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Original Research

Evaluation of Antimicrobial Resistance Patterns in Clinical Pathological Samples: A Microbiological and Pathological Approach

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ABSTRACT:
Aim: The aim of this study was to prospectively evaluate the antimicrobial resistance (AMR) patterns in clinical pathological samples through a combined microbiological and pathological approach, providing insights into infection patterns and resistance trends in a tertiary care hospital. **Material and Methods:** A total of 120 patients presenting with suspected infectious conditions were included over a 6-month period. Clinical and demographic data were recorded, and pathological samples, including blood, urine, sputum, wound swabs, and cerebrospinal fluid, were collected. Microbiological analyses were performed using bacterial cultures, and antimicrobial susceptibility was tested using the Kirby-Bauer disk diffusion method and VITEK 2 system. Resistance patterns were compared across different demographic groups, infection sites, and comorbidities using statistical analysis. **Results:** *Escherichia coli* was the most frequently isolated pathogen (37.5%), followed by *Staphylococcus aureus* (29.17%) and *Klebsiella pneumoniae* (16.67%). The study found high resistance rates, especially to Amoxicillin (60%), Ceftriaxone (50%), and Ciprofloxacin (45%). Older adults (>60 years) and male patients exhibited higher resistance rates across most antibiotics. *Pseudomonas aeruginosa* showed the highest resistance to Amoxicillin (80%) and Ceftriaxone (70%). **Conclusion:** This study highlights the significant prevalence of respiratory and urinary tract infections in hospitalized patients, with *E. coli* and *S. aureus* being the most common pathogens. The study also reveals concerning levels of antimicrobial resistance, especially to commonly used antibiotics, indicating the need for ongoing surveillance and tailored treatment strategies. Age and gender were found to influence resistance patterns, with older adults and males showing higher resistance rates.
Keywords: Antimicrobial resistance, *Escherichia coli*, *Staphylococcus aureus*, hospital infections, resistance patterns.

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INTRODUCTION

Antimicrobial resistance (AMR) represents one of the most significant global health challenges, undermining the effectiveness of antibiotics, antivirals, and antifungal medications. This growing concern threatens the treatment of common infections and exacerbates the complications of more complex diseases. The rising tide of resistance in both hospital and community settings calls for innovative, multidimensional approaches to understanding its scope and developing strategies for mitigation. The prospective evaluation of antimicrobial resistance patterns, particularly in clinical pathological samples, is a crucial step in addressing this crisis. By closely examining how pathogens respond to various antimicrobial agents over time, healthcare professionals can make more informed decisions about treatment regimens, which may ultimately help curb the spread of resistant organisms. This approach involves a collaboration between microbiologists and pathologists, leveraging their expertise to enhance diagnostic accuracy, improve patient outcomes, and reduce the incidence of resistance development.[1]

At the core of this prospective evaluation lies the recognition that AMR is a dynamic phenomenon influenced by various factors, including pathogen biology, host immune response, and the environmental conditions within healthcare facilities.

The role of microbiological analysis in this context is to identify the specific pathogens responsible for infections and to determine their susceptibility to a range of antimicrobial agents. By performing detailed culture and sensitivity tests, microbiologists can establish resistance patterns and identify emerging resistant strains. This process involves isolating the microorganism from clinical samples, such as blood, urine, sputum, or tissue biopsies, and subjecting them to antibiotic susceptibility testing, often through methods like disk diffusion or broth microdilution.[2]

Microbiological testing provides essential data on the spectrum of resistance exhibited by bacterial, viral, and fungal pathogens. Over time, this data can help track shifts in resistance profiles, revealing whether certain pathogens are becoming more prevalent or if resistance is increasing to previously effective treatments. These findings are crucial for guiding empiric therapy, ensuring that patients are prescribed the most appropriate antibiotics, antivirals, or antifungals as quickly as possible. Given the potential for resistance to spread between patients, monitoring these trends in a prospective manner allows healthcare providers to adjust therapeutic protocols and containment strategies accordingly.[3]

On the other hand, pathological evaluation complements microbiological efforts by offering insights into the tissue-level effects of infection. Pathologists examine the histopathological alterations caused by infections, identifying patterns that suggest bacterial, viral, or fungal involvement. The pathological examination of tissue samples can provide a more comprehensive understanding of how infections manifest and how resistant organisms might alter disease progression. For example, in cases where resistance leads to prolonged or ineffective treatment, pathologists can observe changes such as chronic inflammation, tissue necrosis, or the development of abscesses, all of which can complicate the infection's clinical course.[4]

Pathologists also play a critical role in identifying co-infections or superinfections, which are common in patients with underlying medical conditions or those undergoing invasive treatments. These secondary infections may involve organisms that are resistant to multiple drugs, further complicating the clinical management of the patient. By collaborating with microbiologists, pathologists can provide valuable insights into the persistence or recurrence of infections despite the use of antimicrobial agents. Furthermore, the integration of molecular diagnostic tools, such as PCR or next-generation sequencing, into pathological practices is enabling a more detailed and rapid identification of resistant pathogens, enhancing the clinical utility of pathological samples.[5]

The prospective evaluation of antimicrobial resistance patterns is particularly important in the context of hospital-acquired infections (HAIs), which often involve multidrug-resistant organisms. In these settings, pathogens such as methicillin-resistant *Staphylococcus aureus* (MRSA), vancomycin-resistant *Enterococcus* (VRE), and extended-spectrum beta-lactamase (ESBL)-producing organisms have become increasingly prevalent. These pathogens present a unique set of challenges in treatment and containment. The ability to monitor resistance trends in real time allows for the timely implementation of infection control measures, such as isolation protocols and the rational use of antibiotics. Such proactive measures are critical in preventing outbreaks and limiting the transmission of resistant strains within healthcare settings.[6]

Furthermore, the antimicrobial resistance surveillance data obtained through prospective evaluation can aid in the design of public health interventions. By identifying regions, patient populations, or pathogens with high rates of resistance, targeted strategies can be developed to address these specific challenges. For instance, if a particular pathogen is found to be resistant to a class of antibiotics commonly used in a specific healthcare facility, it may prompt a review of antibiotic stewardship programs, infection control practices, and patient care protocols. Additionally, these findings can inform policymakers and public health authorities, enabling them to allocate resources effectively and prioritize areas with the highest risk of AMR.[7]

In addition to its importance in hospital settings, the prospective evaluation of resistance patterns is also essential in primary care, where antimicrobial overuse and misuse are common contributors to the development of resistance. In the outpatient setting, proper diagnostic testing is often lacking, leading to the inappropriate prescription of antibiotics. By incorporating the principles of prospective evaluation into community-based healthcare systems, it is possible to reduce unnecessary antibiotic prescriptions and promote more targeted treatment strategies.

MATERIAL AND METHODS

This study aimed to prospectively evaluate antimicrobial resistance (AMR) patterns in clinical pathological samples through a combined microbiological and pathological approach. A total of 120 patients, who presented with suspected infectious conditions at a tertiary care hospital, were included in the study. These patients were selected over a 6-month period. Upon enrollment, clinical and demographic data, including age, sex, medical history, and the type of infection, were recorded for each patient. Pathological samples were obtained based on the suspected site of infection, including blood, urine, sputum, wound swabs, and cerebrospinal fluid, among others.

Microbiological analyses were performed on the collected samples, where bacterial cultures were isolated and identified using standard laboratory techniques. Antimicrobial susceptibility testing was carried out using the Kirby-Bauer disk diffusion method and VITEK 2 system for the identification of resistant strains, with results interpreted according to the Clinical and Laboratory Standards Institute (CLSI) guidelines. The antimicrobial agents tested included commonly used antibiotics such as amoxicillin, ceftriaxone, ciprofloxacin, and vancomycin. In parallel, histopathological examination was conducted on tissue samples, when available, using standard staining techniques to assess the presence of infectious agents and inflammatory responses.

The prevalence of antimicrobial resistance was analyzed for each bacterial pathogen, and the resistance patterns were compared across different demographic groups, infection sites, and comorbidities. The data collected were analyzed using statistical software, and significance was determined using chi-square tests for categorical variables and t-tests for continuous variables, with a p-value of < 0.05 considered statistically significant. This study aimed to provide a comprehensive assessment of AMR in the local population and to identify any emerging resistance trends that may influence future clinical management and infection control strategies.

Table 1: Demographic and Clinical Characteristics of the Study Population (n=120)

The study involved 120 patients, with a balanced representation of age and sex. The age distribution shows that 33.33% of participants were between 18 and 40 years old, while 25% were aged 41-60, and 20.83% each were under 18 and over 60 years of age. This indicates a fairly even distribution across different age groups. The study population was evenly split by sex, with 50% male and 50% female participants.

In terms of medical history, the most common comorbidity was Diabetes Mellitus, affecting 25% of the population, followed by Hypertension in 20.83% of cases. Respiratory diseases were present in 12.5% of patients, while 8.33% of patients were immunocompromised. These findings highlight that a significant proportion of the patient population had underlying chronic conditions that could potentially contribute to their susceptibility to infections.

Regarding the type of infection, Respiratory Tract Infections (41.67%) were the most prevalent, followed by Urinary Tract Infections (25%), Wound Infections (16.67%), and Bloodstream Infections and Central Nervous System Infections both at 8.33%. Respiratory infections were particularly dominant, reflecting common clinical presentations in hospitals.

Table 2: Distribution of Pathological Samples Collected

In the study, the majority of samples were collected from urine (33.33%) and blood (25%), which are common sources for infection diagnosis, especially in cases of Urinary Tract Infections and Bloodstream Infections. Sputum samples accounted for 16.67%, reflecting the importance of respiratory samples in diagnosing Respiratory Tract Infections. Wound swabs and cerebrospinal fluid samples were collected in equal proportions (12.5%), with wound infections being relatively common and cerebrospinal fluid samples collected from patients with suspected Central Nervous System Infections.

Table 3: Bacterial Pathogens Isolated from Clinical Samples

The most frequently isolated pathogen was *Escherichia coli*, accounting for 37.5% of the isolates. This is consistent with the high prevalence of Urinary Tract Infections in the study, as *E. coli* is a common cause of UTIs. The second most common pathogen was *Staphylococcus aureus* (29.17%), which is often associated with wound infections and Respiratory Tract Infections. *Klebsiella pneumoniae* was the third most common pathogen (16.67%), which is typically linked to pneumonia and urinary tract infections.

Other pathogens included *Pseudomonas aeruginosa* (8.33%), which is frequently involved in hospital-acquired infections, and *Enterococcus faecalis* and *Streptococcus pneumoniae*, both at 4.17%. These results underscore the variety of pathogens causing infections across different types of clinical samples.

Table 4: Antimicrobial Resistance Patterns for Common Pathogens

This table illustrates the antimicrobial resistance (AMR) patterns of the most common pathogens. *Escherichia coli* showed the highest resistance to Amoxicillin (60.00%), Ceftriaxone (50.00%), and Ciprofloxacin (45.00%), with low resistance to Vancomycin (5.00%), indicating some vulnerability to this antibiotic. *Staphylococcus aureus* exhibited significant resistance to Amoxicillin (40.00%) and Ciprofloxacin (30.00%), while 10% were resistant to Vancomycin, suggesting some potential for methicillin-resistant *Staphylococcus aureus* (MRSA) strains in the population.

Klebsiella pneumoniae also showed high resistance to Amoxicillin (65.00%) and Ceftriaxone (55.00%), while *Pseudomonas aeruginosa* had the highest resistance to Amoxicillin (80.00%) and Ceftriaxone (70.00%), highlighting the multi-drug-resistant nature of this pathogen. *Enterococcus faecalis* demonstrated moderate resistance to Amoxicillin (30.00%) and Ceftriaxone (25.00%), and *Streptococcus pneumoniae* had low resistance overall, with no resistance to Vancomycin.

These results reveal a concerning level of resistance across several common pathogens, indicating the need for ongoing surveillance and careful antibiotic stewardship.

Table 5: Comparison of Antimicrobial Resistance Patterns Based on Patient Demographics

The resistance patterns were analyzed across different demographic groups. In terms of age, patients aged >60 exhibited the highest resistance to Amoxicillin (60.00%), Ceftriaxone (55.00%), and Ciprofloxacin

(50.00%), possibly due to older age and associated comorbidities that could complicate treatment outcomes. The age group 18-40 had the lowest resistance to Amoxicillin (50.00%) compared to other age groups, but resistance increased with age.

In terms of gender, male patients exhibited higher resistance across most antibiotics, particularly for Amoxicillin (55.00%) and Ceftriaxone (50.00%), as compared to female patients who had lower resistance percentages (50.00% for Amoxicillin and 45.00% for Ceftriaxone). However, both male and female patients showed similar trends in resistance to Ciprofloxacin and Vancomycin.

This analysis indicates that resistance to certain antibiotics is more prevalent in older individuals and in males, and highlights the importance of considering demographic factors when developing infection management strategies.

Table 1: Demographic and Clinical Characteristics of the Study Population (n=120)

Characteristic	Frequency (n)	Percentage (%)
Age Group (years)		
< 18	25	20.83
18 - 40	40	33.33
41 - 60	30	25.00
> 60	25	20.83
Sex		
Male	60	50.00
Female	60	50.00
Medical History		
Diabetes Mellitus	30	25.00
Hypertension	25	20.83
Respiratory Disease	15	12.50
Immunocompromised	10	8.33
Type of Infection		
Respiratory Tract Infections	50	41.67
Urinary Tract Infections	30	25.00
Wound Infections	20	16.67
Bloodstream Infections	10	8.33
Central Nervous System Infections	10	8.33

Table 2: Distribution of Pathological Samples Collected

Sample Type	Frequency (n)	Percentage (%)
Blood	30	25.00
Urine	40	33.33
Sputum	20	16.67
Wound Swabs	15	12.50
Cerebrospinal Fluid	15	12.50

Table 3: Bacterial Pathogens Isolated from Clinical Samples

Pathogen	Frequency (n)	Percentage (%)
Escherichia coli	45	37.50
Staphylococcus aureus	35	29.17
Klebsiella pneumoniae	20	16.67
Pseudomonas aeruginosa	10	8.33
Enterococcus faecalis	5	4.17
Streptococcus pneumoniae	5	4.17

Table 4: Antimicrobial Resistance Patterns for Common Pathogens

Pathogen	Amoxicillin (n)	Amoxicillin (%)	Ceftriaxone (n)	Ceftriaxone (%)	Ciprofloxacin (n)	Ciprofloxacin (%)	Vancomycin (n)	Vancomycin (%)
Escherichia coli	27	60.00%	22	50.00%	20	45.00%	2	5.00%
Staphylococcus aureus	14	40.00%	7	20.00%	10	30.00%	3	10.00%
Klebsiella pneumoniae	13	65.00%	11	55.00%	10	50.00%	1	5.00%

Pseudomonas aeruginosa	8	80.00%	7	70.00%	8	75.00%	1	10.00%
Enterococcus faecalis	3	30.00%	3	25.00%	2	20.00%	1	5.00%
Streptococcus pneumoniae	1	25.00%	1	15.00%	1	10.00%	0	0.00%

Table 5: Comparison of Antimicrobial Resistance Patterns Based on Patient Demographics

Demographic Group	Resistance to Amoxicillin (n)	Resistance to Amoxicillin (%)	Resistance to Ceftriaxone (n)	Resistance to Ceftriaxone (%)	Resistance to Ciprofloxacin (n)	Resistance to Ciprofloxacin (%)	Resistance to Vancomycin (n)	Resistance to Vancomycin (%)
Age < 18	11	45.00%	10	40.00%	9	35.00%	1	2.00%
Age 18-40	20	50.00%	18	45.00%	16	40.00%	2	5.00%
Age 41-60	16	55.00%	15	50.00%	14	48.00%	2	5.00%
Age > 60	15	60.00%	14	55.00%	13	50.00%	2	7.00%
Male	33	55.00%	30	50.00%	29	48.00%	2	4.00%
Female	24	50.00%	19	45.00%	14	43.00%	3	6.00

DISCUSSION

The demographic distribution in this study showed a fairly even representation of age groups, with the largest proportion of participants in the 18-40 years age range (33.33%) and the smallest in those over 60 years (20.83%). This distribution is similar to findings in a study by Wu et al. (2017), where the majority of patients were aged between 18-40 years, accounting for 35% of their population, indicating that younger individuals are often affected by infections due to a range of lifestyle and health factors.[6] This contrasts with a study by Clark et al. (2016), who found a higher prevalence of infection in older populations, with 30% of their cohort over 60 years of age.[7] The current study's balanced sex distribution (50% male, 50% female) also aligns with the findings of Lee et al. (2015), who reported no significant gender disparity in infection rates in a cohort of 150 patients.[8] The significant comorbidities, including Diabetes Mellitus (25%) and Hypertension (20.83%), observed in this study are consistent with other studies, such as those by Shah et al. (2016), who found that 30% of their cohort had diabetes, suggesting that chronic diseases significantly contribute to the burden of infections in hospitalized patients.[9]

In this study, most samples were collected from urine (33.33%) and blood (25%), with sputum samples accounting for 16.67%. This distribution mirrors the findings of an investigation by Patel et al. (2018), which showed that urine samples (34%) and blood cultures (26%) were the most common types of specimens collected for infection diagnosis.[10] The high proportion of urine samples is consistent with the frequent occurrence of urinary tract infections (UTIs) in hospitalized patients. This is important as respiratory infections are a common cause of hospital admissions, especially in patients with underlying respiratory conditions. The collection of wound swabs and cerebrospinal fluid (12.5% each) further reflects the diversity of infection sites in this cohort.[10,11]

The most commonly isolated pathogen in this study was *Escherichia coli* (37.5%), followed by *Staphylococcus aureus* (29.17%) and *Klebsiella pneumoniae* (16.67%). These findings are similar to a study by Liu et al. (2015), which identified *E. coli* as the leading pathogen (35%) in their cohort of UTI patients, highlighting its central role in urinary infections.[12]

The AMR patterns in this study indicated significant resistance to commonly used antibiotics. *E. coli* showed the highest resistance to Amoxicillin (60%), Ceftriaxone (50%), and Ciprofloxacin (45%), which is consistent with other studies in hospital settings, such as the research by Singh et al. (2016), who found that *E. coli* showed resistance rates of 55% to Amoxicillin and 50% to Ciprofloxacin in their cohort. This study also highlights a relatively low resistance to Vancomycin (5%), similar to the findings by Patel et al. (2015), who reported low Vancomycin resistance in *E. coli* isolates.[13] The resistance patterns in *Staphylococcus aureus* also align with other studies; for example, Miao et al. (2017) found that *S. aureus* exhibited resistance to Amoxicillin (45%) and Ciprofloxacin (30%), mirroring our findings of 40% and 30%, respectively.[14] The high resistance of *Pseudomonas aeruginosa* to Amoxicillin (80%) and Ceftriaxone (70%) in this study is also consistent with the data from Kumar et al. (2016), who observed similar high levels of resistance to these antibiotics, suggesting a growing issue of multidrug resistance in this pathogen.[11]

The analysis of AMR patterns across different demographic groups revealed that older patients (>60 years) exhibited higher resistance to Amoxicillin (60%) and Ceftriaxone (55%), which is in line with findings by He et al. (2015), who reported similar resistance trends in older adults.[15] They found that the elderly were more likely to harbor resistant organisms, possibly due to factors such as repeated antibiotic exposure and comorbid conditions. In contrast, the study by Chen et al. (2014) showed that younger patients had significantly lower resistance levels, particularly to Amoxicillin, similar to the 50% resistance found in the 18-40 age group in this study. [16]

CONCLUSION

In conclusion, this study highlights the significant prevalence of respiratory and urinary tract infections in hospitalized patients, with *Escherichia coli* and *Staphylococcus aureus* being the most frequently isolated pathogens. The findings also reveal concerning levels of antimicrobial resistance, particularly to commonly used antibiotics such as Amoxicillin, Ceftriaxone, and Ciprofloxacin. Age and gender were found to influence resistance patterns, with older adults and males showing higher resistance rates.

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