 | 10.1016/j.ajic.2013.12.009. https://sci-hub.st/https://doi.org/10.1016/j.ajic.2013.12.009.
32. Giantsou, E. et al. Both early-onset and late-onset ventilator-associated pneumonia are caused mainly by potentially multiresistant bacteria. Intensive Care Med 31, 1488–1494 (2005).
33. Ibrahim, E. H., Ward, S., Sherman, G. & Kollef, M. H. A Comparative Analysis of Patients With Early-Onset vs Late-Onset Nosocomial Pneumonia in the ICU Setting. Chest 117, 1434–1442 (2000).
34. Hedrick, T. L. et al. Differences in early- and late-onset ventilator-associated pneumonia between surgical and trauma patients in a combined surgical or trauma intensive care unit. Journal of Trauma - Injury, Infection and Critical Care 64, 714–720 (2008).
35. Vallés, J. et al. Excess ICU mortality attributable to ventilator-associated pneumonia: The role of early vs late onset. Intensive Care Med 33, 1363–1368 (2007).
36. Kollef, M. H., Silver, P., Murphy, D. M. & Trovillion, E. The effect of late-onset ventilator-associated pneumonia in determining patient mortality. Chest 108, 1655–1662 (1995).
37. Semet, C. The ongoing challenge of ventilator-associated pneumonia: epidemiology, prevention, and risk factors for mortality in a secondary care hospital intensive care unit. Infection Prevention in Practice 5, 100320 (2023).
38. Zhang, J., Zhao, Q., Liu, S., Yuan, N. & Hu, Z. Clinical predictive value of the CRP-albumin-lymphocyte index for prognosis of critically ill patients with sepsis in intensive care unit: a retrospective single-center observational study. Front Public Health 12, (2024).
39. Ali, H. S., Khan, F. Y., George, S., Shaikh, N. & Al-Ajmi, J. Epidemiology and Outcome of Ventilator-Associated Pneumonia in a Heterogeneous ICU Population in Qatar. Biomed Res Int 2016, (2016).