Pak. J. Chest Med. 2025;31(03)

Original Article

journal homepage: https:/www.pjcm.net/

Pakistan Journal of Chest Medicine

Official journal of Pakistan Chest Society

Bacteriological Profile and Antibiotic Susceptibility Patterns in Acute Exacerbations of COPD Among Hospitalized Patients

Muhammad Ramazan[1], Junaid Shah[2], Amjad Nawaz[2], Muddasir Shehzad[1]✉

[1]Department of Pulmonology, Mufti Mehmood Teaching Hospital, Dera Ismail Khan - Pakistan [2]Department of Medicine, Mufti Mehmood Teaching Hospital, Dera Ismail Khan - Pakistan

Corresponding Author:
Muddasir Shehzad
Department of Pulmonology,
Mufti Mehmood Teaching Hospital,
Dera Ismail Khan - Pakistan
Email: docshehzad0022 @yahoo.com

Article History:

Received:	May 10, 2025
Revised:	July 25, 2025
Accepted:	Aug 15, 2025
Available Online:	Sep 02, 2025

Author Contributions:
MR conceived idea, JS drafted the study, AN MS collected data, AN did statistical analysis and interpretation of data, MR AN critical reviewed manuscript. All approved final version to be published.

Declaration of conflicting interests:
The authors declare that there is no conflict of interest.

How to cite this article:
Ramazan M, Shah J, Nawaz A, Shehzad M. Bacteriological Profile and Antibiotic Susceptibility Patterns in Acute Exacerbations of COPD Among Hospitalized Patients. Pak J Chest Med. 2025;31(03):255-264.

ABSTRACT

Background: Acute Exacerbations of Chronic Obstructive Pulmonary Disease (AECOPD) are critical events, often triggered by bacterial infections. The bacteriological profile and antibiotic susceptibility patterns are highly region-specific and evolve over time, necessitating local surveillance to guide effective empirical therapy.

Objective: To determine the sputum bacteriological profile in hospitalized patients with acute exacerbation of COPD.

Methodology: A prospective cross-sectional study was conducted on 240 hospitalized patients who met the GOLD criteria for AECOPD and were enrolled. Demographic and clinical data were collected. Sputum samples were obtained for culture and antibiotic susceptibility testing, which was performed using the Kirby-Bauer disk diffusion method.

Results: Results showed that the mean age of participants was 61.4 ± 10.2 years, with a male predominance (76.7%). Sputum culture was positive in 118 patients (49.2%). Streptococcus pneumoniae (28.8%) was the most common single isolate, but Gram-negative bacteria collectively predominated, led by Escherichia coli (16.9%) and Klebsiella pneumoniae (12.7%). Culture positivity showed a strong, significant association with purulent sputum (94.5%), severe GOLD grade (76.7%), and hypoxemia at presentation (SpO_2<80%; 80.0%). Antibiotic susceptibility revealed high resistance in Gram-negative isolates to ceftriaxone (15-30%) and fluoroquinolones (20-45%), while carbapenems and polymyxins remained highly effective.

Conclusion: The bacteriology of AECOPD in our region is characterized by a high prevalence of multidrug-resistant Gram-negative bacilli. Clinical markers, such as sputum purulence and hypoxemia, can help identify patients with a high probability of bacterial infection. The documented resistance patterns necessitate an urgent revision of empirical antibiotic guidelines, favoring carbapenems over cephalosporins and fluoroquinolones in cases of severe infection.

Keywords: Respiratory Diseases; AECOPD; Sputum Bacterial Profile; Antibiotic Resistant Pattern

Introduction

Chronic Obstructive Pulmonary Disease (COPD) is a serious, growing global health problem. Its key features are persistent respiratory symptoms and irreversible airflow limitation. COPD causes substantial morbidity, mortality, and economic and social burdens. Acute exacerbation (AECOPD), a sudden symptom worsening requiring therapy adjustment, is central to COPD.[1] These exacerbations drive disease progression, hasten lung function decline, reduce quality of life, raise healthcare costs, and increase mortality.[2]

The causes of AECOPD are numerous and varied, and it is estimated that approximately 50-70% of cases are attributed to infectious agents, including bacteria and viruses.[3] Among these, the role of bacteria is the most pronounced. The leading "pathogen hypothesis" suggests that the introduction of new bacterial strains or the multiplication of pre-existing bacteria colonizing the lower airways may lead to an exacerbated inflammatory response, thereby triggering exacerbations.[4] The bacterial pathogens most frequently detected in AECOPD are Haemophilus influenzae, Streptococcus pneumoniae, and Moraxella catarrhalis.[5] In patients with serious underlying diseases, a high incidence of exacerbations, and/or a history of previous antibiotic treatment, Gram-negative pathogens such as Pseudomonas aeruginosa and Enterobacteriaceae are becoming increasingly common, posing a major therapeutic challenge.[6]

Management of AECOPD patients mostly relies on the use of empirical antibiotics, particularly in patients who are hospitalized with severe dyspnea, large amounts of sputum, and the presence of pus in sputum.[1,7] The first choice of antibiotic is based on local microbial resistance patterns and patient-specific factors that indicate the presence of drug-resistant organisms. But the increasing antimicrobial resistance (AMR) worldwide is undermining the effectiveness of the standard empirical treatments.[8] Resistance mechanisms like beta-lactamase production in H. influenzae and M. catarrhalis, along with the rise of MDR pathogens such as P. aeruginosa, are making it harder for first-line drugs to work.[9] The situation of increasing resistance is indeed challenging from the clinician's point of view, as it may result in unsuccessful treatments, longer hospital stays, and even poorer patient outcomes.

This issue is very prominent in hospitals. Patients with AECOPD are usually at a more advanced disease stage and have multiple conditions. This makes them more sensitive to infections with resistant bacteria. Updated local bacteriological and susceptibility data are essential for informed empirical antibiotic choice, as emphasized in current clinical guidelines.[1,10] The pattern of bacterial pathogens and their resistance is not fixed. These patterns differ between regions and change over time due to factors such as local antibiotic usage and infection control measures.[11] Using outdated or non-local data can result in incorrect therapy and encourage the emergence of resistant strains.

Being aware of the significant impact of AECOPD on a patient's health and the decisive role of antibiotics in its management, we see the need for ongoing local monitoring. International guidelines suggest treatment, but require modification to the local microbiological situation. Our location urgently needs up-to-date, localized information about the bacteriological profile and antibiotic susceptibility patterns in hospitalized AECOPD patients. This research aims to address this gap. By systematically identifying the main bacteria and their antibiotic resistance in patients' sputum, our results will form a foundation for improving local empirical antibiotic guidelines. These improvements seek to enhance clinical outcomes, shorten hospital stays, and strengthen antimicrobial stewardship programs.

Objective

To determine the sputum bacteriological profile in hospitalized patients with acute exacerbation of COPD.

Methodology

This was a prospective, cross-sectional, observational study conducted to determine the sputum bacteriological profile and antibiotic susceptibility patterns in patients hospitalized with Acute Exacerbation of COPD (AECOPD). The study was conducted in the Department of Pulmonology, Mufti Mahmood Teaching Hospital, D.I. Khan. The data collection period spanned 18 months, from July 2023 to December 2024. The study population consisted of adult patients (age ≥15 years) admitted to the hospital with a clinical diagnosis of AECOPD.

The study enrolled adult patients aged 40 years and above who were admitted to the hospital with a clinical diagnosis of Acute Exacerbation of COPD (AECOPD). A confirmed diagnosis of COPD, as per the Global Initiative for Chronic Obstructive Lung Disease (GOLD) criteria, was a prerequisite for inclusion, established by post-bronchodilator spirometry (FEV1/FVC < 0.70) performed during a prior stable state.[1] The acute exacerbation was defined clinically as a worsening of respiratory symptoms necessitating hospitalization, based on the Winnipeg criteria, which includes Type 1 exacerbations (presence of all three cardinal symptoms: increased dyspnea, increased sputum volume, and increased sputum purulence) or Type 2 (presence of any two of these symptoms).[12] Furthermore, participants had to be able to produce an adequate sputum sample for microbiological analysis.

Patients were excluded from the study if they had a history or radiological evidence of conditions that could confound the diagnosis or bacteriology, such as

bronchiectasis, active pulmonary tuberculosis, bronchial asthma, or lung malignancy. Those with a new lung infiltrate on chest X-ray, indicative of community-acquired pneumonia, were also excluded. To ensure the assessment of a true community-acquired bacterial profile, patients who had been admitted to a hospital or used antibiotics within the 21 days preceding the current admission were excluded. Additionally, the study excluded patients who required immediate admission to the Intensive Care Unit (ICU) or non-invasive/invasive ventilation at presentation, as their critical condition warranted different management protocols. Finally, individuals with significant comorbid conditions, such as congestive heart failure (NYHA Class III/IV) or ischemic heart disease with a recent acute coronary syndrome, were excluded to minimize the potential impact of non-pulmonary organ dysfunction on the study outcomes.

Following the acquisition of informed written consent, all patients enrolled in the study underwent a comprehensive clinical evaluation. A structured proforma was used to systematically collect relevant data. This included recording baseline demographic details such as age, gender, and residential area. A detailed smoking history was obtained, categorizing patients as current, former, or never-smokers and quantifying tobacco exposure in pack-years. A specific history of exposure to biomass fuel was also documented. Upon admission, clinical symptoms and vital signs were meticulously recorded, with particular attention paid to the peripheral capillary oxygen saturation (SpO_2) measured on room air. Furthermore, the character of the expectorated sputum was visually assessed and classified as mucoid, mucopurulent, or purulent.

An early-morning, deep-cough sputum sample was collected from each patient within 24 hours of admission, prior to the initiation of antibiotic therapy. Patients were instructed to rinse their mouth thoroughly with water before expectoration to minimize oropharyngeal contamination. Sputum was collected in a sterile, wide-mouthed, screw-capped container.

The quality of the sputum sample was assessed by Gram staining. A sample was deemed adequate for culture if it contained <10 squamous epithelial cells per low-power field (LPF) and >25 polymorphonuclear leukocytes (pus cells) per LPF.[13] Samples that did not meet this criterion were rejected, and a new sample was requested.

Adequate samples were immediately transported to the hospital's microbiology laboratory for processing. The samples were inoculated onto standard culture media, including Blood Agar, MacConkey Agar, and Chocolate Agar. The plates were incubated aerobically at 37°C for 24 to 48 hours. Bacterial identification was performed using conventional biochemical tests according to standard microbiological techniques.

Antibiotic susceptibility testing of the significant bacterial isolates was performed using the Kirby-Bauer disk diffusion method on Mueller-Hinton agar, as per the guidelines of the Clinical and Laboratory Standards Institute (CLSI).[14] For fastidious organisms like Streptococcus pneumoniae and Haemophilus influenzae, specific media (e.g., Mueller-Hinton agar with 5% sheep blood or HTM agar) were used as required.

The antibiotics tested were selected based on local prescribing patterns and relevance to respiratory pathogens. They included Amoxicillin-Clavulanate, Levofloxacin, Moxifloxacin, Amikacin, Piperacillin-Tazobactam, Third-generation Cephalosporins (Ceftriaxone/Cefotaxime), Carbapenems (Imipenem/Meropenem), Colistin/Polymyxin B. The results were interpreted as Sensitive (S), Intermediate (I), or Resistant (R) based on CLSI breakpoints.

The collected data were entered and analyzed using Statistical Package for the Social Sciences (SPSS) version 26.0. Descriptive statistics were used to summarize demographic and clinical characteristics. Categorical variables (e.g., gender, sputum type, bacterial isolates) were presented as frequencies and percentages. Continuous variables (e.g., age, SpO_2) were presented as mean ± standard deviation or median with interquartile range, depending on the normality of the data. The Chi-square test (or Fisher's exact test, where appropriate) was used to determine the association between categorical variables (e.g., sputum character, SpO_2 < 80%, COPD severity) and sputum culture positivity. A p-value of less than 0.05 was considered statistically significant.

Ethical approval (29-02/22/MTI-IRB) for the study was obtained from the Institutional Ethical Review Committee of Mufti Mahmood Teaching Hospital, D.I. Khan. Written informed consent was obtained from all participants after they were informed of the study's purpose and procedures. Confidentiality of all patient data was maintained throughout the research process.

Results

In the present study a total of 240 hospitalized patients with acute exacerbation of COPD (AECOPD) were included. The mean age of participants was 61.4 ± 10.2 years, with the majority belonging to the 51–60-year age group (34.2%), followed by 61–70 years (26.3%) (Table 1).

Gender-based distribution showed that males were dominant 76.7% (n = 184) among the study population (Figure 1).

Results showed that, out of 240 patients, 118 (49.2%) showed positive sputum culture growth, while 122 (50.8%) were culture negative (Figure 2).

Among the 118 culture-positive specimens, the most frequent isolate was Streptococcus pneumoniae (34/118; 28.8%), followed by Escherichia coli (20/118; 16.9%), Klebsiella pneumoniae (15/118; 12.7%), and Acinetobacter spp. (14/118; 11.9%). Other isolates included Haemophilus influenzae (12; 10.2%), Moraxella

Table 1. Age-wise Distribution of Patients (N = 240)

Characteristics	Frequency (n)	Percentage (%)
Age Group (years)		
40–50	48	20.0
51-60	82	34.2
61-70	63	26.3
71-80	32	13.3
>80	15	6.3
Residence		
Rural	129	53.7
Urban	111	46.3
Smoking History		
Yes	158	65.8
No	82	34.2
Duration of Illness		
≤2 weeks	92	38.3
>2 weeks	148	61.7

catarrhalis (10; 8.5%), Pseudomonas aeruginosa (11; 9.3%) and Citrobacter spp. (2; 1.7%) (Table 2).

Most patients produced mucoid sputum (125/240; 52.1%), while mucopurulent (60/240; 25.0%) and purulent (55/240; 22.9%) expectoration were less common. Culture positivity differed markedly by sputum character: mucoid samples were culture-positive in 20/125 (16.0%), mucopurulent in 46/60 (76.7%), and purulent in 52/55 (94.5%) ($p < 0.001$) (Table 3)

On severity grading (GOLD-based), 110 (45.8%) were classified as mild, 100 (41.7%) moderate, and 30 (12.5%) severe. Culture positivity increased with severity: mild 40/110 (36.4%), moderate 55/100 (55.0%), and severe 23/30 (76.7%) (Table 4). The trend indicates higher likelihood of bacterial isolation in more severe obstruction.

Peripheral oxygen saturation (SPO2) and culture positivity Patients with SPO2 < 80% at presentation had a higher culture positivity rate: 20/25 (80.0%), compared with 98/215 (45.6%) among those with SPO2 ≥ 80% (Table 5). This association suggests lower oxygenation correlates with higher probability of bacterial infection.

The antibiotic susceptibility patterns demonstrated marked differences between Gram-positive and Gram-negative organisms. Streptococcus pneumoniae, Haemophilus influenzae, and Moraxella catarrhalis retained high sensitivity to most of the commonly used agents, including fluoroquinolones, amoxicillin–clavulanate, and amikacin, with susceptibility rates exceeding 85% across these groups. In contrast, Gram-negative bacilli exhibited a distinctly high resistance profile. Enterobacterales, particularly E. coli and Klebsiella pneumoniae, exhibited poor susceptibility to ceftriaxone (15–30%) and fluoroquinolones (20–45%), reflecting significant regional trends in resistance. Aminoglycosides demonstrated moderate activity, with amikacin susceptibility ranging from 45% to 70% among Gram-negative isolates. Carbapenems remained the most reliable β-lactams, with meropenem susceptibility between 70% and 90% across major Gram-negative pathogens. Notably, polymyxins (colistin and polymyxin B) maintained near-universal efficacy, with susceptibility rates of 95–100% for all isolates, including multidrug-resistant strains. Tigecycline showed good activity against Enterobacterales (60–80%), though susceptibility was lower in Acinetobacter spp (Table 6).

Results showed that Gram-positive organisms, particularly Streptococcus pneumoniae and Haemophilus influenzae, demonstrated uniformly high susceptibility across most antibiotic classes, reflected by the darker high-percentage zones. In contrast, Gram-negative bacilli showed extensive resistance to cephalosporins and fluoroquinolones, evident from the lighter color gradients in these columns. Carbapenems and polymyxins remained the most effective agents, displaying the highest susceptibility rates among resistant isolates. The heatmap clearly highlights the disparity in resistance patterns between Gram-positive and Gram-negative pathogens, visually emphasizing the limited efficacy of several commonly prescribed antibiotics in AECOPD

Table 2. Distribution of Bacterial Isolates (n = 118)

Organism	Count	Percentage (%)
Streptococcus pneumoniae	34	28.8
Haemophilus influenzae	12	10.2
Moraxella catarrhalis	10	8.5
Escherichia coli	20	16.9
Klebsiella pneumoniae	15	12.7
Acinetobacter spp.	14	11.9
Pseudomonas aeruginosa	11	9.3
Citrobacter spp.	2	1.7

(Figure 3).

Discussion

A comprehensive exploration of the bacteriological profile and antibiotic resistance trends in hospitalized patients with AECOPD in D.I. Khan, Pakistan, is presented in this prospective study. One of the main outcomes is the detection of bacterial infection in nearly 50% of the exacerbations, with a clear dominance of Gram-negative bacteria. There is also a tight linkage between sputum purulence, disease severity, hypoxemia, and culture positivity. Furthermore, the situation is worrying due to the emergence of antimicrobial resistance among Enterobacterales and non-fermenting bacilli.

The mean age in our cohort was 61.4 years, with the majority of participants being male (76.7%). This matches the usual demographic profile for COPD and often relates to higher smoking rates and male occupational exposures.[15] Many patients were smokers (65.8%), and over half came from rural areas (53.7%). Rural origin suggests a possible influence of biomass fuel exposure, a recognized risk factor for COPD, especially among women.

A pivotal finding of our research was that 49.2% (118/240) of sputum cultures were positive for potential bacterial pathogens, closely aligning with other studies that cite a roughly 50% bacterial cause in AECOPD cases.[3] However, our results indicate a shift in the types of bacteria present. While Streptococcus pneumoniae remained the most frequently isolated species (28.8%), Gram-negative bacteria (GNB) collectively accounted for a substantial share of the isolates, specifically Escherichia coli (16.9%), Klebsiella pneumoniae (12.7%), and

Table 3. Correlation of Sputum Character with Sputum Culture Positivity (N = 240)

Sputum Character	Total Patients (n)	Culture Positive (n)	Culture Positive (%)
Mucoid	125	20	16.0%
Mucopurulent	60	46	76.7%
Purulent	55	52	94.5%
Total	240	118	49.2%

Table 4. Association of COPD Severity (GOLD Grade) with Sputum Culture Positivity

COPD Severity (GOLD)	Total Patients (n)	Culture Positive (n)	Culture Positive (%)
Mild	110	40	36.4%
Moderate	100	55	55.0%
Severe	30	23	76.7%
Total	240	118	49.2%

Acinetobacter spp. (11.9%), and Pseudomonas aeruginosa (9.3%). This is notable because traditional teaching highlights H. influenzae, S. pneumoniae, and M. catarrhalis as the primary pathogens.[15] Our findings, consistent with Sharma et al. (2017) from India, who observed a GNB dominance of 35.7%, suggest that E. coli and Acinetobacter are now prominent isolates.[16] This apparent shift may result from increased antibiotic selective pressure, more severe underlying conditions in hospitalized patients, or geographic differences in microbial populations.

Sputum quality is a reliable clinical indicator of bacterial infection. Culture positivity rises markedly from 16.0% in patients with mucoid sputum to 94.5% in those with purulent sputum ($p < 0.001$). This strongly supports the Anthonisen criteria, identifying sputum purulence as a key marker for bacterial exacerbation and a rationale for antibiotic use.[7] We also found a strong correlation between airflow obstruction and culture positivity. Patients with severe GOLD-grade COPD have a much higher bacterial isolation rate (76.7%) than those with mild disease (36.4%). This trend supports the idea that advanced disease, marked by impaired mucus clearance and lung damage, fosters a more favorable environment for bacterial colonization and infection.[4]

The main contribution of our study is the revelation of a strong link between hypoxemia at admission and positive sputum cultures. Patients with SpO_2 below 80% on room air had an 80% chance of a positive bacterial culture, compared to 45.6% for those with better oxygenation ($p < 0.001$). The causes of hypoxemia in AECOPD are complex; however, this evidence suggests that more severe bacterial infections may produce a greater ventilation-perfusion mismatch and physiological shunting. This finding, also noted by Sharma et al., warrants further study as a potential simple bedside

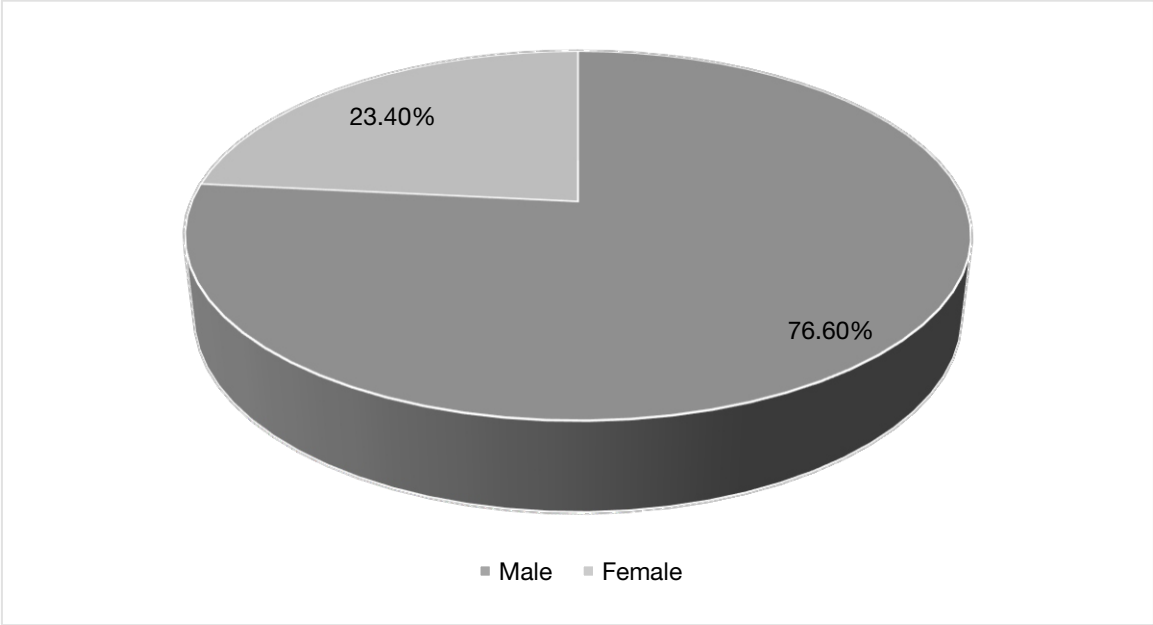

Figure 1. Gender based distribution of study cases

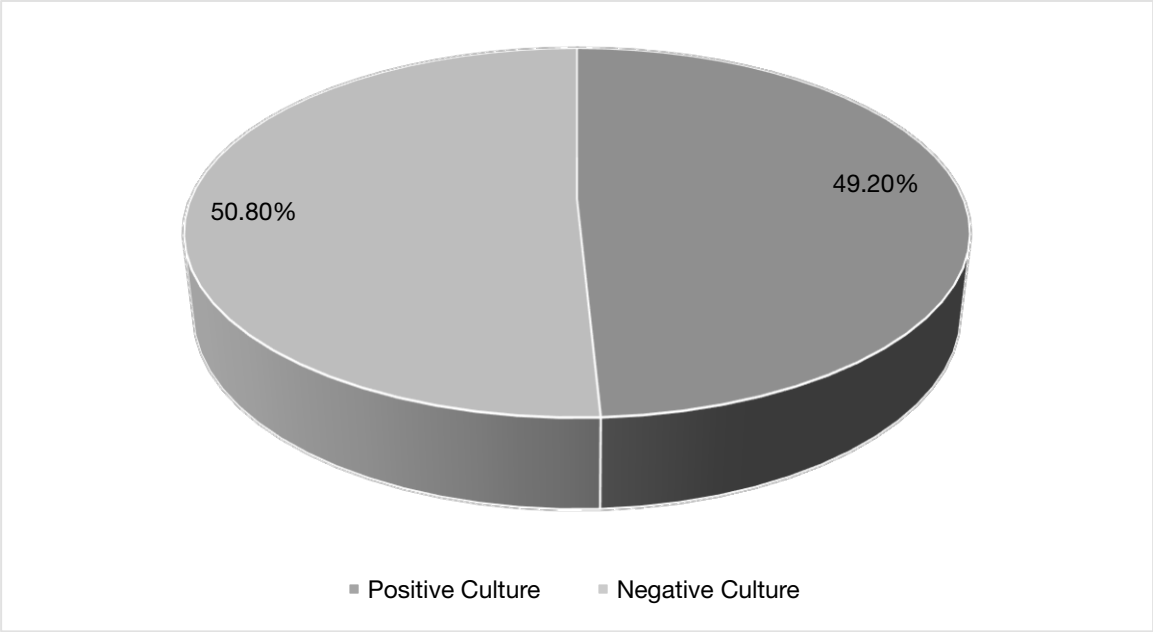

Figure 2. Sputum culture results of the study cases

predictor to aid in guiding empirical antibiotics in resource-limited settings where rapid microbiological tests are unavailable.[16]

The antibiotic susceptibility patterns showed a significant difference between Gram-positive and Gram-negative pathogens. The classic pathogens (S. pneumoniae, H. influenzae, M. catarrhalis) remained highly susceptible (>85%) to many first- and second-line antibiotics, including fluoroquinolones, amoxicillin-clavulanate, and cephalosporins. This aligns with the patterns reported in a multinational study by Dimopoulos et al., which showed good sensitivity to common oral agents for these organisms.[9]

The Gram-negative isolates, on the other hand, showed complete resistance. E. coli and K. pneumoniae's susceptibility to ceftriaxone was very low (25% and 22%, respectively), which was a clear indication of the great extent of the production of extended-spectrum beta-lactamase (ESBL). Fluoroquinolone resistance was also extremely high, and the susceptibility of these organisms ranged from 20% to 45%. Thus, the resistance profile very much restricts the use of these two groups of drugs, which are often given for oral and intravenous administration. Our results are more drastic but in the same direction as the study in Nepal by Chawla et al. (2008), which also observed increasing resistance in Gram-negative isolates from AECOPD patients, especially to cephalosporins and fluoroquinolones.[17] A recent study from Pakistan has confirmed the rise in Gram-negative resistance in respiratory isolates. The study found that ICU settings have a high prevalence of multidrug-resistant Acinetobacter baumannii and K. pneumoniae, thereby exacerbating the situation in the region.[18] It is possible that high resistance in our area is due to the fact that these antibiotics are available over the counter and that their use is not always justified in the community. This is supported by regional surveillance data, which show that non-prescription antibiotic use is a primary factor contributing to the resistance patterns found in clinical isolates throughout South Asia.[19]

Carbapenems, particularly meropenem, have been dependable for treating GNB infections, with suscep-

Table 5. Correlation of SPO_2 at Presentation with Sputum Culture Positivity

SPO_2 Category	Total Patients (n)	Culture Positive (n)	Culture Positive (%)
< 80%	25	20	80.0%
≥ 80%	215	98	45.6%
Total	240	118	49.2%

Table 6. Antibiotic Susceptibility Pattern of Bacterial Isolates

Organism	Amox-Clav	Levo flox	Moxi flox	Amika cin	Pip-Tazo	Ceftria xone	Merope nem	Colistin	Polymy xin-B	Tigec ycline	Azithro mycin
Strep. pneumoniae (n=34)	90%	88%	95%	92%	85%	80%	98%	100%	100%	95%	85%
H. influenzae (n=12)	85%	90%	92%	80%	88%	78%	95%	100%	100%	88%	82%
M. catarrhalis (n=10)	88%	90%	90%	85%	85%	82%	92%	100%	100%	87%	88%
E. coli (n=20)	20%	35%	30%	65%	50%	25%	85%	98%	98%	80%	10%
K. pneumoniae (n=15)	15%	40%	45%	60%	48%	22%	80%	95%	95%	70%	12%
Acinetobacter spp. (n=14)	10%	20%	25%	45%	30%	15%	70%	98%	98%	65%	8%
P. aeruginosa (n=11)	25%	45%	50%	70%	60%	30%	90%	99%	99%	85%	15%
Citrobacter spp. (n=2)	30%	35%	40%	55%	45%	20%	75%				

tibility rates ranging from 70% to 90%. Yet, the rise of non-susceptibility in Acinetobacter spp. (70% prevalence), In particular, it is regarded as a serious concern and has raised the alarm over the gradual threat of carbapenem resistance. The polymyxins (colistin and polymyxin B) were the most consistently effective agents against all bacterial isolates, including multidrug-resistant GNB, with susceptibility rates higher than 95%. This can be taken as confirmation of their positioning as last-resort agents, but their pronounced nephrotoxicity and neurotoxicity limit their use. Tigecycline was found to exhibit variable activity, being more potent against Enterobacterales than against Acinetobacter.

Limitations

Our investigation has several limitations. One of the biggest drawbacks is that, despite performing quality checks, we still faced a risk of oropharyngeal contamination when using spontaneously expectorated sputum. This risk may have led us to overestimate the role of some organisms, such as E. coli. Bronchoscopic sampling could have provided a more accurate representation of the lower airway microbiome; however, this method was not suitable for our study. Furthermore, we did not conduct molecular testing for viral pathogens or atypical bacteria, despite their known ability to cause a significant number of exacerbations. As a result, we were unable to evaluate the true microbiological yield and the interaction between viral and bacterial pathogens. Additionally, since we conducted a single-center study, the local epidemiology in D.I. Khan may have influenced our results, which may not be applicable to other areas or populations. Even so, we acknowledge that our findings support the argument for regional differences in AECOPD bacteriology and contribute to the growing literature in this area.

Conclusion

To summarize, our research reveals a significant shift in local AECOPD bacteriology, with Gram-negative bacteria now predominating. These bacteria often display resistance, especially among multi-resistant strains. Clinical signs, such as the presence of pus in sputum, significant decline in lung capacity, and low blood oxygen levels strongly indicate positive cultures. Local strains have become resistant to cephalosporins and fluoroquinolones, making these drugs unsuitable for empirical AECOPD treatment in hospitals. We recommend preparing and strictly following local antibiotic guidelines based on regular monitoring of microbial susceptibility. For severe or GNB-risk cases, consider carbapenems; reserve polymyxins for culture-confirmed resistant infections. Future studies should add viral diagnostics and evaluate the cost-effectiveness and clinical impact of

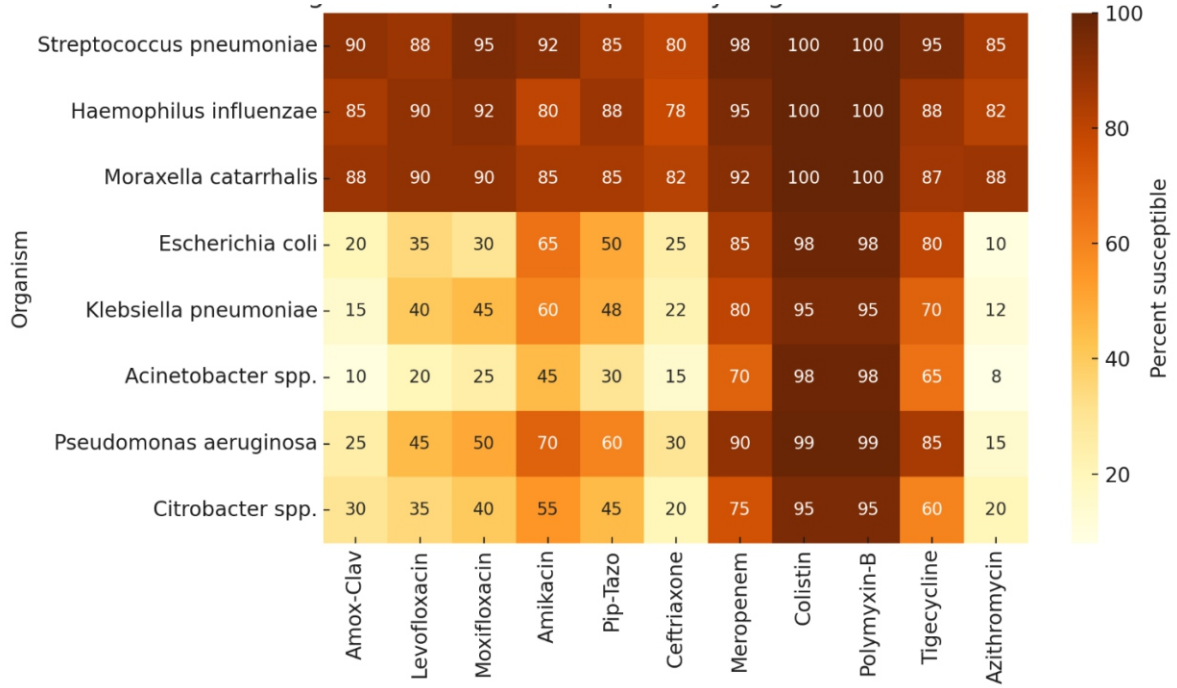

Figure 3. Percent Susceptible by Organism and Antibiotic

local guidelines.

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