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Original Article

Burden and Outcomes of Bacterial and Fungal Infections in Mechanically Ventilated ICU Patients: A Prospective Cohort Study

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ABSTRACT

Background: Mechanical ventilation is a life-saving intervention in critically ill patients but is associated with an increased risk of bacterial and fungal respiratory infections, leading to significant morbidity and mortality. The present study aimed to determine the incidence of bacterial and fungal infections among mechanically ventilated ICU patients and assess the associated mortality.
Methods: This prospective observational study was conducted in the Medical Intensive Care Unit of Swaroop Rani Nehru Hospital, Prayagraj, India, from July 2020 to June 2021. A total of 100 adult patients receiving mechanical ventilation for more than 48 hours and suspected of ventilator-associated pneumonia were included. Endotracheal aspirate (ETA) samples were collected under aseptic precautions and processed for Gram staining, culture, and antimicrobial susceptibility testing. Clinical outcomes were recorded until discharge or death.
Results: ETA culture demonstrated microbial growth in 81% of patients. Bacterial infections accounted for 76% of cases, while fungal infections were observed in 5%; 19% of cultures showed no growth. Klebsiella spp. was the most common isolate (27%), followed by Staphylococcus spp. (19%), Escherichia coli (14%), and Pseudomonas spp. (14%). The overall mortality rate was 58%. Mortality was highest among patients infected with Escherichia coli and Proteus spp. (100% each), followed by Pseudomonas spp. (64.3%), Candida spp. (60.0%), and Klebsiella spp. (59.3%). A significant association was observed between microbial isolate and clinical outcome ($\chi^2 = 17.958$, $p = 0.002$).
Conclusion: Bacterial infections predominated among mechanically ventilated ICU patients, with gram-negative organisms being the most common pathogens. Microbial etiology was significantly associated with mortality, highlighting the importance of early microbiological diagnosis and targeted antimicrobial therapy to improve patient outcomes.

Keywords: Mechanical ventilation; Endotracheal aspirate culture; Ventilator-associated pneumonia; Bacterial infection; Mortality.

INTRODUCTION

For critically ill patients hospitalized to intensive care units (ICUs), mechanical ventilation is a crucial life-support strategy. However, prolonged mechanical ventilation and endotracheal intubation raise the risk of lower respiratory tract infections,

especially ventilator-associated pneumonia (VAP), which is still one of the most prevalent illnesses linked to healthcare in critically sick patients. Pneumonia that develops 48 hours or longer after endotracheal intubation and the start of mechanical breathing is commonly referred to as ventilator-associated pneumonia (VAP). Longer ICU stays, higher medical expenses, antibiotic resistance, and higher mortality are all linked to it.[1]

Ventilator-associated infections have a complex etiology that involves biofilm formation on endotracheal tubes, colonization of the aerodigestive tract, microaspiration of contaminated secretions, and compromised host defense mechanisms. These elements make it easier for harmful microbes to enter and multiply in the lower respiratory tract, which leads to illness. Due to underlying illness, immunosuppression, invasive operations, and exposure to broad-spectrum antibiotics, critically ill individuals are especially vulnerable.[2]

Globally, ventilator-associated infections are still primarily caused by gram-negative bacteria. Klebsiella pneumoniae, Pseudomonas aeruginosa, Escherichia coli, Acinetobacter species, and other Enterobacteriaceae are often isolated organisms; the most common gram-positive pathogen is Staphylococcus aureus. Furthermore, it is becoming more widely acknowledged that fungal colonization and infection, especially that caused by Candida species, can lead to unfavourable clinical outcomes in patients on mechanical ventilation.[3]

The management of ventilator-associated infections has become more challenging due to the rise of multidrug-resistant (MDR) pathogens. In order to direct empirical antibiotic therapy, current international guidelines stress the significance of local microbiological surveillance and antimicrobial susceptibility data. Therefore, optimizing antimicrobial treatment and enhancing patient outcomes require an understanding of prevalent infections and their resistance trends.[4]

Microbial profiles and susceptibility patterns must be regularly monitored in order to reduce infection-related mortality and start the right medication on time.A popular, minimally intrusive, and reasonably priced technique for determining respiratory infections in patients on mechanical ventilation is endotracheal aspirate (ETA) culture. In addition to helping with early identification, ETA cultures offer important details about the microbiological range and antibiotic susceptibility of infecting organisms, which helps doctors customize treatment based on regional epidemiological trends.[5]

Despite advances in critical care, data on the incidence, microbiological profile, and mortality associated with bacterial and fungal infections among mechanically ventilated patients remain limited in many Indian ICUs. Understanding local pathogen distribution and outcome patterns is essential for guiding antimicrobial therapy and improving patient outcomes. Therefore, this study was undertaken to determine the incidence of bacterial and fungal infections and assess the associated mortality among mechanically ventilated ICU patients using endotracheal aspirate culture.

Aim and Objective

- To determine the incidence of bacterial and fungal infections in ICU patients on mechanical ventilation.
- To determine the mortality associated with the various bacterial and fungal infections.

METHODOLOGY

Study Design and Setting

This prospective observational study was conducted in the Medical Intensive Care Unit (MICU) of the Department of Medicine, Swaroop Rani Nehru Hospital, Prayagraj, Uttar Pradesh, India, over a period of one year from July 2020 to June 2021.

Study Population

A total of 100 adult patients receiving mechanical ventilation for more than 48 hours and suspected of having ventilator-associated pneumonia (VAP) were enrolled in the study.

Inclusion Criteria

- Patients aged ≥18 years.
- Patients receiving mechanical ventilation for more than 48 hours.
- Presence of clinical and radiological findings suggestive of ventilator-associated pneumonia.

Exclusion Criteria

- Patients with severe immunocompromised conditions, including acquired immunodeficiency syndrome (AIDS), organ transplantation, and terminal-stage malignancy.
- Patients diagnosed with pneumonia before initiation of mechanical ventilation or within the first 48 hours of mechanical ventilation.

Data Collection
After obtaining informed consent from the patient's legally authorized representative, detailed demographic and clinical information was recorded using a predesigned proforma. Data collected included age, sex, underlying comorbidities, date of admission, level of consciousness, duration of mechanical ventilation, date of endotracheal intubation or tracheostomy, prior antibiotic exposure, laboratory investigations, and clinical outcomes. Patients were followed from enrollment until discharge from the MICU or death.

Sample Collection and Microbiological Processing
Endotracheal aspirate (ETA) samples were collected under strict aseptic precautions from patients meeting the inclusion criteria. Samples were transported immediately to the microbiology laboratory for processing.

Microbiological analysis was performed according to the Clinical and Laboratory Standards Institute (CLSI) guidelines. A portion of each ETA sample was subjected to Gram staining, while the remaining sample was inoculated onto Blood agar, MacConkey agar, and Chocolate agar media. The inoculated plates were incubated aerobically at 37°C and examined after 24 and 48 hours for microbial growth. Cultures showing no growth were retained for up to five days before being reported as negative.

Microorganisms isolated from culture were identified based on colony morphology, Gram staining characteristics, and standard biochemical tests. Bacterial and fungal isolates were recorded, and antimicrobial susceptibility testing was performed using standard CLSI recommendations.

Study Variables
The primary outcome was the incidence of bacterial and fungal infections detected by ETA culture among mechanically ventilated ICU patients.

The secondary outcome was mortality associated with various bacterial and fungal pathogens isolated from ETA cultures. Severity of illness was assessed using the Simplified Acute Physiology Score II (SAPS II). Clinical outcome was categorized as discharge from the ICU or death during hospitalization.

Statistical Analysis
Data were entered into Microsoft Excel and analyzed using appropriate . Continuous variables were expressed as mean ± standard deviation (SD) or median with interquartile range (IQR), depending on data distribution. Categorical variables were presented as frequencies and percentages.

Comparisons among ETA culture groups were performed using the Kruskal–Wallis test for continuous variables and Fisher's exact test for categorical variables. A p-value <0.05 was considered statistically significant.

RESULT
The study comprised 100 ICU patients who were on mechanical ventilation. The study participants' ages ranged from 18 to 90 years old, with a mean age of 45.40 ± 19.99 years and a median age of 45 years (IQR: 28–60.25 years). Of the patients in the study, 39.0% were female and 61.0% were male. In 81% of patients, ETA culture showed bacteria growth. Fungal infections were found in 5% of patients, while bacterial infections accounted for 76% of all cases. 19% of ETA cultures showed no microbial growth (Figure 1).

Different ETA culture isolates had varying levels of sickness as determined by the SAPS II score. Patients infected with Escherichia coli had the highest median SAPS II score [56.5 (IQR: 49.25–60.75)], followed by Klebsiella spp. [56 (IQR: 43.5–59.5)]. The median SAPS II scores for patients infected with Pseudomonas and Candida species were 46 (IQR: 42–52.75) and 46 (IQR: 46–59), respectively. Patients without microbial growth had a median SAPS II score of 50 (IQR: 44–56). Nevertheless, SAPS II scores did not differ statistically significantly between the different ETA culture groups (Kruskal–Wallis test, $\chi^2 = 9.781$, $p = 0.201$) (Table 2).

In total, 42% of the patients were released from the hospital, while 58% of them died while there. The kind of bacterium recovered from ETA cultures was significantly correlated with clinical outcome ($\chi^2 = 17.958$, $p = 0.002$). Patients infected with Proteus spp. and Escherichia coli had the highest mortality rate, with all patients dying (100%). Additionally, patients with Pseudomonas spp. (64.3%), Candida spp. (60.0%), and Klebsiella spp. (59.3%) infections had high death rates. On the other hand, patients with no microbial growth had a mortality rate of 36.8%, but patients with Staphylococcus spp. infection had a mortality rate of 42.1%. The lone patient who had an infection with Acinetobacter spp. lived and was released. Figure 2 and Table 3 show the distribution of mortality by ETA culture isolates.

Table 1: Baseline Characteristics of Mechanically Ventilated ICU Patients

Variable	Value

Age, mean ± SD (years)	45.40 ± 19.99
Age, median (IQR) (years)	45 (28–60.25)
Age range (years)	18–90
Male, n (%)	61 (61.0)
Female, n (%)	39 (39.0)

Figure 1: Prevalence of Bacterial and Fungal Infections Based on ETA Culture (N = 100)

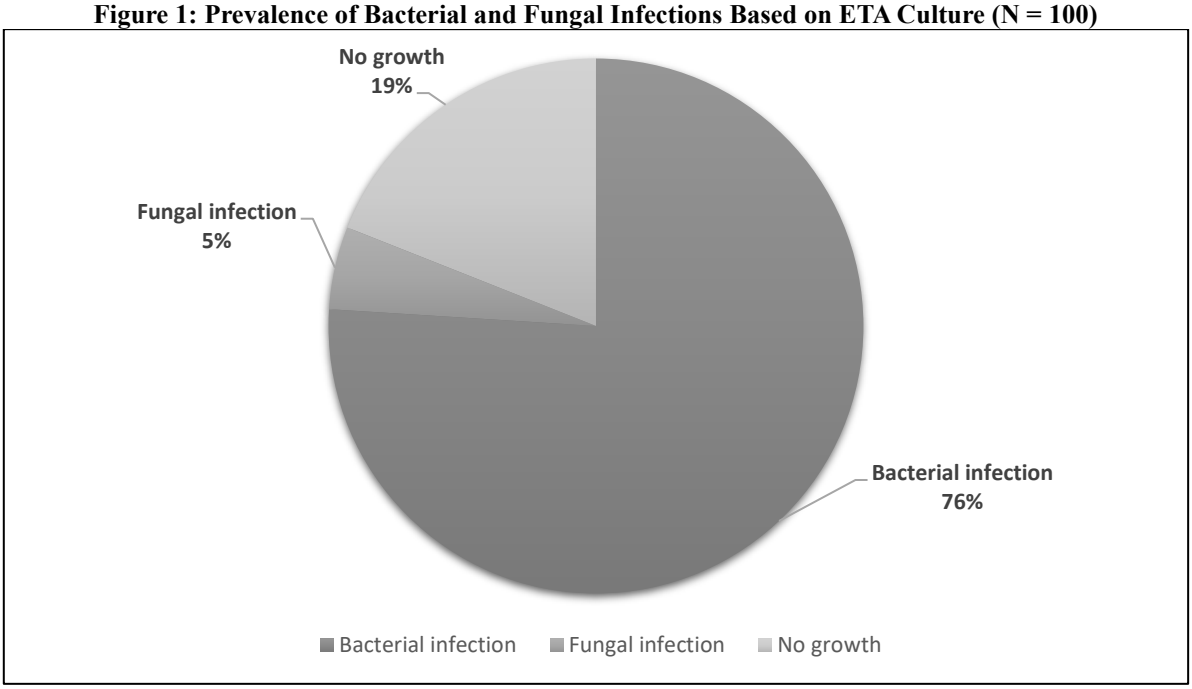


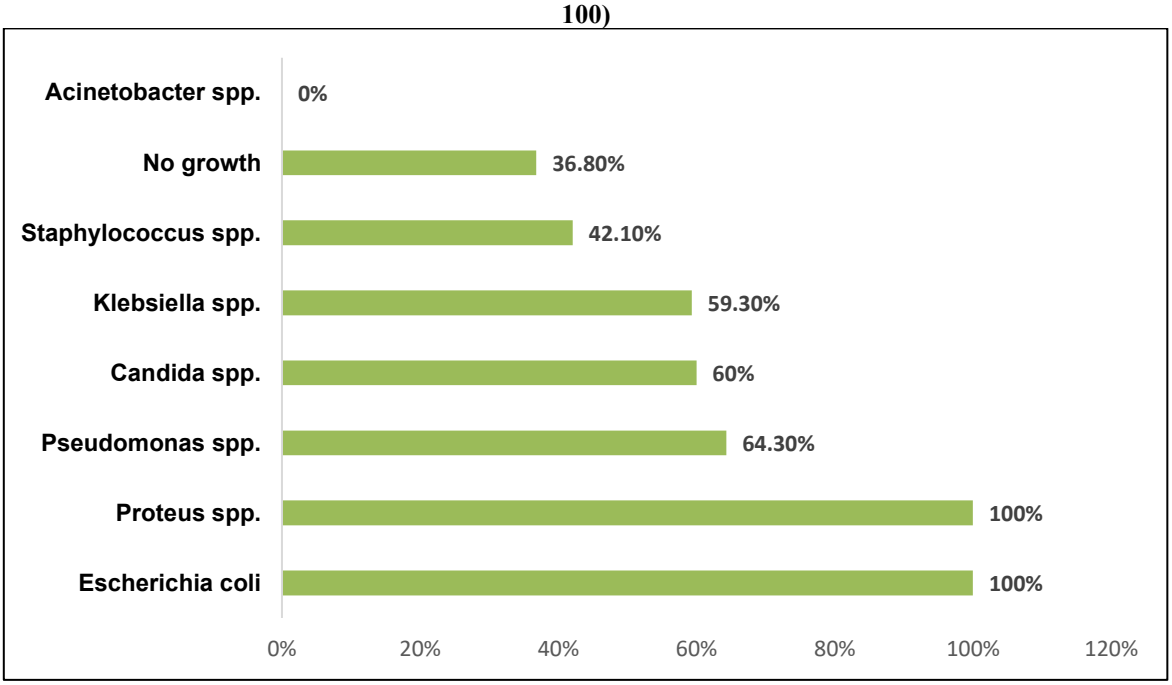
Table 2: Comparison of SAPS II Scores Across Different ETA Culture Isolates Among Mechanically Ventilated ICU Patients (N = 100)

ETA Culture	SAPS II Score, Median (IQR)	Kruskal–Wallis test statistic	p - value
Acinetobacter spp. (n=1)	37 (37–37)	9.781	0.201
Candida spp. (n=5)	46 (46–59)		
Escherichia coli (n=14)	56.5 (49.25–60.75)		
Klebsiella spp. (n=27)	56 (43.5–59.5)		
Proteus spp. (n=1)	44 (44–44)		
Pseudomonas spp. (n=14)	46 (42–52.75)		
Staphylococcus spp. (n=19)	45 (39–53.5)		
No growth (n=19)	50 (44–56)		

Table 3: Association Between ETA Culture Isolates and Clinical Outcome Among Mechanically Ventilated ICU Patients (N=100)

Organism (n)	Discharged n (%)	Expired n (%)	χ^2	p-value
Acinetobacter spp. (1)	1 (100.0%)	0 (0.0%)	17.958	0.002
Candida spp. (5)	2 (40.0%)	3 (60.0%)		
Escherichia coli (14)	0 (0.0%)	14 (100.0%)		
Klebsiella spp. (27)	11 (40.7%)	16 (59.3%)		
Proteus spp. (1)	0 (0.0%)	1 (100.0%)		
Pseudomonas spp. (14)	5 (35.7%)	9 (64.3%)		
Staphylococcus spp. (19)	11 (57.9%)	8 (42.1%)		
No growth (19)	12 (63.2%)	7 (36.8%)		
Total	42 (42.0%)	58 (58.0%)		

Figure 2: Mortality Rates According to ETA Culture Isolates Among Mechanically Ventilated ICU Patients (N = 100)



DISCUSSION

The mean age of the study population was 45.40 ± 19.99 years, and males constituted 61% of participants. Comparable demographic characteristics were reported by Charles et al., who found a predominance of male patients among ventilated ICU populations.[6] Similarly, Ibrahim et al. reported that middle-aged and elderly male patients represented the majority of cases with ventilator-associated infections.[7]

In the present study, bacterial pathogens were isolated more frequently than fungal pathogens, with Klebsiella spp. being the predominant isolate (27%), followed by Staphylococcus spp. (19%), Escherichia coli (14%), and Pseudomonas spp. (14%). Similar findings were reported by Joseph et al., who observed that gram-negative bacilli were the predominant causative organisms of ventilator-associated pneumonia, with Klebsiella and Pseudomonas species being the most frequently isolated pathogens.[8] Likewise, Tandel et al. reported a predominance of multidrug-resistant gram-negative organisms, particularly Klebsiella pneumoniae and Pseudomonas aeruginosa, among mechanically ventilated ICU patients. The predominance of gram-negative organisms in the present study may be attributed to prolonged ICU stay, extensive antibiotic exposure, and increased respiratory tract colonization by nosocomial pathogens.[5]

The incidence of fungal infection in the present study was 5%, with Candida spp. accounting for all fungal isolates. This finding is consistent with the observations of Azoulay et al., who reported Candida species as the most common fungal organisms isolated from respiratory secretions of critically ill patients.[9] Although Candida isolation frequently represents colonization rather than true invasive infection, Delisle et al. demonstrated that Candida colonization may be associated with prolonged mechanical ventilation and poorer clinical outcomes.[10]

Severity of illness was assessed using the SAPS II score. Although patients with Escherichia coli and Klebsiella infections had relatively higher median SAPS II scores, no statistically significant difference was observed among the different microbial groups ($p = 0.201$). Similar findings were reported by Papazian et al., who noted that severity scores such as SAPS II are useful predictors of overall mortality but may not significantly differ according to specific infecting microorganisms.[1]

The overall mortality rate in the present study was 58%. This mortality rate is higher than that reported by Charles et al., who documented a mortality rate of approximately 29% among ventilated patients with VAP.[6] Similarly, Joseph et al. reported mortality rates ranging from 30% to 40%. The comparatively higher mortality observed in the present study may be attributable to delayed referral, severity of underlying illness, antimicrobial resistance, and resource limitations.[8]

A significant association was observed between ETA culture isolate and clinical outcome ($p = 0.002$). Mortality was highest among patients infected with Escherichia coli and Proteus spp. (100%), followed by Pseudomonas spp. (64.3%), Candida spp. (60.0%), and Klebsiella spp. (59.3%). Similar observations were made by Kalanuria et al., who reported that infections caused by gram-negative bacilli, particularly Pseudomonas aeruginosa and Enterobacteriaceae, were associated with poorer

clinical outcomes and increased mortality.[11] Likewise, Chastre and Fagon emphasized that infections caused by multidrug-resistant gram-negative pathogens contribute substantially to ICU mortality.[12]

In contrast, patients infected with Staphylococcus spp. in the present study exhibited a comparatively lower mortality rate (42.1%). Similar findings were reported by Kollef et al., who observed relatively better outcomes among patients infected with susceptible gram-positive organisms compared with those infected by resistant gram-negative pathogens.[13]

The findings of the present study highlight the substantial burden of bacterial infections among mechanically ventilated ICU patients and demonstrate a significant relationship between microbial etiology and patient outcome.

CONCLUSION

Bacterial and fungal infections were common among mechanically ventilated ICU patients, with bacterial infections predominating. *Klebsiella* spp. was the most frequently isolated organism, while *Candida* spp. accounted for all fungal isolates. Clinical outcome was significantly associated with the infecting organism, with the highest mortality observed among patients with *Escherichia coli* and *Proteus* infections. No significant difference in SAPS II scores was observed among the microbial groups. Early pathogen identification and appropriate antimicrobial therapy are crucial for improving patient outcomes and reducing mortality.

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