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Bacterial Etiology and Antibiotic Susceptibility Patterns in Acute Exacerbations of Chronic Obstructive Pulmonary Disease: Implications for Targeted Antimicrobial Therapy

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ABSTRACT

Background: Hospitalization is frequently required for acute exacerbations of chronic obstructive pulmonary disease (AECOPD), which have a substantial impact on patient morbidity and mortality. These exacerbations are mostly caused by bacterial infections and managing them effectively is made more difficult by the growing trend of antibiotic resistance.

Objective: To identify the bacterial infections that cause AECOPD and ascertain their patterns of antibiotic susceptibility to inform the development of suitable treatment plans.

Methodology: A prospective, cross-sectional observational study was carried out over a period of six months. A total of 110 participants with clinically confirmed AECOPD who were at least 40 years old and had not taken antibiotics during the previous 48 hours were included in the study. Following the recommendations set forth by the Clinical and Laboratory Standards Institute (CLSI), sputum samples were obtained and submitted to Gramme staining, culture, and antibiotic susceptibility testing utilizing the Kirby-Bauer disc diffusion method.

Results: Among study cases, sputum samples of 82 (74.5%) had notable bacterial growth. Gram-negative bacteria accounted for 82.9% of the total, with the most frequent isolates being Klebsiella pneumoniae (34.1%) and Pseudomonas aeruginosa (24.4%). Haemophilus influenzae (9.8%) and Streptococcus pneumoniae (12.2%) were commonly found among Gram-positive organisms. It is noteworthy that 43.9% of isolates were multidrug-resistant (MDR), with Pseudomonas aeruginosa (60%) and Acinetobacter baumannii (75%) having the highest MDR frequencies.

Conclusion: The study concludes that Gram-negative bacilli with high rates of multidrug resistance are the primary cause of the notable incidence of bacterial infections in AECOPD. These results highlight the need for regular sensitivity testing and sputum culture to direct targeted antibiotic treatment, enhancing patient outcomes and halting the spread of antibiotic resistance.

Keywords: Acute Exacerbation of COPD (AECOPD); Sputum Bacteriology; Bacterial Profile; Multidrug Resistance (MDR)

Introduction

Chronic Obstructive Pulmonary Disease (COPD) is a widespread and worsening lung disease that causes airflow problems and long-term inflammation in the lungs. It is usually caused by breathing in harmful particles or gases for a long time, with tobacco smoking being the most common cause.[1] It includes conditions like chronic bronchitis and emphysema and is linked to changes in the structure of the lungs, restriction of the tiny airways, and destruction of the alveoli. The World Health Organization (WHO) says that COPD is the third greatest cause of death in the world. It affects more than 250 million people and adds a lot to the global illness burden.[2] In South Asia and low- to middle-income nations, COPD is becoming more common because of more pollution in cities, exposure to biomass fuel, and not being diagnosed correctly.

One of the most important things about the condition is that it gets worse over time, with sudden worsening episodes called Acute Exacerbations of COPD (AECOPD). During these episodes, symptoms including cough, shortness of breath, and sputum volume or purulence suddenly get worse, and they typically need a change in medication or hospitalization.[3] Recurrent exacerbations speed up the deterioration of lung function, make life worse, raise healthcare expenditures, and elevate the risk of death. When stable COPD turns into frequent exacerbations, it is a very important turning point in the management of the disease. It requires quick diagnosis and the right treatment.

A diagnosis of AECOPD is mostly based on clinical evidence, such as the patient's symptom history and the results of a physical exam. But other diagnostic spreading methods are used to rule out other diseases and figure out how serious the problem is. Spirometry is still the best way to establish COPD, although during flare-ups, procedures including chest X-rays, pulse oximetry, arterial blood gases (ABG), and sputum analysis (including Gramme stain and culture) are often performed.[4] Finding the cause of the infection, especially bacterial infections, is very important for guiding antimicrobial therapy during AECOPD.

Bronchodilators, corticosteroids, oxygen, and, if necessary, antibiotics are all used to treat AECOPD. A lot of people use antibiotics without a prescription, especially when they think they have a bacterial infection based on Anthonisen's criteria (increased dyspnoea, sputum volume, and sputum purulence).[5] However, because antimicrobial resistance is becoming more common, especially in patients who are already in the hospital, it is now very important to choose the right antibiotics. Klebsiella pneumoniae, Pseudomonas aeruginosa, and Escherichia coli are some of the common bacteria that are becoming more resistant to fluoroquinolones, cephalosporins, and even carbapenems in some circumstances.[6,7]

It is important to do antibiotic susceptibility testing according to the Clinical and Laboratory Standards Institute (CLSI) criteria to find the best treatment options and stop the overuse of broad-spectrum antibiotics.[8] In this case, culture and sensitivity testing of sputum samples is an important tool for making clinical decisions, lowering the number of treatment failures, and stopping the spread of multidrug-resistant (MDR) organisms. The changing range of bacteria and their susceptibility profiles mean that constant monitoring is needed to change empirical treatment procedures as needed.[9]

There is an urgent need to collect data on the bacterial causes of AECOPD and the antibiotic sensitivity patterns that go along with them in lower-middle-income countries where antibiotic usage is frequent. This is because antibiotic resistance is becoming a bigger problem. Much international research has brought this issue to light, yet there is still not enough regional evidence to help antibiotic stewardship efforts. The purpose of this study is to fill in this gap by looking at the types of bacteria and how resistant they are to antibiotics in pathogens taken from hospitalized AECOPD patients in our context. This information will help doctors make smart judgements about treatment and help create antibiotic guidelines that are tailored to each region.

Objective

To identify the bacterial infections that cause AECOPD and ascertain their patterns of antibiotic susceptibility to inform the development of suitable treatment plans.

Methodology

An observational study was conducted at a CMH Peshawar from January 2023 to December 2023 to identify the responsible bacteria for COPD exacerbations and understand antibiotic susceptibility patterns. In this study a total of 110 COPD patients were enrolled.

The included patients strictly follow the inclusion criteria of adults aged 40 years and older experiencing a clinical diagnosis of acute COPD exacerbation, marked by increased cough, sputum production, and dyspnoea and had not taken antibiotics in the 48 hours before enrolment. Patients were excluded if they had asthma, active pulmonary tuberculosis, interstitial lung disease, bronchiectasis, were immunocompromised (e.g. HIV/AIDS, cancer, immunosuppressive drugs), recently used antibiotics, pregnant or breastfeeding, or had cognitive impairment affecting consent.

Each participant was asked to provide sputum samples. To ensure sample quality, they first rinsed their mouths and avoided eating or drinking for at least one hour before sputum collection. After collecting, the samples were then quickly transported to the laboratory within two hours,

which is required to keep any potential bacteria alive for accurate testing. In the lab, the sputum was first examined visually for color and thickness. Next, a Gram stain was performed to check for white blood cells (neutrophils, which indicate infection) and mouth cells (epithelial cells, which suggest contamination). Only samples with enough neutrophils (more than 25 per slide view) and minimal mouth cells (fewer than 10 per slide view) were processed further for bacterial culture. Cultures were incubated for 18–24 hours at 37 °C, with bacterial colonies identified by appearance, Gram stain features, and biochemical tests such as catalase, oxidase, and coagulase. When available, advanced identification methods like MALDI-TOF or automated systems (e.g., VITEK 2) were used to precisely determine bacterial species.

Antibiotic susceptibility was tested using the Kirby–Bauer disc diffusion method, following Clinical and Laboratory Standards Institute standards. Antibiotics tested included Imipenem, Meropenem, Amikacin, Ciprofloxacin, and Ceftriaxone for Gram-negative bacteria; Vancomycin, Linezolid, and Amoxicillin-Clavulanic acid for Gram-positive bacteria. Zone diameters determined whether bacteria were susceptible, intermediate, or resistant.

For study purposes, special proforma was designed for data collection. Demographic data included age, gender, smoking history, and any other comorbidity, clinical details (duration and severity of exacerbation, history of past exacerbations, steroid or inhaler use), and laboratory results (culture findings and antibiotic susceptibility profiles) were gathered. All data were entered into SPSS version 24 for anlaysis. Means and standard deviations were used for continuous variables, and frequencies and percentages for categorical ones. Associations between categorical variables were tested with Chi-square, with p-values under 0.05 considered significant.

Ethical approval was obtained and every participant provided informed consent, assuring they understood the study's purpose, procedures, and any potential risks.

Results

A total of 110 patients who were presented with an acute aggravation of chronic obstructive pulmonary disease (AECOPD) were included in this cross-sectional study. A thorough analysis was conducted of the sputum's bacteriological spectrum, antibiotic susceptibility patterns, and demographic profile. Male patients made up 70.9% of the total, with female patients making up 29.1% (Figure 1).

The mean age of the study participants was 66.3 ± 8.9 years with majority of participants (41.8%) were between the ages of 60 and 69 years (Figure 2).,

Culture results showed that, out of 110 sputum samples, 82 (74.5%) showed bacterial growth, whereas the remaining 28 (25.5%) showed no significant bacterial growth (Table 1).

Among the positive culture samples, Gram-negative bacilli made up most of the organisms identified from the 82 culture-positive samples (82.9%). Pseudomonas aeruginosa (24.4%) and Escherichia coli (14.6%) were the next most frequent isolates, after Klebsiella pneumoniae (34.1%). The most prevalent Gram-positive bacteria were Streptococcus pneumoniae (12.2%) and Haemophilus influenzae (9.8%), but Acinetobacter baumannii (4.9%)

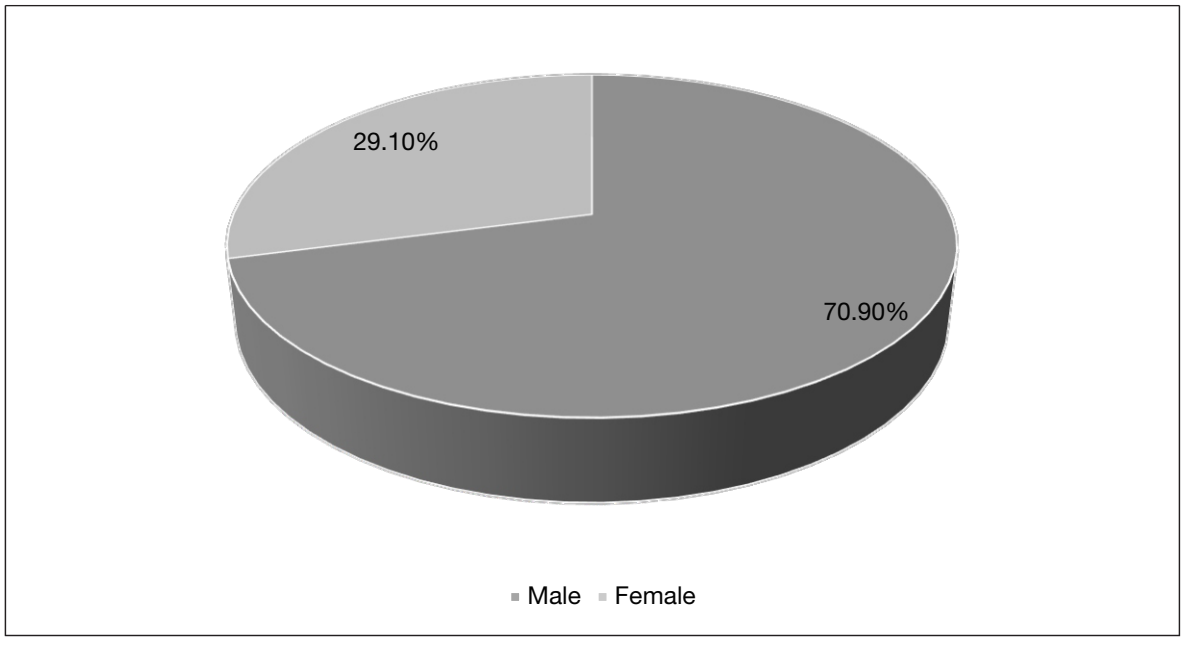

Figure 1. Gender distribution of study cases

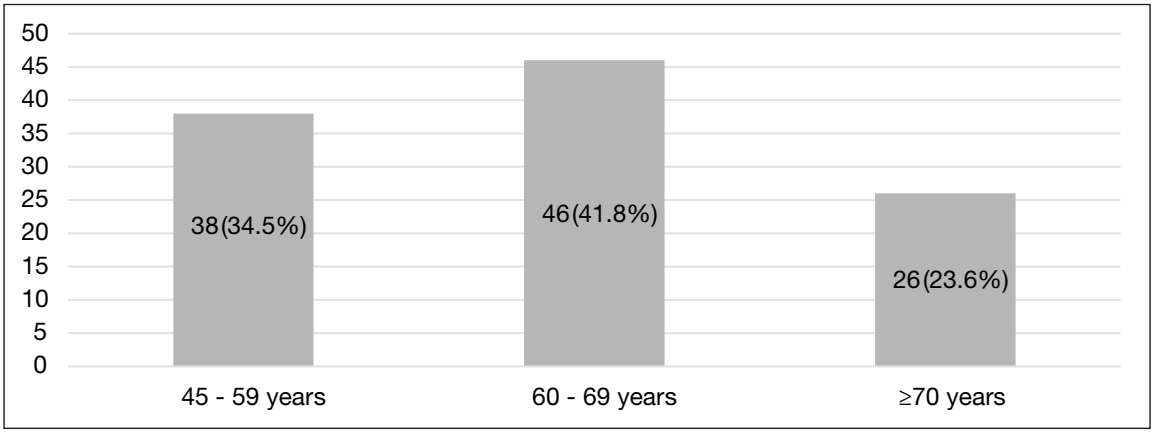

Figure 2. Distribution of study cases by age

recovered less frequently (Table 2).

Meropenem and amikacin were the most effective antibiotics against Gram-negative isolates, according to the antibiotic susceptibility profile, with sensitivity exceeding 80% against all important pathogens. Good efficacy was also demonstrated by piperacillin-tazobactam, especially against Pseudomonas aeruginosa. On the other hand, significant resistance to ceftriaxone, co-trimoxazole, and amoxicillin-clavulanate was noted.

Among the Gram-positive isolates, Haemophilus influenzae and Streptococcus pneumoniae both exhibited intermediate sensitivity to cefotaxime and macrolides and high sensitivity to amoxicillin-clavulanate (≥87%). With co-trimoxazole, the lowest susceptibility was seen.

Results showed that 36 isolates (43.9%) of the culture-positive cases were found to be multidrug-resistant (MDR). Acinetobacter baumannii (75%), Pseudomonas aeruginosa (60%), and Klebsiella pneumoniae (57.1%) had the greatest MDR rates. This is concerning because respiratory infections in people with COPD are becoming more resistant to several antibiotic classes.

According to this study, over three-quarters (74.5%) of patients experiencing a COPD exacerbation had a bacterial infection. The majority of the pathogens were gram-negative bacilli, with the most often isolated organisms being Pseudomonas aeruginosa and Klebsiella

Table 1. Culture results of the study cases

Culture results	Frequency (n)	Frequency (%)
Positive Growth	82	74.5
No Growth	28	25.5

Table 2. Distribution of bacteria growth among sputum samples of study cases

Organism	Frequency (n)	Percentage (%)
Klebsiella pneumoniae	28	34.1%
Pseudomonas aeruginosa	20	24.4%
Escherichia coli	12	14.6%
Streptococcus pneumoniae	10	12.2%
Haemophilus influenzae	8	9.8%
Acinetobacter baumannii	4	4.9%

Table 3. Drug sensitivity pattern of Gram-negative Bacteria to different antibiotics

Drugs	Klebsiella (n=28)	Pseudomonas (n=20)	E. coli (n=12)
Amikacin	85.7%	70%	91.6%
Meropenem	92.8%	90%	83.3%
Piperacillin-tazobactam	75%	85%	66.7%
Ceftriaxone	57.1%	40%	50%
Ciprofloxacin	50%	75%	58.3%
Amoxicillin-clavulanate	32.2%	20%	41.6%
Co-trimoxazole	28.6%	15%	33.3%

pneumoniae. The most effective antibiotics were found to be meropenem and amikacin, whereas oral antibiotics including co-trimoxazole and amoxicillin-clavulanate were ineffective. Acinetobacter baumannii had the highest level of multidrug resistance, accounting for an alarming 43.9% of isolates.

Discussion

In this study of 110 patients experiencing acute COPD flare-ups, we found that about three-quarters had bacterial infections in their sputum. Most of the bacteria were Gram-negative, particularly Klebsiella pneumoniae, Pseudomonas aeruginosa, and E. coli. Among the Gram-positive bacteria, Streptococcus pneumoniae and Haemophilus influenzae were also present. A major concern was that nearly 44% of these bacteria were resistant to multiple antibiotics, especially Acinetobacter baumannii, which showed the highest level of resistance. Among the antibiotics tested, meropenem and amikacin worked best, while common oral antibiotics like co-trimoxazole and amoxicillin-clavulanate were far less effective.

These results reflect a growing trend where bacteria involved in COPD exacerbations are becoming more drug-resistant. Repeated antibiotic exposure, frequent hospital visits, and environmental factors may be contributing to this shift. Similar findings have been reported in other countries. For example, Mussema et al.[10] found that patients with COPD in Ethiopia had high levels of resistance, especially to commonly used antibiotics, while stronger drugs like carbapenems were more effective. Abden et al.[11] also identified resistant organisms in COPD cases, with similar antibiotic response patterns.

In a study, Al-Ezee [12] observed that P. aeruginosa and Klebsiella were frequently isolated, and that these bacteria showed low sensitivity to first-line antibiotics. Raveendra and Devapriya[13] in their study also highlighted a high prevalence of resistant Gram-negative organisms, suggesting a shift in the microbial landscape. In a study, Khatun et al.[14] reported a similar bacteriological profile and stressed the need for updated treatment strategies in hospitals. These studies back up our findings and highlight a common challenge in treating COPD exacer-

Table 4. Drug susceptibility patterns of Gram-Positive bacteria to different Antibiotics

Antibiotic	S. pneumoniae (n=10)	H. influenzae (n=8)
Amoxicillin-clavulanate	90%	87.5%
Cefotaxime	80%	62.5%
Azithromycin	70%	62.5%
Erythromycin	60%	50%
Co-trimoxazole	50%	37.5%

Table 5. Frequency of Multidrug-Resistant (MDR) bacteria among study cases

Organism	MDR Cases (n)	MDR Rate (%)
Klebsiella pneumoniae	16	57.1%
Pseudomonas aeruginosa	12	60%
Escherichia coli	5	41.6%
Acinetobacter baumannii	3	75%
Total MDR Cases	36	43.9%

bations across different settings.

Because of this high resistance, we may need to rethink our approach to treatment. Relying solely on empirical therapy and starting treatment without knowing the exact responsible bacteria and their resistant pattern can lead to poor outcomes. Using culture and sensitivity results to guide treatment can make therapies more effective, especially for high-risk patients. studies like those by Rosenwasser et al.[15] and Reissig et al.[16] also emphasize the importance of choosing antibiotics carefully, especially in severe or hospitalized COPD cases. Vanoverschelde et al.[17] in their study further point out that hospitals need to regularly update their antibiotic policies to keep up with these changes in resistance.

However, this study isn't without its limitations. Since it was conducted in a single hospital, the results might not apply to all settings. We also didn't test for viruses or atypical bacteria, which could be responsible for some cases. Other factors like prior antibiotic use and existing health conditions weren't deeply explored and may have influenced the results. Also, we didn't evaluate how patients responded to treatment or how long they stayed in the hospital.

To improve understanding and treatment, future research should include larger, more diverse populations and consider seasonal or regional patterns in bacterial resistance. It would also be helpful to include viral and atypical infections, and to follow patients over time to assess treatment success. Lastly, investing in quicker and more affordable testing for resistant bacteria can help guide better, faster decisions in treating COPD exacerbations.

Conclusion

With 74.5 percent of patients having culture-positive sputum, this study highlights the substantial prevalence of bacterial infections in AECOPD. The bacteriological profile was dominated by gram-negative bacilli, especially Pseudomonas aeruginosa and Klebsiella pneumoniae. Common oral antibiotics like amoxicillin-clavulanate and co-trimoxazole showed limited performance against these infections, but meropenem and amikacin showed the highest efficacy. Acinetobacter baumannii had the most alarming rates of multidrug resistance, accounting for 43.9% of isolates. These results urge strategic antimicrobial stewardship and emphasize the vital significance of targeted, culture-guided antibiotic therapy, particularly in regions with high MDR incidence. To reduce resistance and improve treatment outcomes in COPD exacerbations, routine regional antibiogram surveillance and prudent empirical antibiotic usage are crucial.

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