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Original Research Article

Microbiological Profile of Bronchoalveolar Lavage Samples from Lower Respiratory Tract Infection Patient

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Abstract

Background: Bronchoalveolar lavage (BAL) sample is the fluid specimen obtained from bronchoalveolar washing during bronchoscopy to diagnose various lung pathologies. This research aims to isolate organisms from BAL samples and determine their antibiotic sensitivity pattern to treat infected patients.

Materials and Methods: This is a prospective observational study conducted at Government Medical College Namakkal in the Department of Microbiology for one year, involving 75 BAL samples from lower respiratory tract infection patients. BAL samples were obtained via bronchoscopy and processed as per standard laboratory guidelines.

Results: Among 75 BAL samples processed, 39 (52%) were culture positive for bacterial growth. The most common organisms isolated were Pseudomonas aeruginosa 19 (48%), Acinetobacter baumannii 10 (25%), Klebsiella pneumoniae 9 (23%), and Burkholderia species 1 (2%). Klebsiella pneumoniae showed high sensitivity to piperacillin-tazobactam 8 (88%), meropenem 8 (88%), and cefotaxime-sulbactam 7 (77%). Pseudomonas aeruginosa was susceptible to ceftazidime-avibactam 15 (78%), meropenem 16 (84%), and piperacillin-tazobactam 16 (84%). Acinetobacter species were susceptible to ceftazidime-avibactam 3 (75%), meropenem 3 (75%), and piperacillin-tazobactam 3 (75%). Among the 19 isolates of Pseudomonas aeruginosa, three were multidrug-resistant organisms (MDROs), and one among the ten Acinetobacter isolates was an MDRO.

Conclusion: BAL sample culture is more useful in diagnosing lung infections compared to sputum culture, where normal flora may overgrow pathogens. Determining antibiotic sensitivity patterns aids clinicians in selecting appropriate antibiotics.

Keywords: Bronchoalveolar Lavage; Lower Respiratory Tract Infection; Bacterial Profile; Antibiotic Susceptibility Pattern; Pseudomonas Aeruginosa; Acinetobacter Baumannii; Klebsiella Pneumoniae.

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Introduction

Lower respiratory tract infections involve the lungs, airways, and air sacs. Patients typically present with symptoms such as fever, productive cough, breathing difficulty, and chest tightness. Pulmonary infections are a leading cause of morbidity and mortality in the community [1].

Bronchoalveolar lavage (BAL) fluid is an appropriate specimen for identifying infectious pathogens. BAL is now commonly used as a diagnostic tool, though it was primarily an investigative and research tool in the past. The advent of bronchoscopy and bacteriological culture of BAL aids in diagnosing various pulmonary infections [2]. The microbiological profile of BAL samples involves isolating organisms and identifying their antimicrobial sensitivity patterns [3].

This analysis helps determine the cause of lower respiratory infections and guides clinicians in treating patients with appropriate antibiotics. This research isolates aerobic bacteria and studies their resistance to antibiotics from BAL fluid.

Aim and Objectives

- To identify infective organisms from BAL samples.

- To isolate aerobic bacteria from BAL fluid specimens.
- To evaluate antibiotic sensitivity and resistance patterns.

Materials and Methods

This prospective study was conducted at Government Medical College Namakkal in the Department of Microbiology for one year.

Inclusion Criteria: Adult patients with lower respiratory diseases undergoing bronchoalveolar lavage procedure.

Exclusion Criteria: Cardiac patients and antenatal mothers were excluded.

Under aseptic precautions, bronchoalveolar washings were obtained during bronchoscopy and immediately processed as per standard laboratory guidelines. Seventy-five BAL fluid samples from lower respiratory tract infection patients were included.

The macroscopic appearance of the samples was noted. Direct Gram staining was performed to detect neutrophils and organisms. BAL fluid was cultured on MacConkey agar, blood agar, chocolate agar, and incubated at 37°C for 24-48 hours. Bacterial growth was identified by cultural characteristics. Antimicrobial sensitivity testing was determined using Clinical and Laboratory Standards Institute (CLSI) guidelines. Zone diameters were measured in millimeters and interpreted as per CLSI guidelines.

Results

Out of 75 BAL samples, 52 (69%) were from males and 23 (31%) from females. The majority of cases were in the age group 51-60 years (37%). Among 75 BAL samples processed, 39 (52%) were culture positive for bacterial isolates. Of these, 31 (79%) were from males and 8 (20%) from females. The predominant organisms isolated were Pseudomonas aeruginosa 19 (48%), Acinetobacter baumannii 10 (25%), Klebsiella pneumoniae 9 (23%), and Burkholderia species 1 (2%). Klebsiella pneumoniae showed high sensitivity to piperacillin-tazobactam 8 (88%), meropenem 8 (88%), and cefotaxime-sulbactam 7 (77%). Most Klebsiella isolates were resistant to amikacin, gentamicin, and ciprofloxacin. Pseudomonas aeruginosa was susceptible to ceftazidime-avibactam 15 (78%), meropenem 16 (84%), and piperacillin-tazobactam 16 (84%). Acinetobacter species were susceptible to ceftazidime-avibactam 3 (75%), meropenem 3 (75%), and piperacillin-tazobactam 3 (75%), showing resistance to ciprofloxacin. Among the 19 Pseudomonas aeruginosa isolates, three were multidrug-resistant organisms (MDROs), and one among the ten Acinetobacter isolates was an MDRO.

Table 1: Age-Gender Wise Distribution

S. No	Age in Years	Male	Female	Total
1	20-30 years	7	2	9
2	31-40 years	11	5	16
3	41-50 years	15	7	22
4	51-60 years	19	9	28
Total		**52**	**23**	**75**

Table 2: Spectrum of Bacterial Isolates from BAL Fluid

Organism Isolated (n=39)	No. of Isolates	Percentage (%)
Pseudomonas aeruginosa	19	48
Acinetobacter baumannii	10	25
Klebsiella pneumoniae	9	23
Burkholderia species	1	2

Table 3: Antibiotic Susceptibility Pattern of the Isolated Organisms

Antibiotic	Klebsiella pneumoniae (9)	Pseudomonas aeruginosa (19)	Acinetobacter baumannii (10)
Cotrimoxazole (1.25/23.75 µg)	-	-	5 (50%)
Ampicillin (10 µg)	-	-	4 (40%)
Amoxycillin-clavulanic acid (20/10 µg)	5 (55%)	-	6 (60%)
Ampicillin-sulbactam (10/10 µg)	-	-	6 (60%)
Gentamicin (10 µg)	3 (33%)	-	4 (40%)
Amikacin (30 µg)	3 (33%)	-	4 (40%)
Ciprofloxacin (5 µg)	4 (44%)	9 (47%)	4 (40%)
Cefepime (30 µg)	6 (66%)	11 (57%)	7 (70%)
Ceftazidime (30 µg)	-	13 (68%)	8 (80%)
Cefotaxime (30 µg)	6 (66%)	-	8 (80%)

Ceftriaxone (30 µg)	6 (66%)	-	8 (80%)
Ceftazidime-avibactam (30/20 µg)	-	15 (78%)	9 (90%)
Cefotaxime-sulbactam (30/10 µg)	7 (77%)	-	9 (90%)
Piperacillin-tazobactam (100/10 µg)	8 (88%)	16 (84%)	9 (90%)
Meropenem (10 µg)	8 (88%)	16 (84%)	9 (90%)
Imipenem (10 µg)	-	-	9 (90%)

(Note: The provided document references images (image1.png to image5.png), which likely represent figures such as bar graphs for bacterial distribution, pie charts for age-gender, or antibiotic sensitivity visualizations. As these are not described in detail, placeholders are used below. In a full publication, these would be embedded figures.)

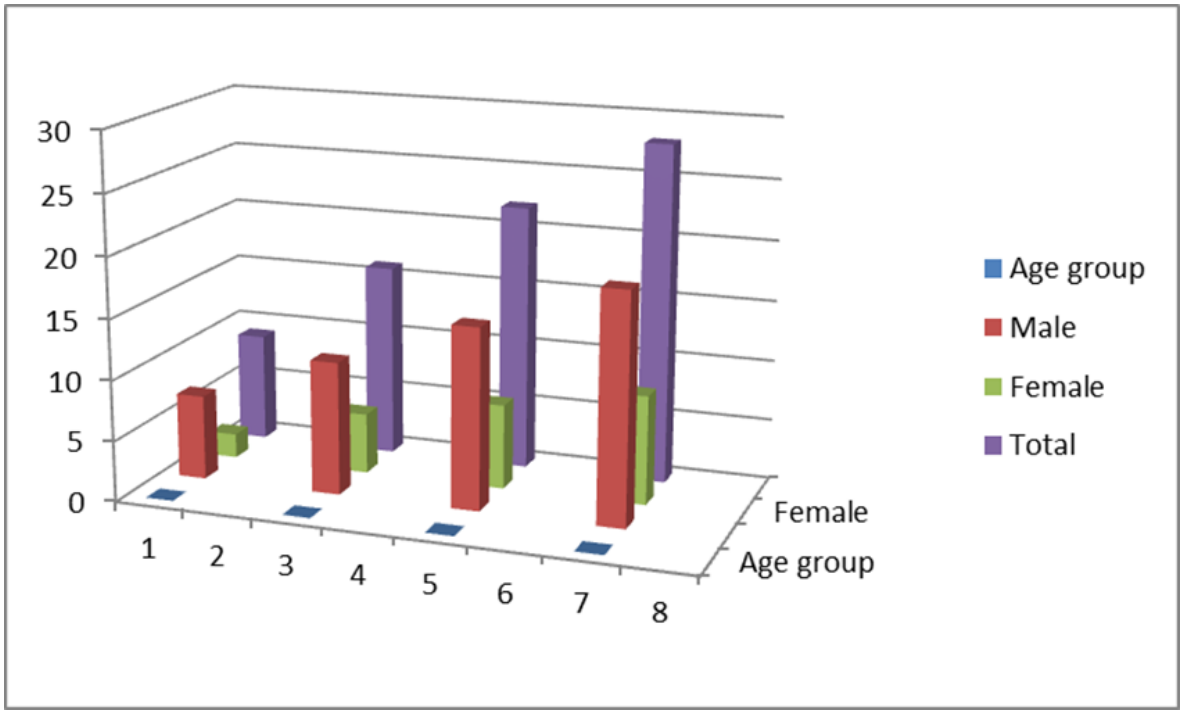

Figure 1: Age-Gender Distribution Bar Graph - Illustrates distribution across age groups by gender).

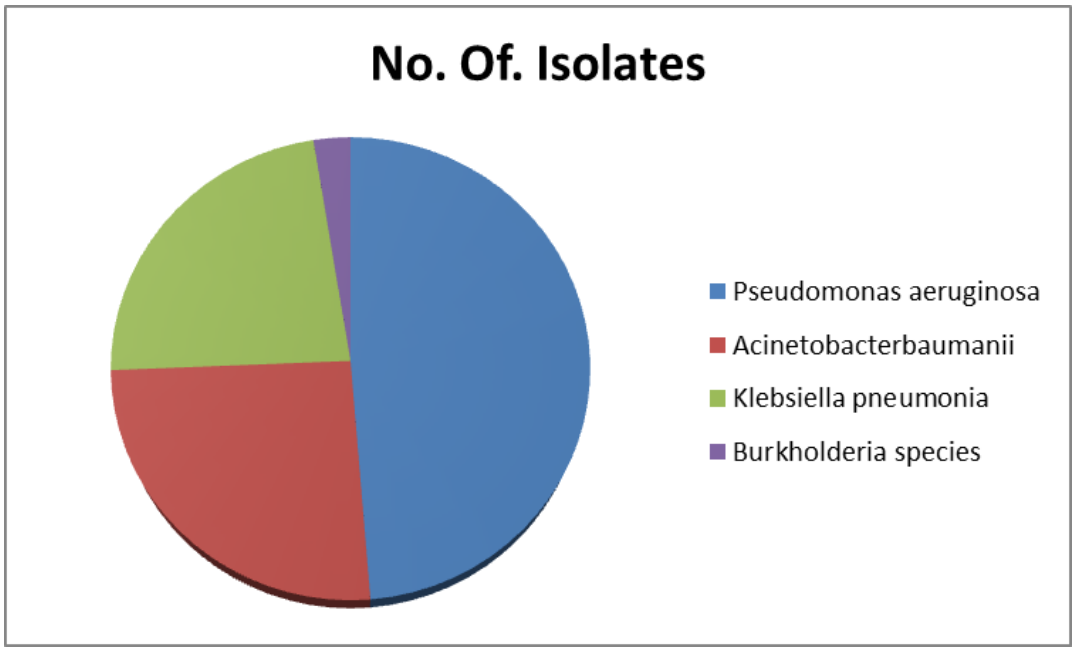

Figure 2: Spectrum of Bacterial Isolates Pie Chart - Shows percentage breakdown of isolated organisms.

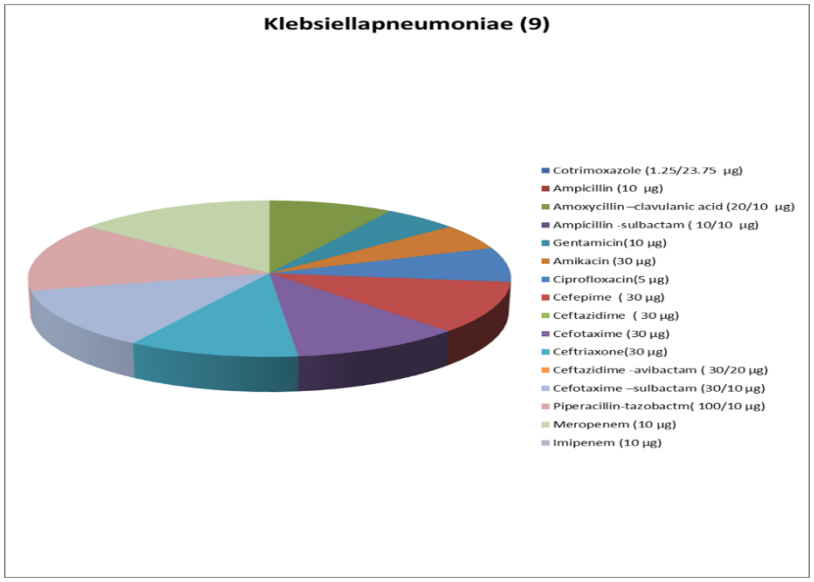

Figure 3: Antibiotic sensitivity pattern of Klebsiella pneumoniae

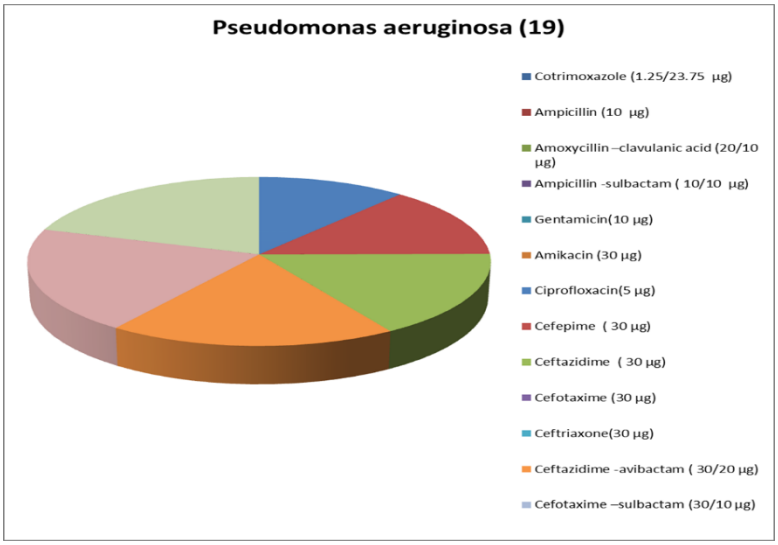

Figure 4: Antibiotic sensitivity pattern of Pseudomonas aeruginosa

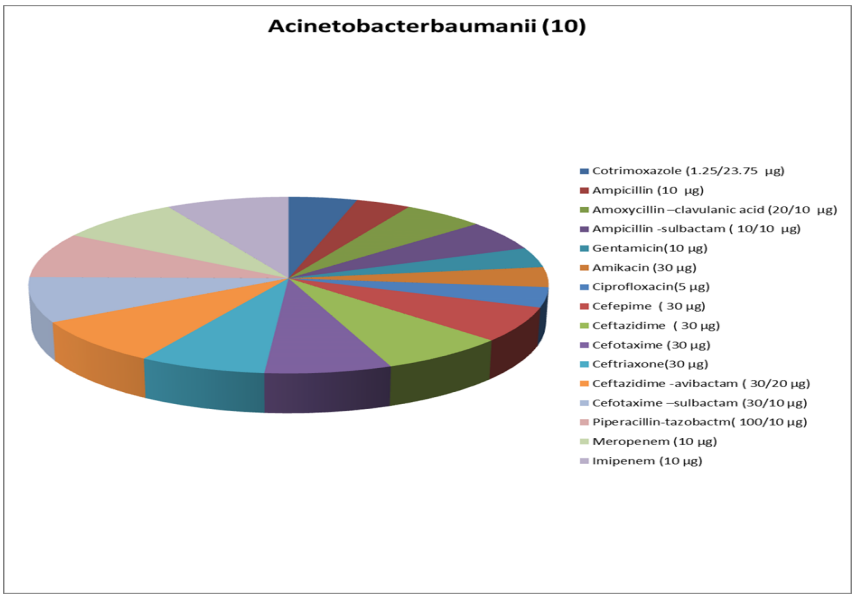

Figure 5: Antibiotic sensitivity pattern of Acinetobacter baumanii

In this prospective observational study, a total of 75 bronchoalveolar lavage (BAL) samples were collected from adult patients diagnosed with lower respiratory tract infections (LRTIs) at Government Medical College, Namakkal, Tamil Nadu, over a one-year period. The demographic analysis revealed a male predominance, with 52 samples (69%) obtained from males and 23 (31%) from females. Age-wise distribution indicated that the majority of patients fell within the 51-60 years age group, accounting for 28 cases (37%), followed by 41-50 years (22 cases, 29%), 31-40 years (16 cases, 21%), and 20-30 years (9 cases, 12%). This age distribution suggests that LRTIs in this cohort were more prevalent among middle-aged and older adults, potentially linked to factors such as comorbidities, occupational exposures, or weakened immune responses in these age brackets (Table 1).

Microbiological processing of the BAL samples yielded significant findings. Out of the 75 samples, 39 (52%) demonstrated positive bacterial growth on culture, highlighting a substantial burden of bacterial etiology in these LRTIs. Gender-specific analysis of culture positivity showed that 31 (79%) positive cultures were from males, compared to only 8 (20%) from females, underscoring a higher incidence or severity of bacterial LRTIs in male patients. This gender disparity may be attributed to behavioral factors such as smoking, outdoor work, or delayed healthcare-seeking behavior among males, as noted in similar studies.

The spectrum of bacterial isolates was dominated by Gram-negative bacilli, which aligns with the typical microbiology of community-acquired LRTIs in immunocompromised or critically ill patients. The most frequently isolated organism was Pseudomonas aeruginosa, comprising 19 isolates (48% of positive cultures), followed by Acinetobacter baumannii with 10 isolates (25%), Klebsiella pneumoniae with 9 isolates (23%), and Burkholderia species with 1 isolate (2%) (Table 2). This distribution emphasizes the role of opportunistic Gram-negative pathogens in LRTIs, particularly in settings where invasive procedures like bronchoscopy are indicated. No Gram-positive bacteria or fungi were reported in this study, which focused solely on aerobic bacterial isolates, potentially due to the exclusion of anaerobic cultures or the specific patient population.

Antibiotic susceptibility testing (AST) was performed using the Kirby-Bauer disk diffusion method, interpreted according to Clinical and Laboratory Standards Institute (CLSI) guidelines. The results revealed varying patterns of sensitivity and resistance among the isolates, with a concerning emergence of multidrug-resistant organisms (MDROs). For Klebsiella pneumoniae, high susceptibility was observed to beta-lactam/beta-lactamase inhibitor combinations and carbapenems: piperacillin-tazobactam (8/9, 88%), meropenem (8/9, 88%), and cefotaxime-sulbactam (7/9, 77%). However, resistance was prominent to aminoglycosides (gentamicin 3/9, 33% sensitive; amikacin 3/9, 33% sensitive) and fluoroquinolones (ciprofloxacin 4/9, 44% sensitive), indicating selective pressure from commonly used empirical antibiotics. Intermediate sensitivities were noted for cephalosporins like cefepime (6/9, 66%), cefotaxime (6/9, 66%), and ceftriaxone (6/9, 66%), and amoxicillin-clavulanic acid (5/9, 55%).

Pseudomonas aeruginosa isolates demonstrated strong susceptibility to advanced antipseudomonal agents: meropenem (16/19, 84%), piperacillin-tazobactam (16/19, 84%), and ceftazidime-avibactam (15/19, 78%). Moderate sensitivities were seen for ceftazidime (13/19, 68%) and cefepime (11/19, 57%), while ciprofloxacin sensitivity was lower (9/19, 47%). Notably, three out of the 19 P. aeruginosa isolates (16%) were classified as MDROs, defined by resistance to at least one agent in three or more antimicrobial categories, posing challenges for treatment .

For Acinetobacter baumannii, susceptibility was highest to carbapenems and beta-lactam combinations: meropenem (9/10, 90%), imipenem (9/10, 90%), piperacillin-tazobactam (9/10, 90%), ceftazidime-avibactam (9/10, 90%), and cefotaxime-sulbactam (9/10, 90%). Cephalosporins like ceftazidime (8/10, 80%), cefotaxime (8/10, 80%), and ceftriaxone (8/10, 80%) also showed good activity, alongside cefepime (7/10, 70%). However, resistance to aminoglycosides (gentamicin 4/10, 40% sensitive; amikacin 4/10, 40% sensitive), fluoroquinolones (ciprofloxacin 4/10, 40% sensitive), and other agents like cotrimoxazole (5/10, 50%), ampicillin (4/10, 40%), amoxicillin-clavulanic acid (6/10, 60%), and ampicillin-sulbactam (6/10, 60%) was evident. One out of the 10 A. baumannii isolates (10%) was an MDRO, further highlighting the growing threat of carbapenem-resistant strains in healthcare settings.

The single Burkholderia species isolate was not detailed in the AST patterns, likely due to its rarity, but such organisms are inherently resistant to many antibiotics and require tailored therapy. Overall, the AST results underscore the efficacy of carbapenems and beta-lactamase inhibitors as first-line options, while aminoglycosides and fluoroquinolones appear less reliable due to widespread resistance (Table 3). These findings were visualized in figures (placeholders: Figure 1 for age-gender distribution, Figure 2 for bacterial spectrum, Figure 3 –Antibiotic sensitivity pattern of Klebsiella pneumoniae ,Figure 4- Antibiotic sensitivity pattern of Pseudomonas aeruginosa and Figure:5-Antibiotic sensitivity pattern of

Acinetobacter baumanii which provide graphical representations to aid in interpreting the data trends.

Discussion

The findings of this study provide valuable insights into the microbiological landscape of LRTIs in a tertiary care setting in Tamil Nadu, India, where BAL sampling offers a more precise diagnostic yield compared to non-invasive methods like sputum culture. The 52% culture positivity rate for bacterial isolates is consistent with previous research, such as the study by Dhanashree P. Inamdar et al. (2021), which reported similar positivity in BAL samples from LRTI patients, attributing it to the ability of BAL to sample deeper alveolar regions without contamination from upper respiratory flora [1]. This reinforces the diagnostic superiority of BAL over sputum, where commensal overgrowth often masks pathogens, leading to false negatives or inappropriate antibiotic use [5].

The male predominance in both sample collection (69%) and culture positivity (79%) mirrors epidemiological patterns observed in other Indian studies. For instance, Vivek KU and Nutan Kumar (2016) documented higher LRTI rates among males in chronic respiratory disease patients, linking it to socioeconomic factors like smoking prevalence (estimated at 20-30% among Indian males), occupational hazards (e.g., exposure to dust or pollutants in agriculture and industry common in Tamil Nadu), and cultural norms that may delay medical intervention [6-11]. In our cohort, the peak incidence in the 51-60 age group aligns with global trends from the Global Burden of Disease (GBD) 2019 study, which highlights increasing respiratory disease burden with age due to cumulative exposures and comorbidities like diabetes or COPD [12-18]. Environmental risk factors in India, as reviewed by Rajkumar et al. (2021), including air pollution and biomass fuel use, further exacerbate this vulnerability [16].

Gram-negative bacilli dominating the isolates (100% of positive cultures) is a hallmark of nosocomial or severe community-acquired LRTIs, particularly in patients requiring bronchoscopy. Pseudomonas aeruginosa as the leading pathogen (48%) is corroborated by multiple studies; Shahida Akhtar et al. (2021) reported P. aeruginosa in 35-40% of BAL cultures from pulmonary infection patients in a similar tertiary setup, emphasizing its role in biofilm formation .

[19,4]. Similarly, Nesegopu Padmaja et al. (2021) found P. aeruginosa and Acinetobacter species as top isolates, with percentages akin to ours (25% for A. baumannii) [20,2]. The presence of Klebsiella pneumoniae (23%) reflects its emergence as a hypervirulent pathogen in Asian populations, as noted in guidelines from the Infectious Diseases Society of America (IDSA) [15]. The rare Burkholderia isolate (2%) underscores the need for vigilance against environmental pathogens in immunocompromised hosts. Antibiotic resistance patterns reveal a critical public health concern. High susceptibility to meropenem and piperacillin-tazobactam across isolates suggests these as empirical choices, but the detection of MDROs (16% in P. aeruginosa and 10% in A. baumannii) signals escalating resistance, consistent with antimicrobial surveillance data from Mathur et al. (2012), which reported carbapenem resistance rates of 20-50% in Indian ICUs [21]. Resistance to aminoglycosides and fluoroquinolones likely stems from overuse in community settings, as highlighted in WHO reports on chronic respiratory diseases [12]. Comparative studies like Ramasubramanian et al. (2022) show similar trends, with beta-lactamase inhibitors retaining activity against 80-90% of isolates [19]. However, the lower sensitivity to older cephalosporins indicates plasmid-mediated resistance mechanisms, necessitating molecular typing in future research.

The implications of these findings are multifaceted. Clinically, BAL-guided AST can optimize antibiotic stewardship, reducing morbidity from inappropriate therapy and curbing resistance spread. From a public health perspective, the high MDRO prevalence calls for infection control measures, as per IDSA/ATS guidelines [15]. Limitations include the study's focus on aerobic bacteria, excluding anaerobes, fungi, or viruses (e.g., as in Jain et al., 2015, where viral etiologies were significant [17]), and the single-center design, which may not generalize to other regions. Future studies could incorporate quantitative cultures (as in Kale and Joshi, 2025 [7]) or molecular diagnostics to enhance pathogen detection.

In summary, this study affirms BAL's utility in precise LRTI diagnosis, revealing a Gram-negative predominance with emerging resistance. These insights guide targeted therapy and highlight the need for ongoing surveillance in resource-limited settings.

Conclusion

BAL fluid culture is more useful for diagnosing lung infections than sputum culture, where normal flora may overgrow pathogens. Determining antibiotic sensitivity patterns aids clinicians in choosing appropriate antibiotics, preventing morbidity and mortality.

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