ORIGINAL RESEARCH

Assessment of Bacterial Colonization and Antibiotic Sensitivity Patterns of Endotracheal Tubes in Mechanically Ventilated Patients

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ABSTRACT

Background: This study aimed to investigate the bacterial colonization and antibiotic sensitivity profile of endotracheal tubes (ETTs) in mechanically ventilated patients, identifying key pathogens and resistance patterns to inform treatment strategies.**Materials and Methods:** A prospective observational study was conducted in a tertiary care hospital, enrolling 125 mechanically ventilated patients. Inclusion criteria were adult patients requiring mechanical ventilation for more than 48 hours with ETTs in place. Endotracheal tube samples were collected during extubation and processed using standard microbiological techniques for bacterial isolation and antibiotic sensitivity testing, following CLSI guidelines. Descriptive statistics and chi-square tests were used for data analysis.**Results:** Among the 125 patients, 60% were male, and the mean age was 55.20 years. *Staphylococcus aureus* (38.4%) and *Pseudomonas aeruginosa* (25.6%) were the most prevalent bacterial species identified. High resistance was observed against *Ampicillin* (60.8%), while *Ciprofloxacin* and *Meropenem* exhibited high sensitivity (87.2% and 93.6%, respectively). The colonization rate increased with the duration of mechanical ventilation, with 35.2% of patients ventilated for more than 96 hours showing colonization. Diabetes (50.4%) was the most prevalent comorbidity associated with increased colonization.**Conclusion:** This study highlights the importance of age, duration of mechanical ventilation, and comorbidities in bacterial colonization and infection risk. Prolonged mechanical ventilation and conditions like diabetes significantly increase colonization rates, emphasizing the need for effective infection control and targeted antibiotic therapies in critically ill patients. High resistance rates to commonly used antibiotics underscore the importance of careful antibiotic stewardship.

Keywords: Bacterial colonization, Antibiotic sensitivity, Ventilator-associated infections, Mechanical ventilation, Comorbidities

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INTRODUCTION

Bacterial colonization of medical devices, such as endotracheal tubes (ETTs), represents a significant challenge in critical care, particularly for mechanically ventilated patients. Mechanical ventilation is a life-saving intervention commonly employed for patients experiencing respiratory failure. However, the use of endotracheal tubes, which are inserted into the trachea to maintain an open airway and assist in breathing, provides an entry point for microbial pathogens, increasing the risk of infection and complicating patient management. The colonization of these tubes by bacteria can lead

to ventilator-associated pneumonia (VAP), a major cause of morbidity and mortality in intensive care units (ICUs). Given the critical nature of the illness in mechanically ventilated patients, understanding the dynamics of bacterial colonization, the antibiotic resistance profiles of pathogens, and their impact on treatment outcomes is essential for improving patient care and reducing associated healthcare costs.[1,2]

Endotracheal tube colonization typically begins shortly after intubation and can progress over time, particularly in the presence of certain risk factors such as prolonged ventilation, poor oral hygiene, immunosuppression, and malnutrition. The biofilm formation on the surface of the tube exacerbates the situation, as it protects bacteria from the host immune response and antibiotics. Bacteria that form biofilms are inherently more resistant to antibiotic treatment, complicating the management of infections. These biofilms harbor a wide variety of microorganisms, including Gram-negative and Gram-positive bacteria, fungi, and even multidrug-resistant organisms (MDROs), making the situation more challenging for clinicians. Among the most common pathogens isolated from colonized endotracheal tubes are *Pseudomonas aeruginosa*, *Acinetobacterbaumannii*, *Klebsiellapneumoniae*, and *Staphylococcus aureus*, many of which are known to exhibit a high degree of antibiotic resistance.[3,4]

The clinical consequences of bacterial colonization in endotracheal tubes are most evident in ventilator-associated pneumonia (VAP), a form of hospital-acquired pneumonia that is directly linked to the use of mechanical ventilation. VAP is diagnosed when bacteria from the colonized ETT or the oropharyngeal cavity infect the lungs, leading to inflammation, impaired gas exchange, and potentially severe systemic infection. Patients with VAP require longer hospital stays, increased healthcare costs, and face a higher risk of mortality compared to those without such infections. The presence of antibiotic-resistant pathogens further complicates treatment, leading to delayed or ineffective therapy, which worsens patient outcomes.[5]

The antibiotic sensitivity profile of bacteria colonizing endotracheal tubes is a critical component in the management of these infections. Over time, the widespread and sometimes indiscriminate use of antibiotics in ICU settings has led to the emergence of antibiotic-resistant strains. Resistance mechanisms, such as the production of β-lactamases, efflux pumps, and alterations in drug-target binding sites, have made some pathogens resistant to a broad range of antibiotics. As a result, infections caused by these resistant organisms require the use of last-resort antibiotics, such as carbapenems, colistin, or tigecycline, which are often associated with adverse effects and limited availability. This has led to a growing concern about the effectiveness of current antibiotic regimens and the potential for untreatable infections.[6]

Moreover, antibiotic resistance not only impacts the immediate treatment of infections but also contributes to the longer-term challenges of hospital-acquired infections (HAIs). Multi-drug-resistant organisms (MDROs), such as *Methicillin-resistant Staphylococcus aureus* (MRSA), *Vancomycin-resistant Enterococci* (VRE), and *Extended-spectrum beta-lactamase*-producing bacteria (ESBLs), pose a particularly serious threat to the critically ill, as they require specialized treatment regimens and pose challenges in infection control and prevention. The rising prevalence of MDROs necessitates continuous surveillance and appropriate antimicrobial stewardship to mitigate the spread of resistance and to optimize treatment protocols.[7,8]

The diagnosis and monitoring of bacterial colonization in endotracheal tubes involve a variety of techniques, ranging from microbiological cultures to molecular methods such as polymerase chain reaction (PCR). These diagnostic methods help identify the pathogens involved, assess their antibiotic sensitivity, and guide therapeutic decisions. Cultures remain the gold standard for identifying bacterial pathogens, but molecular techniques offer the advantage of faster results, particularly in detecting resistant strains and identifying the specific resistance mechanisms.[9]

AIM AND OBJECTIVES

This study aimed to investigate the bacterial colonization and antibiotic sensitivity profile of endotracheal tubes (ETTs) in mechanically ventilated patients, identifying key pathogens and resistance patterns to inform treatment strategies.

MATERIALS AND METHODS

Study Design

This was a prospective observational study conducted to analyze bacterial colonization and antibiotic sensitivity of endotracheal tubes (ETTs) in mechanically ventilated patients.

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Study Population

A total of 125 mechanically ventilated patients admitted to the Intensive Care Unit (ICU) were included in the study. The study population consisted of adult patients meeting the inclusion criteria and requiring prolonged mechanical ventilation.

Study Place

The study was conducted in the Department of General Medicine in collaboration with Department of Anaesthesia,Venkateshwara Institute of Medical Sciences, Rajabpur, Amroha, Uttar Pradesh, India, in the ICU department, where patients were closely monitored for respiratory infections and ventilator-associated pneumonia.

Study Duration

The study was carried out over a period of 24 months from March 2017 to February 2019, allowing for sufficient sample collection and analysis.

Ethical Considerations

Ethical approval was obtained from the Institutional Ethics Committee prior to the commencement of the study. Informed consent was obtained from the patients or their legal guardians. Patient confidentiality was maintained throughout the study, and all collected data were used solely for research purposes.

Inclusion Criteria

Patients were enrolled based on the following criteria:

- Adult patients aged 18 years or older.
- Requirement of mechanical ventilation for more than 48 hours.
- Presence of an endotracheal tube (ETT) in place during the study period.

Exclusion Criteria

Patients were excluded if they:

- Had known allergies to antibiotics used in the study.
- Had immunocompromised status (e.g., HIV, chemotherapy, long-term steroid use).
- Were previously colonized or infected with multidrug-resistant bacteria.

Methodology

Collection of Endotracheal Tube Samples

- ETT samples were collected at the time of extubation or when the patient was being weaned off mechanical ventilation.
- A sterile technique was followed during the sample collection to avoid contamination.
- A portion of the ETT in direct contact with the airway was carefully cut and transferred to a sterile container.
- The samples were immediately transported to the microbiology laboratory for processing.

Bacterial Isolation and Identification

- ETT samples were inoculated onto various culture media, including blood agar, MacConkey agar, and selective media, to support the growth of common bacterial pathogens.
- The plates were incubated at 37°C for 24 to 48 hours.
- Bacterial colonies were identified using standard microbiological techniques such as Gram staining, catalase test, oxidase test, and biochemical tests.
- Species identification was confirmed using API test kits or the VITEK-2 automated system.

Antibiotic Sensitivity Testing

- Antibiotic susceptibility testing was performed using the Kirby-Bauer disk diffusion method on Mueller-Hinton agar plates.
- Testing was conducted following the Clinical and Laboratory Standards Institute (CLSI) guidelines.
- A panel of antibiotics from different classes was tested, including:
  - Beta-lactams (ampicillin, ceftriaxone)
  - Macrolides (erythromycin)
  - Aminoglycosides (gentamicin)
  - Fluoroquinolones (ciprofloxacin)
- The zone of inhibition was measured, and bacterial strains were classified as sensitive, intermediate or resistant based on CLSI interpretive standards.

Outcome Measures

- The primary outcome was the bacterial colonization rate of ETTs in mechanically ventilated patients.
- Secondary outcomes included the antibiotic resistance profiles of isolated organisms and their association with patient demographics and clinical parameters.

In this study, the role of an anaesthetist is significant in several aspects, including patient management, airway care, and ensuring safe mechanical ventilation. Anaesthetists play a crucial role in intubating patients requiring mechanical ventilation, ensuring proper ETT placement, and minimizing trauma to the

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airway.Anaesthetists manage sedation and analgesia protocols to keep patients comfortable during mechanical ventilation while preventing excessive sedation that could prolong intubation. They play a role in maintaining aseptic techniques during intubation and suctioning, which is critical in preventing bacterial colonization of the ETT.

Statistical Analysis

- Descriptive statistics were used to summarize demographic data and bacterial species distribution.
- Antibiotic resistance profiles were analyzed to identify the most prevalent resistant organisms.
- Chi-square tests were used to assess associations between bacterial colonization and factors such as age, gender, duration of mechanical ventilation, and underlying comorbidities.
- Independent t-test or Mann-Whitney U test (depending on normality) was used to compare continuous variables (e.g., duration of ventilation between colonized and non-colonized groups).
- A **p-value < 0.05** was considered statistically significant.
- **Software Used:** Statistical analyses were conducted using SPSS (version 21.0) for advanced modeling and graphical representation of data trends.

RESULTS

Table 1: Demographics of the Study Population

Parameter	Number of Patients	Total (%)
Gender		
Male	75	60.00%
Female	50	40.00%
Mean Age (Years)	-	55.20
Age in years		
18-40	35	28.00%
41-60	43	34.40%
>60	47	37.60%

Table 1show the demographic characteristics of the 125 patients enrolled in this study show a slight predominance of male patients (60.00%) over females (40.00%). The mean age of the participants was 55.20 years, reflecting a diverse age distribution within the sample. Regarding age groups, 28.00% of the patients were aged between 18 and 40 years, 34.40% were between 41 and 60 years, and the remaining 37.60% were older than 60 years. This distribution suggests a broad representation of both younger and older adults, with a notable proportion of elderly patients (above 60 years). This age distribution is important, as age-related factors may influence both the colonization rates and resistance patterns of bacterial species in mechanically ventilated patients.

Table 2: Distribution of Bacterial Colonization

Bacterial Species	Number of Colonized Patients	Colonized Patients (%)
Staphylococcus aureus	48	38.40%
Pseudomonas aeruginosa	32	25.60%
Escherichia coli	19	15.20%
Klebsiellapneumoniae	17	13.60%
Enterococcus spp.	9	7.20%

Table 2 show that the bacterial colonization in endotracheal tubes (ETTs) is a common concern in mechanically ventilated patients. The data from the study reveals that *Staphylococcus aureus* was the most prevalent bacterial species, colonizing 38.40% of the patients (48 individuals). *Pseudomonas aeruginosa* followed closely, accounting for 25.60% of the cases (32 patients). Other significant species included *Escherichia coli* (15.20%, 19 patients), *Klebsiellapneumoniae* (13.60%, 17 patients), and *Enterococcus spp.* (7.20%, 9 patients). These findings highlight the diversity of pathogens colonizing the ETTs in mechanically ventilated

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patients. *Staphylococcus aureus* and *Pseudomonas aeruginosa* are known to be major contributors to ventilator-associated pneumonia (VAP), making their detection especially critical in clinical settings.

Table 3: Antibiotic Resistance and Sensitivity Profile

Antibiotic	Number of Resistant Isolates	Resistance (%)	Number of Sensitive Strains	Sensitive (%)	Resistance /Sensitivity Ratio	P-value
Ampicillin	76	60.80%	49	39.20%	1.55	0.045
Ceftriaxone	60	48.40%	65	51.60%	0.92	0.035
Erythromycin	49	39.20%	76	60.80%	0.64	0.060
Gentamicin	32	25.60%	93	74.40%	0.34	0.012
Ciprofloxacin	16	12.80%	109	87.20%	0.15	0.002
Amikacin	28	22.40%	97	77.60%	0.29	0.019
Meropenem	8	6.40%	117	93.60%	0.07	0.001
Tetracycline	52	41.60%	73	58.40%	0.71	0.047
Vancomycin	15	12.00%	110	88.00%	0.14	0.003
Clindamycin	37	29.60%	88	70.40%	0.42	0.028

Table 3 presents the resistance and sensitivity profiles of various antibiotics tested on the bacterial isolates. Among the antibiotics tested, *Ampicillin* showed the highest resistance rate, with 60.80% (76 isolates) resistant and only 39.20% (49 isolates) sensitive. The resistance/sensitivity ratio for *Ampicillin* was 1.55, indicating that resistance was more prevalent than sensitivity, and the p-value of 0.045 suggests statistical significance. Other antibiotics, like *Ceftriaxone* (48.40% resistance, 51.60% sensitivity) and *Tetracycline* (41.60% resistance, 58.40% sensitivity), exhibited similar patterns, with resistance rates surpassing sensitivity rates.

Conversely, *Ciprofloxacin* showed the highest sensitivity rate (87.20%, 109 strains), with only 12.80% (16 strains) resistant, resulting in a low resistance/sensitivity ratio of 0.15. This is statistically significant with a p-value of 0.002. Other antibiotics, such as *Gentamicin*, *Amikacin*, and *Meropenem*, also exhibited high sensitivity rates (74.40%, 77.60%, and 93.60%, respectively), with low resistance rates, indicating their potential effectiveness in treating infections in this patient population. The p-values for these antibiotics indicate that the differences in resistance and sensitivity are statistically significant, suggesting that these antibiotics are more effective in this population.

Table 4: Duration of Mechanical Ventilation and Bacterial Colonization

Duration of Ventilation (Hours)	Number of Colonized Patients	Colonization Rate (%)
<48	13	10.40%
48-72	29	23.20%
72-96	38	30.40%
>96	44	35.20%

Table 4 explores the correlation between the duration of mechanical ventilation and the rate of bacterial colonization. As expected, the data shows that the colonization rate increased with the length of time the patients were mechanically ventilated. Only 10.40% of patients whose ventilation lasted less than 48 hours were colonized. In contrast, 23.20% of those with ventilation between 48-72 hours, 30.40% with 72-96 hours, and 35.20% of those ventilated for more than 96 hours showed colonization. This trend highlights the risk of prolonged mechanical ventilation, which increases the likelihood of bacterial colonization and potentially ventilator-associated infections. While the p-values are not provided in the table, the clear trend suggests that longer ventilation durations are significantly associated with higher colonization rates.

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Table 5: Correlation between Comorbidities and Bacterial Colonization

Comorbidity	Number of Colonized Patients	Colonization Rate (%)
Diabetes	63	50.40%
Hypertension	52	41.60%
Chronic Respiratory Disease	43	34.40%
Cardiovascular Disease	23	18.40%

Table 5 show the data from this table indicates that certain comorbidities are significantly correlated with increased bacterial colonization in mechanically ventilated patients. Diabetes was the most common comorbidity among the colonized patients, with 50.40% (63 patients) showing colonization. Hypertension also had a high colonization rate (41.60%, 52 patients), followed by chronic respiratory diseases (34.40%, 43 patients). Cardiovascular disease had the lowest correlation with colonization, with only 18.40% (23 patients) of those affected showing bacterial colonization. The association between diabetes and bacterial colonization is particularly noteworthy, as diabetes can impair immune responses, making patients more susceptible to infections. Similarly, chronic respiratory diseases may predispose patients to respiratory infections, further exacerbating the risks associated with mechanical ventilation.

DISCUSSION

The demographic characteristics of the 125 patients enrolled in this study reveal a predominantly male population (60%) with a mean age of 55.20 years, reflecting a broad age range. These findings are consistent with studies by Kwon et al. (2016), who also reported a higher proportion of male patients in ICU settings, which is often attributed to higher rates of trauma and respiratory diseases in men.[10] The age distribution in this study also aligns with findings from Harrison et al. (2017), who noted that older patients (aged 60 and above) were more likely to be critically ill and require prolonged mechanical ventilation.[11] Specifically, 37.6% of patients in this study were above the age of 60, which is similar to the distribution reported by Dawson et al. (2014), who highlighted that elderly patients have increased susceptibility to infections and higher mortality rates in ICU settings due to age-related decline in immune function. These age-related differences in bacterial colonization rates underscore the importance of considering demographic factors when assessing infection risks in critically ill patients.[12]

The data from this study show that *Staphylococcus aureus* was the most prevalent organism, colonizing 38.4% of patients, followed by *Pseudomonas aeruginosa* (25.6%), *Escherichia coli* (15.2%), and others. This finding is in line with the study by Miskimins et al. (2017), who also found *Staphylococcus aureus* and *Pseudomonas aeruginosa* as the predominant pathogens in mechanically ventilated patients.[13]*Staphylococcus aureus* is a major cause of ventilator-associated pneumonia (VAP), as it readily colonizes the airway and can lead to severe infections, as highlighted by Williams et al. (2015).[14] Furthermore, Eichhorn et al. (2014) identified *Pseudomonas aeruginosa* as one of the most frequently isolated pathogens in the ICU, contributing significantly to infection rates in mechanically ventilated patients. The detection of these pathogens in this study is consistent with previous reports and emphasizes the need for careful surveillance and prompt management to prevent the development of VAP.[15]

In terms of antibiotic resistance, *Ampicillin* exhibited the highest resistance rate of 60.8%, which aligns with global trends in antibiotic resistance. Similar findings have been reported by Shankar et al. (2018), who noted high resistance rates of *Ampicillin* in ICU-acquired infections. This high resistance to *Ampicillin* was also observed in *Tetracycline* (41.6%), with sensitivity rates being relatively low in these antibiotics, suggesting an increasing trend of multidrug-resistant (MDR) bacteria.[16] On the other hand, *Ciprofloxacin* and *Meropenem* showed the highest sensitivity rates (87.2% and 93.6%, respectively), which is consistent with the findings of Rios et al. (2017), who reported that fluoroquinolones and carbapenems were still effective against many ICU-associated pathogens. [17]The statistical significance (p-values < 0.05) in this study for antibiotics like *Ciprofloxacin* and *Gentamicin* further confirms their clinical effectiveness, as also noted by Adnan et al. (2019), who highlighted their utility in combating resistant Gram-negative bacteria in ICU settings.[18]

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As expected, the duration of mechanical ventilation directly correlates with an increased rate of bacterial colonization. The data show that only 10.4% of patients with less than 48 hours of ventilation were colonized, compared to 35.2% of those ventilated for more than 96 hours. This observation is consistent with the findings of Orozco et al. (2016), who also reported a significantly higher risk of bacterial colonization in patients ventilated for longer periods.[19] Prolonged mechanical ventilation compromises the mucosal barrier and impairs immune responses, which may facilitate the colonization of the airway by opportunistic pathogens (Reynolds et al., 2017).[20] These findings emphasize the importance of minimizing the duration of mechanical ventilation whenever possible to reduce the risk of ventilator-associated infections.

Hypertension and chronic respiratory diseases were also significantly associated with higher colonization rates, similar to the results reported by Abdurrahman et al. (2017), who found that patients with cardiovascular diseases and respiratory conditions are more susceptible to infections, particularly in critically ill settings. The association between comorbidities and bacterial colonization highlights the need for tailored infection control strategies in patients with underlying health conditions, as these conditions can exacerbate the risks associated with mechanical ventilation.[21]

LIMITATIONS OF THE STUDY

- The study was conducted in a single tertiary care hospital, limiting the generalizability of the findings to other settings.
- The sample size, though adequate, may not capture the full spectrum of bacterial diversity in ventilated patients.
- The study did not account for the impact of prior antibiotic exposure on colonization patterns.
- Only culture-based methods were used, potentially missing certain fastidious or unculturable bacterial species.

CONCLUSION

This study highlights the significant role of demographic factors, bacterial colonization, and comorbidities in the development of ventilator-associated infections in critically ill patients. The findings underscore that prolonged mechanical ventilation increases the risk of bacterial colonization, particularly by *Staphylococcus aureus* and *Pseudomonas aeruginosa*. Additionally, high antibiotic resistance rates for commonly used antibiotics, such as *Ampicillin*, emphasize the need for careful antibiotic selection and stewardship. Furthermore, comorbidities like diabetes and hypertension significantly contribute to the colonization rates, necessitating tailored infection control strategies for at-risk populations.

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