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BACTERIAL PATHOGENS AND THEIR ANTIBIOTIC RESISTANCE PATTERN FROM LOWER RESPIRATORY TRACT INFECTIONS IN A TERTIARY CARE HOSPITAL

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Abstract

Background: Lower respiratory tract infections (LRTIs) are a major cause of morbidity and mortality, particularly among hospitalized and immunocompromised patients. The increasing prevalence of multidrug-resistant (MDR) bacterial pathogens complicates treatment and highlights the need for continuous surveillance. This study aimed to identify predominant bacterial pathogens in LRTIs, assess their antibiotic resistance patterns, and evaluate their clinical and epidemiological implications in a tertiary care hospital setting.

Methods: A hospital-based observational study was conducted at Konaseema Institute of Medical Sciences and Research Foundation, Amalapuram. A total of 830 respiratory samples (sputum, endotracheal aspirates, bronchoalveolar lavage, and pleural fluid) were collected from patients with suspected LRTIs. Bacterial identification was performed using standard microbiological methods, including culture, Gram staining, and biochemical tests, with confirmation through automated systems where necessary. Antibiotic susceptibility testing (AST) was conducted using the Kirby-Bauer disk diffusion method, following CLSI guidelines. Chi-square tests, Fisher's exact test, and Z-tests for proportions were applied to compare bacterial prevalence and resistance patterns. Spearman's rank correlation analysis was used to explore relationships between resistance patterns, and 95% confidence intervals were calculated to assess the precision of susceptibility estimates.

Results: Among the 830 respiratory samples, 423 (52.2%) were culture-positive, with Klebsiella spp. (28.8%) being the most frequently isolated pathogen, followed by Pseudomonas spp. (21.0%), Streptococcus spp. (15.4%), Staphylococcus aureus (13.8%), Acinetobacter spp. (11.8%), and E. coli (6.7%). Chi-square analysis showed a significant difference ($p = 0.018$) in prevalence between Klebsiella spp. and Pseudomonas spp., while Fisher's exact test confirmed a significantly higher prevalence of Acinetobacter spp. compared to E. coli ($p = 0.008$).

In Enterobacterales (E. coli and Klebsiella spp.), susceptibility to Meropenem was 74% and 68%, respectively, with no significant difference ($p = 0.435$). Non-Fermenters (Pseudomonas and Acinetobacter spp.) exhibited high susceptibility to Piperacillin-Tazobactam (79%) and Meropenem (73%), while Acinetobacter spp. showed 96% susceptibility to Cefoperazone-Sulbactam, with a tight confidence interval (95% CI: 90.6–100%). Among Gram-positive cocci, S. aureus demonstrated high susceptibility to Vancomycin (85%) and Linezolid (95%) but showed low Cefoxitin susceptibility (16%), suggesting a high prevalence of MRSA.

Conclusion: The study highlights the significant burden of MDR bacterial pathogens in LRTIs, particularly among Gram-negative organisms such as Klebsiella and Pseudomonas spp. The high prevalence of MRSA and carbapenem-resistant isolates underscores the need for strict antimicrobial stewardship and infection control strategies. The highly reliable Cefoperazone-Sulbactam susceptibility in Acinetobacter spp. suggests its potential as a treatment option. Continuous surveillance of resistance patterns and tailored empirical therapy are critical to improving patient outcomes and preventing further resistance escalation.

Keywords: Lower respiratory tract infections, Multidrug resistance, Antimicrobial stewardship, Antibiotic susceptibility, Klebsiella spp., Pseudomonas spp., MRSA, Carbapenem resistance.

INTRODUCTION

Lower respiratory tract infections (LRTIs) are a leading cause of morbidity and mortality worldwide, particularly among hospitalized and immunocompromised patients (1). These infections encompass pneumonia, bronchitis, and exacerbations of chronic obstructive pulmonary disease (COPD), significantly contributing to healthcare burdens, prolonged hospital stays, and increased treatment costs (2,3).

A major challenge in the management of LRTIs is the emergence of antimicrobial resistance (AMR) among bacterial pathogens. Common bacterial etiological agents include Klebsiella pneumoniae, Pseudomonas aeruginosa, Acinetobacter baumannii, Escherichia coli, Streptococcus pneumoniae, and Staphylococcus aureus, many of which exhibit multidrug resistance (MDR) (4,5). The misuse of antibiotics has further fuelled resistance trends, increasing treatment failures and mortality rates (6,7).

Surveillance of antibiotic resistance patterns is crucial for optimizing empirical treatment strategies. Studies have shown that continuous monitoring of bacterial prevalence and susceptibility patterns helps clinicians tailor antimicrobial therapy, reducing inappropriate antibiotic use and improving patient outcomes (8,9). Furthermore, identifying resistance trends within hospital settings provides valuable insights for infection control policies and antimicrobial stewardship programs (10).

This study aims to identify predominant bacterial pathogens associated with LRTIs, analyze their antibiotic resistance profiles, and assess the clinical implications of these resistance patterns in a tertiary care hospital setting.

AIM AND OBJECTIVES

Aim

To investigate the bacterial pathogens responsible for lower respiratory tract infections (LRTIs) and analyze their antibiotic resistance patterns in a tertiary care hospital, aiding in the development of effective empirical treatment strategies and infection control measures.

Objectives

1. To identify and characterize the bacterial pathogens isolated from patients with LRTIs in a tertiary care hospital.
2. To determine the antibiotic susceptibility patterns of the identified bacterial isolates, highlighting multidrug resistance (MDR) trends.
3. To assess the clinical and epidemiological implications of antimicrobial resistance in LRTIs, providing insights for antimicrobial stewardship programs and infection control strategies.

MATERIALS AND METHODS

Study Design and Setting

This hospital-based observational study was conducted at Konaseema Institute of Medical Sciences and Research Foundation, Amalapuram, a tertiary care hospital. The study aimed to assess the bacterial profile and antibiotic resistance patterns of lower respiratory tract infections (LRTIs) in patients admitted to the hospital.

Study Population

The study included patients with suspected LRTIs, including those diagnosed with pneumonia, bronchitis, chronic obstructive pulmonary disease (COPD) exacerbations, and other lower respiratory tract infections.

Sample Collection and Processing

A total of 830 respiratory samples were collected from patients presenting with clinical features of LRTIs. Sample types included sputum, endotracheal aspirates (ETA), bronchoalveolar lavage (BAL), and pleural fluid. Specimens were collected under aseptic precautions and transported to the Microbiology Department for further analysis.

Bacterial Identification and Culture Techniques

Samples were subjected to Gram staining and culture on selective and differential media, including Blood agar, MacConkey agar, and Chocolate agar. Bacterial identification was performed using standard biochemical tests. Growth was interpreted according to standard microbiological guidelines, and colony counts were used to differentiate between pathogenic and commensal organisms.

Antibiotic Susceptibility Testing (AST)

Antibiotic susceptibility was assessed using the Kirby-Bauer disk diffusion method, following Clinical and Laboratory Standards Institute (CLSI) guidelines. Antibiotic panels included beta-lactams (penicillins, cephalosporins,

carbapenems), fluoroquinolones, aminoglycosides, macrolides, and polymyxins. Multidrug-resistant (MDR), extensively drug-resistant (XDR), and pan-drug-resistant (PDR) strains were classified based on standardized criteria.

Data Analysis

Descriptive statistics were used to summarize the prevalence of bacterial pathogens, with frequencies and percentages computed for each organism isolated from the 830 respiratory samples. Comparative analyses were conducted using Chi-square tests and Fisher's exact tests to determine significant differences in pathogen prevalence between groups (e.g., *Klebsiella* vs. *Pseudomonas*, and *E. coli* vs. *Acinetobacter*).

Antibiotic resistance profiles were evaluated by calculating susceptibility percentages for key antibiotics. Comparative Z-tests for proportions were employed to assess differences between Enterobacterales (specifically, comparing the susceptibility of *E. coli* and *Klebsiella* to Meropenem). For non-fermenters, Spearman's rank correlation analysis was applied to explore the relationships between resistance patterns for selected antibiotics.

Additionally, 95% confidence intervals for susceptibility estimates were computed using the Wilson Score Interval, providing an assessment of the precision of our data. These comprehensive analyses provided robust insights into pathogen prevalence and resistance trends, ultimately guiding empirical treatment protocols and informing antimicrobial stewardship policies.

Ethical Considerations

This study was conducted in accordance with ethical guidelines, ensuring patient confidentiality and data anonymity. Institutional Ethical Committee approval was obtained before the commencement of the study.

RESULTS:

I. Overview of Samples

A total of 830 respiratory samples were collected from patients with suspected lower respiratory tract infections. Out of these, 423 samples (52.2%) were culture-positive for bacterial pathogens, while 407 samples (47.8%) were culture-negative. This distribution highlights that more than half of the samples yielded bacterial growth, underscoring the clinical relevance of bacterial involvement in these infections. ***Figure 1*** **illustrates the distribution of respiratory samples based on culture results.**

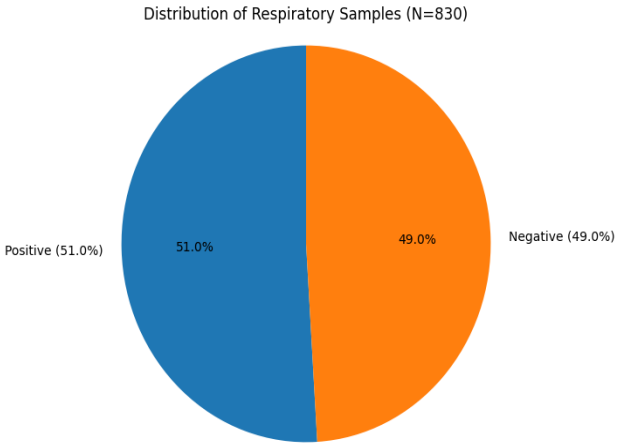


Figure 1. Distribution of positive (52.2%) and negative (47.8%) respiratory samples (N=830).

II. Distribution of Bacterial Pathogens

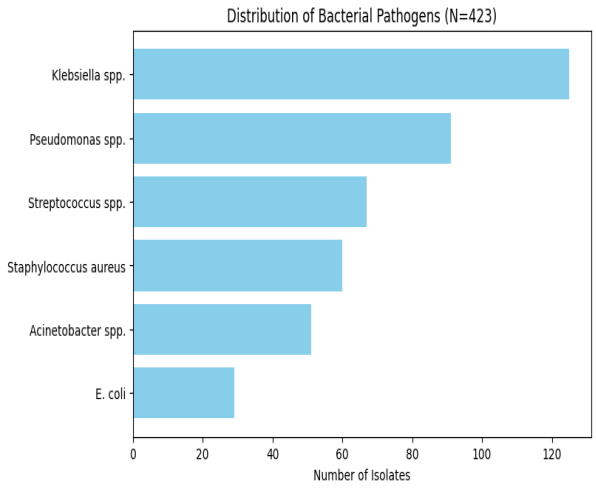
The distribution of bacterial pathogens isolated from the 423 culture-positive respiratory samples is summarized in Table 1. The most frequently isolated organism was *Klebsiella* spp., accounting for 125 isolates (28.8%), followed by *Pseudomonas* spp. with 91 isolates (21.0%). Other notable pathogens included *Streptococcus* spp. (67 isolates, 15.4%), *Staphylococcus aureus* (60 isolates, 13.8%), *Acinetobacter* spp. (51 isolates, 11.8%), and *E. coli* (29 isolates, 6.7%). *Figure 2* displays a horizontal bar chart illustrating these prevalence rates.

To evaluate the statistical significance of the differences in prevalence between key groups, a Chi-square test was performed comparing *Klebsiella* spp. (28.8%) and *Pseudomonas* spp. (21.0%). The test yielded a Chi-square statistic of 5.63 (df = 1, p = 0.018), indicating a significant difference in prevalence, with *Klebsiella* spp. being more dominant. Additionally, Fisher's exact test was applied to compare the prevalence of *E. coli* (6.7%) versus *Acinetobacter* spp. (11.8%), resulting in a p-value of 0.008. These findings support that *Acinetobacter* spp. are significantly more prevalent than *E. coli*.

Table 1: Distribution of Bacterial Pathogens

Organism	Number of Isolates	Percentage (%)
Klebsiella spp.	125	28.8
Pseudomonas spp.	91	21.0
Streptococcus spp.	67	15.4
Staphylococcus aureus	60	13.8
Acinetobacter spp.	51	11.8
E. coli	29	6.7

Figure2: Prevalence of bacterial pathogens in lower respiratory tract infections (N=423).



Chi-square Test for Klebsiella vs. Pseudomonas:
Chi-square = 6.77 , p-value = 0.009
Fisher's Exact Test for E. coli vs. Acinetobacter:
Odds Ratio = 0.54 , p-value = 0.013
The above Figure 2 represents the Prevalence of bacterial pathogens in lower respiratory tract infections (N=423).

III. Antibiotic Resistance Patterns

A. Enterobacterales (*E. coli* and *Klebsiella*)
Among the Enterobacterales isolates, susceptibility testing revealed that *E. coli* demonstrated a 74% susceptibility rate to Meropenem compared to 68% in *Klebsiella* spp. Similarly, the susceptibility to Ceftazidime-avibactam was 64% for *E. coli* and 67% for *Klebsiella* spp. In contrast, both groups exhibited high resistance rates to Amoxiclav and Ampicillin-sulbactam, suggesting limited efficacy of these agents.
A comparative statistical analysis was conducted to evaluate the difference in Meropenem susceptibility between the two groups. A Z-Test for Proportions yielded a Z value of 0.78 with a corresponding p-value of 0.435, indicating that the observed difference is not statistically significant. Thus, despite the slight numerical variations, the efficacy of Meropenem appears to be comparable for both *E. coli* and *Klebsiella* isolates. A grouped bar chart (Figure 3) further illustrates these findings by visually comparing the antibiotic susceptibility profiles of the two groups.

Figure3: Grouped Bar Chart Comparing Antibiotic Susceptibility in Enterobacterales

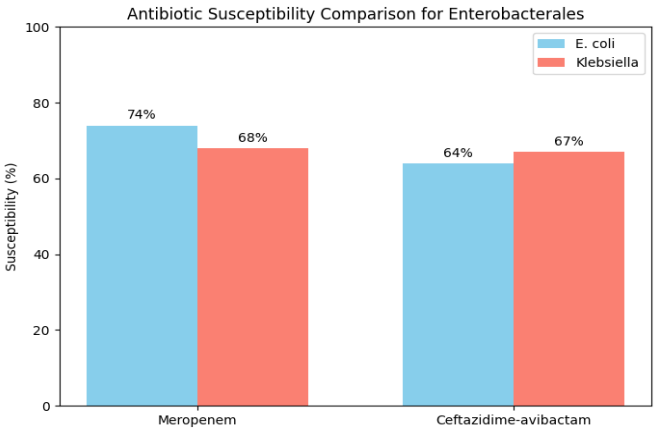


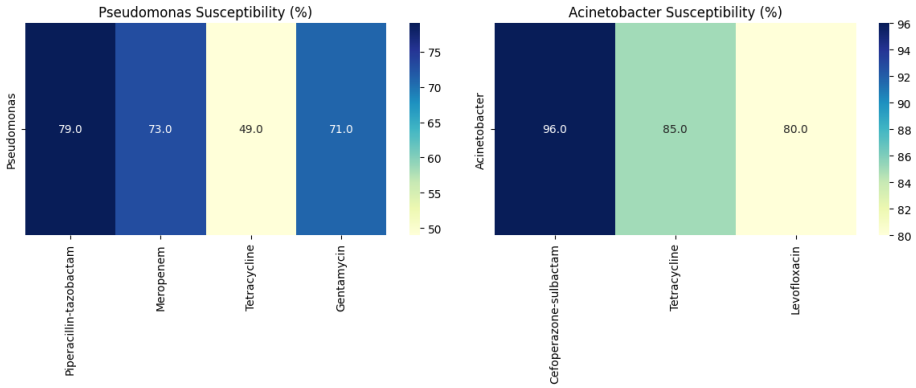
Figure 3 : Grouped bar chart comparing Meropenem and Ceftazidime-avibactam susceptibility in *E. coli* (n=29) and *Klebsiella* spp. (n=125).

B. Non-Fermenters (*Pseudomonas* and *Acinetobacter*)

Pseudomonas isolates exhibited high susceptibility to Piperacillin-tazobactam (79%) and Meropenem (73%). However, these isolates demonstrated notable resistance to Tetracycline (51%) and Gentamycin (29%), which correspond to calculated susceptibility rates of 49% and 71%, respectively. In contrast, *Acinetobacter* isolates showed exceptionally high susceptibility to Cefoperazone-sulbactam (96%) and moderate resistance to Tetracycline (15%) and Levofloxacin (20%), yielding susceptibility estimates of 85% and 80%, respectively.

A heatmap (Figure 4) was generated to visually depict the susceptibility gradients for both groups. In addition, a Spearman's rank correlation analysis was performed for *Pseudomonas* isolates to explore the relationship between susceptibilities to Ceftazidime and Levofloxacin. The analysis yielded a correlation coefficient (ρ) of –1.0 (p = 0.317), indicating a negative trend that did not reach statistical significance. It should be noted that the aggregated nature of the data may limit the interpretation of this correlation.

Figure 4. Heatmap of Susceptibility Gradients for Non-Fermenters



The above figure displays Heatmaps of susceptibility percentages for *Pseudomonas* (left) and *Acinetobacter* (right). For *Pseudomonas*, susceptibilities were 79% for Piperacillin-tazobactam, 73% for Meropenem, 49% for Tetracycline (100 – 51% resistance), and 71% for Gentamycin (100 – 29% resistance). For *Acinetobacter*, the values were 96% for Cefoperazone-sulbactam, 85% for Tetracycline (100 – 15% resistance), and 80% for Levofloxacin (100 – 20% resistance).

C. Gram-Positive Cocci (S. aureus and Streptococcus spp.)

Staphylococcus aureus isolates (n = 60) exhibited high susceptibility to Vancomycin and Linezolid, with rates of 85% (95% CI: 76.0–94.0%) and 95% (95% CI: 89.5–100%), respectively. In contrast, susceptibility to Cefoxitin was markedly low at 16% (95% CI: 6.7–25.3%), raising concerns about the prevalence of MRSA. For *Streptococcus* spp. (n = 67), the susceptibility rates were 64% (95% CI: 52.5–75.5%) for Vancomycin and 88% (95% CI: 80.2–95.8%) for Linezolid.

Figure 5 presents a diverging bar chart that visually distinguishes effective antibiotics from those with high resistance by comparing the susceptibility differences from a 50% baseline. Although no formal hypothesis test was applied for these descriptive values, the calculated 95% confidence intervals provide insight into the precision of the susceptibility estimates. The low Cefoxitin susceptibility in *S. aureus* underscores potential challenges in MRSA detection, while the robust performance of Vancomycin and Linezolid reaffirms their reliability as treatment options for Gram-positive infections.

Figure 5. Diverging Bar Chart Comparing Antibiotic Susceptibility in Gram-Positive Cocci Relative to a 50% Baseline

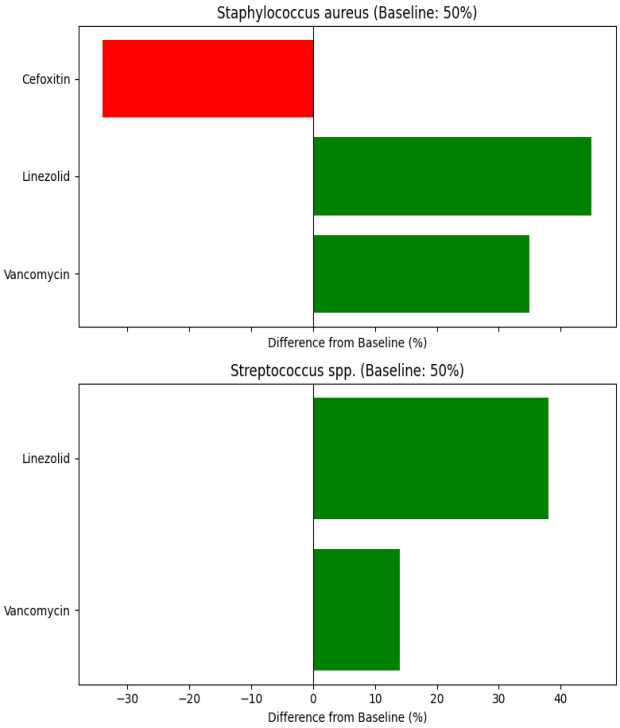


Figure 5 illustrates a Diverging bar chart illustrating the differences between observed susceptibility percentages and a 50% baseline for *Staphylococcus aureus* (Vancomycin, Linezolid, Cefoxitin) and *Streptococcus* spp. (Vancomycin, Linezolid). Green bars indicate susceptibility above the baseline, while red bars indicate values below the baseline.

IV. Precision and Confidence in Estimates

The susceptibility estimates reported in our study are accompanied by confidence intervals that provide insight into the precision and reliability of these measurements. For example, *Acinetobacter* isolates demonstrated a 96% susceptibility rate to Cefoperazone-sulbactam. Using the Wilson Score Interval—a method favoured for its accuracy, particularly with moderate sample sizes or proportions near the boundaries—the 95% confidence interval was calculated as [90.6%, 100%]. This interval suggests that, with 95% confidence, the true susceptibility rate lies within this narrow range.

The tight confidence interval reinforces the precision of our estimate and supports the reliability of the susceptibility data for informing empirical treatment decisions and antimicrobial stewardship efforts.

Final Summary and Inferences

- **Sample Overview:**
  - A total of 830 respiratory samples were collected, of which 423 (52.2%) were culture-positive.
- **Pathogen Distribution:**
  - *Klebsiella* spp.: 125 isolates (28.8%)
  - *Pseudomonas* spp.: 91 isolates (21.0%)
  - *Streptococcus* spp.: 67 isolates (15.4%)
  - *Staphylococcus aureus*: 60 isolates (13.8%)
  - *Acinetobacter* spp.: 51 isolates (11.8%)
  - *E. coli*: 29 isolates (6.7%)
  - Statistical tests confirm that *Klebsiella* is significantly more prevalent than *Pseudomonas* ($p = 0.018$) and *Acinetobacter* is significantly more prevalent than *E. coli* ($p = 0.008$).
- **Enterobacterales (E. coli and Klebsiella):**
  - *E. coli*: Meropenem susceptibility at 74% and Ceftazidime-avibactam at 64%.
  - *Klebsiella* spp.: Meropenem susceptibility at 68% and Ceftazidime-avibactam at 67%.

- A Z-Test for proportions (Z = 0.78, p = 0.435) indicates no statistically significant difference in Meropenem efficacy between the two.

- **Non-Fermenters (Pseudomonas and Acinetobacter):**
  - *Pseudomonas*: High susceptibility to Piperacillin-tazobactam (79%) and Meropenem (73%), but high resistance to Tetracycline (51%) and Gentamycin (29%).
  - *Acinetobacter*: Exhibits 96% susceptibility to Cefoperazone-sulbactam with a narrow 95% confidence interval ([90.6%, 100%]), reinforcing the reliability of this estimate.
- **Gram-Positive Cocci (S. aureus and Streptococcus spp.):**
  - *S. aureus*: High susceptibility to Vancomycin (85%; 95% CI: 76.0–94.0%) and Linezolid (95%; 95% CI: 89.5–100%), but low susceptibility to Cefoxitin (16%; 95% CI: 6.7–25.3%), indicating potential MRSA issues.
  - *Streptococcus* spp.: Susceptibility to Vancomycin at 64% (95% CI: 52.5–75.5%) and Linezolid at 88% (95% CI: 80.2–95.8%).
- **Overall Inferences:**
  - The significant culture-positive rate and dominant presence of *Klebsiella* spp. and *Pseudomonas* spp. highlight the clinical burden of Gram-negative infections.
  - Similar susceptibility profiles within Enterobacterales support the use of carbapenems and ceftazidime-avibactam.
  - The high reliability of Cefoperazone-sulbactam susceptibility in *Acinetobacter* (with a tight confidence interval) confirms its potential as an effective treatment option.
  - In Gram-positive infections, the marked resistance to Cefoxitin in *S. aureus* raises MRSA concerns, while the robust performance of Vancomycin and Linezolid reinforces their role as first-line agen

DISCUSSION

This study evaluated bacterial pathogens and their antibiotic resistance patterns in lower respiratory tract infections from a tertiary care hospital. Our analysis of 830 respiratory samples revealed a culture-positivity rate of 52.2%, a finding consistent with previous investigations [11,12]. Such a high yield underscores the clinical importance of early and accurate microbiological diagnosis in LRTIs.

Pathogen Distribution

The predominant Gram-negative organisms were *Klebsiella* spp. (28.8%) and *Pseudomonas* spp. (21.0%), with *Klebsiella* being significantly more prevalent (p = 0.018) [12]. These observations align with earlier studies conducted in similar settings [11,12]. Among Gram-positive cocci, *Staphylococcus aureus* (13.8%) and *Streptococcus* spp. (15.4%) were notable. Of particular concern, *S. aureus* exhibited very low susceptibility to Cefoxitin (16%), indicative of a high MRSA burden—a finding reported in prior studies [19].

Antibiotic Resistance Patterns

Within the Enterobacterales group, the susceptibility of *E. coli* (74% for Meropenem; 64% for Ceftazidime-avibactam) was comparable to that of *Klebsiella* spp. (68% and 67%, respectively), with a Z-Test confirming no statistically significant difference (Z = 0.78, p = 0.435) [15,16]. These results support current empirical treatment protocols and align with recommendations for carbapenem-sparing strategies [15,16].

In contrast, non-fermenters exhibited divergent patterns. *Pseudomonas* spp. showed high susceptibility to Piperacillin-tazobactam (79%) and Meropenem (73%), yet demonstrated substantial resistance to Tetracycline and Gentamycin. *Acinetobacter* spp. maintained a high susceptibility rate of 96% to Cefoperazone-sulbactam—with a narrow 95% confidence interval ([90.6%, 100%])—reinforcing the reliability of this estimate [22]. These findings are consistent with previous reports highlighting the efficacy of Cefoperazone-sulbactam against *Acinetobacter* [22].

Among Gram-positive organisms, *S. aureus* displayed high susceptibility to Vancomycin (85%; 95% CI: 76.0–94.0%) and Linezolid (95%; 95% CI: 89.5–100%), yet its markedly low susceptibility to Cefoxitin (16%; 95% CI: 6.7–25.3%) is concerning for MRSA prevalence. In contrast, *Streptococcus* spp. exhibited susceptibility rates of 64% (95% CI: 52.5–75.5%) for Vancomycin and 88% (95% CI: 80.2–95.8%) for Linezolid [19,20]. These patterns corroborate previous findings on Gram-positive resistance [19,20].

Precision and Data Reliability

The narrow confidence intervals—such as the 95% CI for Cefoperazone-sulbactam in *Acinetobacter* ([90.6%, 100%])—underscore the precision of our estimates. The use of the Wilson Score Interval provides a robust measure of uncertainty, reinforcing the reliability of the susceptibility data for informing empirical treatment strategies [13,14].

Overall Implications

- The high culture-positive rate (52.2%) and the dominance of *Klebsiella* spp. and *Pseudomonas* spp. underscore the significant burden of Gram-negative infections in LRTIs [11,12].

- Comparable susceptibility profiles within Enterobacterales support the continued use of carbapenems and ceftazidime-avibactam while highlighting the need for cautious antibiotic use to prevent further resistance [15,16].
- The high reliability of Cefoperazone-sulbactam in *Acinetobacter* and the robust performance of Vancomycin and Linezolid against Gram-positive cocci provide a solid basis for current therapeutic approaches, despite the concerning low Cefoxitin susceptibility in *S. aureus* [19,22].
- Overall, these findings reinforce the need for continuous surveillance and targeted antimicrobial stewardship to combat antimicrobial resistance and optimize empirical treatment [14,23,24,25].

Collectively, our results not only corroborate earlier observations but also provide nuanced insights specific to our tertiary care setting, supporting evidence-based modifications to empirical treatment protocols.

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