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ANALYSIS OF ANTIBIOTIC UTILIZATION PATTERNS AND EMERGING ANTIMICROBIAL RESISTANCE

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Abstract
Antimicrobial resistance (AMR) has become a major global public health concern due to the increasing misuse and overuse of antibiotics in healthcare settings. Monitoring antibiotic utilization patterns and resistance profiles is essential for understanding prescribing practices and strengthening antimicrobial stewardship programs. The present study aimed to analyze antibiotic utilization patterns and evaluate antimicrobial resistance among patients receiving antibiotic therapy in a tertiary care hospital. A retrospective observational analysis was conducted using hospital electronic medical records, pharmacy prescription databases, and microbiology laboratory reports. A total of 80 patient records with confirmed bacterial infections and documented antibiotic prescriptions were included in the study. Data regarding demographic characteristics, antibiotic classes prescribed, bacterial isolates identified, and antimicrobial susceptibility results were collected and analyzed. Descriptive statistical methods were applied to determine frequencies and percentages of antibiotic utilization and bacterial isolates. Chi-square analysis was performed to evaluate the association between antibiotic class and antimicrobial resistance patterns. Pearson correlation and logistic regression analyses were also conducted to assess the relationship between antibiotic utilization score and resistance outcomes. The results showed that most patients belonged to the middle-aged group and that cephalosporins and fluoroquinolones were the most frequently prescribed antibiotics. Microbiological findings revealed that Escherichia coli, Staphylococcus aureus, and Klebsiella pneumoniae were the predominant bacterial isolates identified. Correlation and regression analyses further indicated that antibiotic utilization score was not a significant predictor of antimicrobial resistance. Continuous monitoring of antibiotic use and resistance patterns remains essential for promoting rational antibiotic prescribing and improving antimicrobial stewardship practices.

Keywords: *antimicrobial resistance, antibiotic utilization, bacterial isolates, antimicrobial stewardship, retrospective study*

1. Introduction

Regardless of significant achievements in medical science, infectious diseases continue to be one of the leading causes of morbidity and mortality in the world. The development and popularization of antibiotics has helped to greatly enhance the control of bacterial infections and also to lower the death rates of infectious diseases. Nevertheless, the widespread and excessive application of antibiotics has led to the development and spread of antimicrobial resistance (AMR), and it is challenging antimicrobial drugs (Sterling et al., 2019). Antibiotic resistance takes place when microorganisms adapt to resist the effects of antimicrobial agents that would stop their growth. With time, the spread of resistant pathogens can occur in the healthcare facilities and society. The further evolution of the resistant strains of bacteria has also been promoted by the misuse and overuse of antibiotics in human health, veterinary care, and agricultural activities (Aarestrup, 2015). With the prescription of antibiotics in many regions, there are often cases of not being prescribed based on proper diagnostic confirmation and/or use of improper dosages and length of time. These practices cause selective pressure that leads to the survival and proliferation of resistant microorganisms (Ferri et al., 2017). Therefore, formerly curable infections are turning out to be harder to handle and are becoming a big problem to the contemporary health care systems. Antimicrobial resistance has become a severe worldwide health issue of concern that impacts both the developed and developing nations. The resistance infections are related to extended hospital stay, high cost of healthcare and death rates. Research has demonstrated that the proliferation of resistant pathogens around the world is rising faster because of the growth in the use of antibiotics and insufficient infection containment procedures (Ferri et al., 2017). The problem is further increased in developing countries due to the lack of access to diagnostic facilities and the ineffectiveness of regulation to control the sale of antibiotics (Acharya & Wilson, 2019). There are alarming cases of resistance by several bacterial pathogens to commonly used antibiotics. As an example, the methicillin-resistant Staphylococcus aureus (MRSA) has become one of the most significant causes of hospital-acquired infections all over the world (Kaur & Chate, 2015). On the same note, growing resistance in Gram-negative bacteria like Enterobacter species has been well known in clinical practice (Davin-Regli et al., 2019). Moreover, the rise of resistance to such antibiotics like fluoroquinolones and macrolides in pathogens such as Helicobacter pylori has been reported, which underscores the complexity of the antimicrobial treatment (Aftab et al., 2016). Global health crises have also complicated the situation such as the COVID-19 pandemic, where the use of antibiotics may have prompted the emergence of resistance (Knight et al., 2021; Martinez-Guerra et al., 2021).

Surveillance of the pattern of antibiotic use is a vital part of the antimicrobial stewardship interventions that should be in place to control resistance. It has been shown that overprescription and improper use of antibiotics is a major cause of resistant microorganisms (Olesen et al., 2018). The need to assess the trends in prescribing antibiotics, as a way to encourage rational use of drugs and minimize unneeded exposure to antibiotics, is becoming acknowledged in healthcare institutions. Massive studies on the use of antibiotics in hospitals have demonstrated that fluctuations in the prescribing process were typical among healthcare centers (Baggs et al., 2016). Irrational prescriptions of antibiotics have also been indicated in pediatric and inpatient settings, which explains the necessity to enhance surveillance and control of antibiotic use (Mukherjee et al., 2015). To inform the rational use of antibiotics and promote the use of antimicrobial stewardship programs worldwide, the World Health Organization has unveiled the Access, Watch, and Reserve (AWaRe) system of classifications (Hsia et al., 2019). Such strategies may be useful in maximizing the use of antibiotic therapy and delaying resistance development.

The surveillance research is essential in comprehending the pattern of use of antibiotics and drug resistance patterns in clinical settings. Hospital record retrospective studies are informative in terms of antibiotics usage and dominant resistance bacterial isolates. The studies can assist the healthcare providers to detect the incorrect prescribing patterns and create specific intervention to enhance the use of antibiotics (Godman et al., 2021). Also, the surveillance of the contemporary trends in antimicrobials resistance patterns of clinical isolates may inform about the new resistant strains of pathogenic organisms as well as inform empirical treatment with antibiotics (Ahmed et al., 2019). A number of studies have identified the growing rates of antibiotic resistance in hospitals and underscored the importance of monitoring the use and resistance trends in antibiotics (Muhie, 2019). The role of the coordinated efforts of the healthcare segments to restrain the distribution of resistant microorganisms has also been highlighted by national and regional studies on the policies and practices of antimicrobial resistance (Hoque et al., 2020). The utilization of the large datasets to address the aspects of tracking the trends of antibiotic use and resistance with time has additionally been presented in recent analyses based on the electronic health record data (Moradigaravand et al., 2023).

Even though there are many research studies carried out on the issue of antibiotic resistance or on the use of antibiotics in isolation, comparatively few research studies have examined the two as related to each other in hospital environments. The dynamics between the patterns of antibiotic prescription and the emergence of the antimicrobial resistance is critical to the development of effective interventions and antimicrobial stewardship programs. Combining data on the use of antibiotics with the microbiological resistance profile has the potential to offer a more detailed picture of the factors that lead to resistance in healthcare settings. Consequently, it is necessary to conduct additional studies to evaluate the prescription of antibiotics and the resistance pattern to antibiotics among clinical patients.

Objectives of the Study

1. To examine the trends in antibiotic use in the patients undergoing antibiotic therapy in a tertiary care hospital.
2. To determine the patterns of antimicrobial resistance of bacterial isolates and to test how these patterns relate to the practices of antibiotic use.

2. Methodology

2.1 Study Design

The retrospective design was used to conduct the study to assess the patterns of antibiotic use and antimicrobial resistance in patients undergoing antibiotic therapy. The retrospective analysis was selected as it was necessary to investigate the previously registered clinical, pharmacy and microbiological data without affecting the treatment choice. This type of design enabled the researchers to evaluate the actual practices and trends of prescribing and resistance in the healthcare context. The method also enabled determination of common classes of antibiotics and pattern of resistance exhibited by bacterial isolates. The study uses the available medical records to present fruitful findings on the behavior of antibiotic use and the emerging antimicrobial resistance in clinical practice.

2.2 Study Setting

This study was conducted in a tertiary care hospital which offered both inpatient and outpatient medical care. The hospital had various branches like internal medicines, surgery, and emergency where the antibiotic treatment of infectious diseases was widely prescribed. The healthcare establishment had well-developed electronic medical history, pharmacy records, and microbiology laboratory reports, which were the useful sources of information used in the retrospective analysis. The access to clinical and laboratory data in good condition allowed the systematic analysis of the patterns of antibiotics prescription and bacterial resistance in the hospital environment.

2.3 Data Sources

The data was gathered with the help of various institutional sources to be able to provide the extensive assessment of the antibiotic usage and resistance trends. These were the hospital electronic medical records, pharmacy prescription database and microbiology laboratory reports. EMRs have contained data on patient demographic, diagnosis and treatment. Pharmacy databases provided information on the type and class of antibiotics prescribed and microbiology lab records contained information on bacterial isolates and antimicrobial susceptibility outcomes. Combination of these datasets enabled proper evaluation of the pattern of antibiotic use and the simulated antimicrobial resistance profile of a clinical isolate.

2.4 Study Population

The patient population was considered in the study that underwent antibiotic treatment and had a clinical or microbiological record in the hospital database. The analysis was limited to patients who were known to have bacterial infections and have had an antibiotic prescription. The number of patient records to be used in the study was 80 and the records satisfied the eligibility criteria. These records contained information on demographic features, antibiotic prescriptions and microbiological culture outcomes in detail. The chosen data allowed assessing the patterns of antibiotic use and determining the prevalence of typical bacterial pathogens and their susceptibility among the target population.

2.5 Inclusion Criteria

The eligibility criteria were also applied to the patient records in the study to make sure that the data gathered was reliable. Inclusions criteria were that the patients had confirmed bacterial infections either by clinical examination or microbiological test results. Also, the patients who received at least one antibiotic within the treatment period were also eligible to be included. The records with full clinical and laboratory data, including demographic aspects, antibiotic prescriptions, and microbiological culture outcomes were included in the analysis. These inclusion criteria made sure that the dataset had enough information to assess the pattern of antibiotic use and antimicrobial resistance.

2.6 Exclusion Criteria

Some records on patients were not used in the study because of accuracy and consistency of data. Incomplete clinical, microbiological, or prescription data had records that were not included in the analysis. Patients whose infections did not need the use of antibiotic treatment like viral infections were excluded as well. Besides that, the records that did not have antimicrobial susceptibility results or incomplete laboratory documentation were eliminated in the dataset. The use of these exclusion criteria also assisted in ensuring that the final data only consisted of useful and valid information that would be required to measure the antibiotic prescribing behaviors and antimicrobial resistance trends.

2.7 Data Collection Variables

The hospital databases were systemically searched to extract data with the help of a structured method of data collection. The variables that were collected were patient demographic variables (including age and gender), and clinical variables associated with the diagnosis of infections. The additional variables were the type and class of antibiotics prescribed, the length of antibiotic therapy, bacterial isolates detected using clinical samples and the antimicrobial susceptibility outcomes. These variables were chosen due to the fact that they were necessary variables that give critical information necessary when measuring the pattern of antibiotic use and the patterns of resistance. The gathered data was used to thoroughly examine the pattern of antibiotic prescriptions and microbial resistance profiles in patients who are under antibiotic treatment.

2.8 Antibiotic Classification

Antibiotics that were found in the dataset were classified as per internationally recognized classification systems as this would enable a systematic analysis. It was a grouping of the prescribed antibiotics within the classification of the Anatomical Therapeutic Chemical (ATC) system and the Watch, Reserve (AWaRe) classification as provided by the World Health Organization (WHO). This classification method made it possible to identify the key antibiotic classes of cephalosporins, fluoroquinolones, penicillins, macrolides, and carbapenems. The classification of antibiotics into such groups enabled comparison of the trends in prescribing and analysis of the patterns of antibiotic use within each of the therapeutic classes of the study population.

2.9 Antimicrobial Susceptibility Testing

Testing of bacterial isolates was done in the hospital microbiology laboratory in accordance with Clinical and Laboratory Standards Institute (CLSI) principles. Bacterial pathogens that were isolated in clinical samples were identified through standard microbiological methods. Susceptibility testing was done to identify the sensitive and resistant isolates to the antibiotics tested. The findings were presented based on CLSI interpretive guidelines, indicating that the isolates are either susceptible, intermediate or resistant. To conduct statistical analysis, the results of susceptibility were classified as sensitive or resistant to analyze the patterns of resistance to various antibiotic classes.

2.10 Statistical Analysis

The data collected was statistically analyzed through statistical software. The types of descriptive statistical procedures were used to describe the attributes of the study population and the patterns of antibiotic usage. Categorical variables (gender, antibiotic classes, and bacteria isolates) were calculated in terms of frequencies and percentages. Continuous variables were the mean and standard deviation, age was used as an example. To compare the relationship between antibiotic classes and antimicrobial resistance pattern, the chi-square test was applied to assess the relationship between the two variables. Besides, Pearson correlation analysis was done to check the relationship between the score of antibiotic utilization and the rate of resistance. The additional analysis conducted was the logistic regression analysis, which was conducted to examine the hypothesis that the outcomes of antimicrobial resistance could be predicted by the use of antibiotics.

3. Results

3.1 Demographic profile

In this retrospective study, 80 records of patients undergoing antibiotic treatment were examined. The largest category of the study population was males with 60 percent and females with 40 percent. The distribution of the age groups showed that the vast majority of the patients belonged to the age group of 31 years to 45 years, then there were also the age groups of 46-60 years and 61-80 years (Table 1).

Table 1. Demographic Profile

Variable	Category	Frequency (n)	Percentage (%)
Gender	Male	48	60.0
	Female	32	40.0
Age Group (years)	18–30	14	17.5
	31–45	26	32.5
	46–60	24	30.0
	>60	16	20.0
Total		80	100

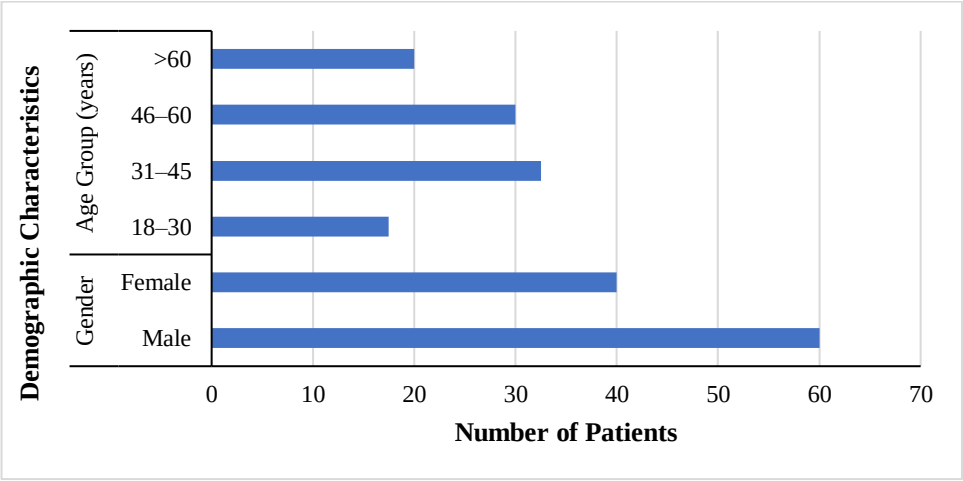

Figure 1. Distribution of Study Participants by Gender and Age Group

The demographic profile of the study population is presented in figure 1 and depicts the distribution of the participants based on their gender and various age groups. It shows a comparative figure of the male and female representation and shows how the participants were distributed across the categorized age ranges in the sample analyzed.

3.2 Antibiotic Utilization Patterns

Analysis of prescription records showed that the most prescribed class of antibiotics were cephalosporins (28.75% of all prescriptions) and fluoroquinolones (27.50%). Prescription of penicillins, macrolides and carbapenems was less common. The overwhelming use of cephalosporins and fluoroquinolones indicates that they are used extensively to treat bacterial infections. Table 2 provides the detailed distribution of antibiotics in therapeutic class.

Table 2. Distribution of Antibiotics by Therapeutic Class

Antibiotic Class	Frequency	Percentage (%)
Cephalosporins	23	28.75
Fluoroquinolones	22	27.50
Penicillins	14	17.50
Macrolides	11	13.75
Carbapenems	10	12.50
Total	80	100

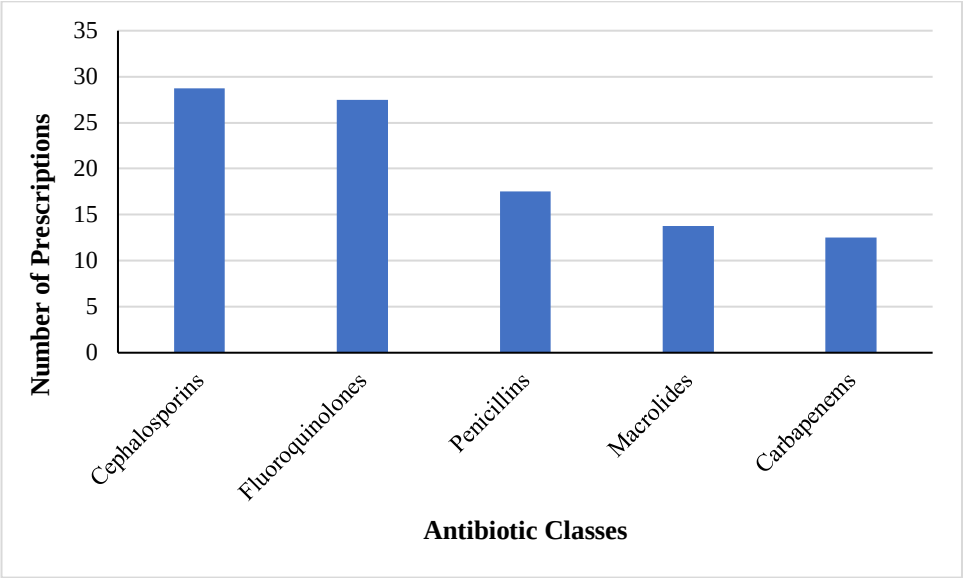

Figure 2. Distribution of Antibiotic Utilization by Therapeutic Class

Figure 2 shows the distribution of antibiotic prescriptions in various classes of therapeutic agent applied in treatment of bacterial infections. It depicts how the commonly used antibiotic groups are prescribed in relation to each other, which demonstrated a difference in clinical preference between these classes among the research population.

3.3 Distribution of Bacterial Isolates

The analysis of the microbiological culture reports revealed that Escherichia coli was the most common bacterial isolate with 30 percent of the total isolates. It was then Staphylococcus aureus (27.5) and Klebsiella pneumoniae (21.25). Pseudomonas aeruginosa (16.25%) and Enterococcus species (5%), were also represented as other isolates. These results show that Gram-negative bacteria are mostly predominant among clinical isolates, which are collected in infected patients (Table 3).

Table 3. Distribution of Bacterial Isolates

Bacterial Isolate	Frequency	Percentage (%)
E. coli	24	30.00
Staphylococcus aureus	22	27.50
Klebsiella pneumoniae	17	21.25
Pseudomonas aeruginosa	13	16.25
Enterococcus spp.	4	5.00
Total	**80**	**100**

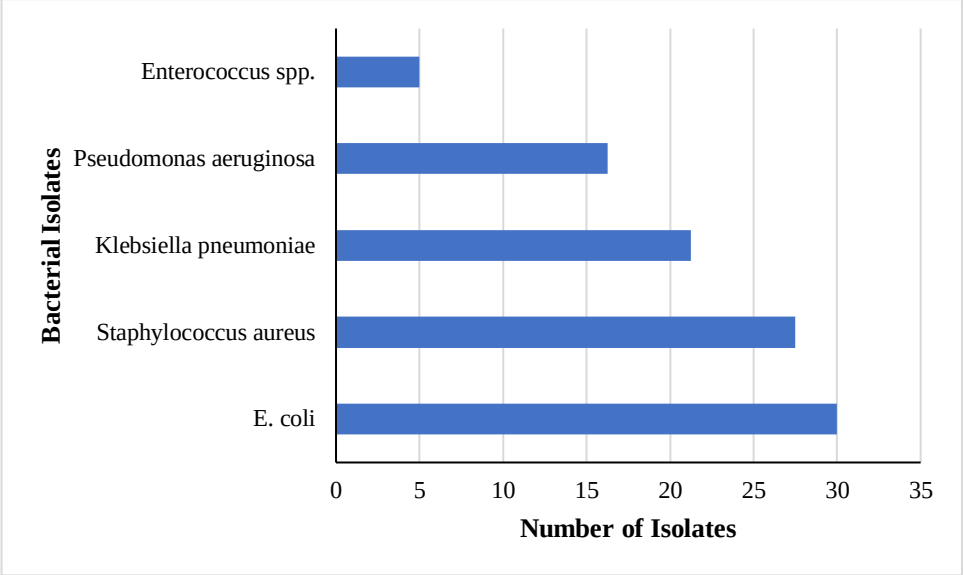

Figure 3. Distribution of Bacterial Isolates Identified from Clinical Samples

Figure 3 shows the distribution of bacterial species that were isolated on clinical samples that were collected on the study population. It points at the comparative prevalence of both Gram-negative and Gram-positive bacteria which were detected by microbiological study. The distribution gives an understanding of the most common pathogens related to the infections of patients receiving antibiotic treatment.

3.4 Antimicrobial Resistance Patterns

Analysis was done on the antimicrobial resistance profile of bacterial isolates against the antibiotic classes prescriptions. Similar percentages of sensitive and resistant isolates were found in the antibiotic groups. Cephalospin and fluoroquinolones exhibited moderate resistance and carbapenems exhibited fairly balanced resistance and sensitivity patterns. As demonstrated in Table 4, no significant correlation was found between the antibiotic class and resistance pattern (2 = 0.40, p = 0.982).

Table 4. Association Between Antibiotic Class and Resistance Pattern

Antibiotic Class	Sensitive (n)	Resistant (n)
Cephalosporins	12	11
Fluoroquinolones	12	10
Penicillins	8	6
Macrolides	5	6
Carbapenems	5	5

Chi-square (χ^2) = 0.40, p-value = 0.982

3.5 Correlation Between Antibiotic Utilization and Resistance

The Pearson correlation analysis was used to test the connection between antimicrobial resistance and antibiotic utilization intensity. The findings showed that the relationship between resistance rate and antibiotic utilization score was very weak (r = -0.039). The correlation was statistically insignificant (p = 0.730) and this implied that the use of antibiotics as a single variable might not be the direct cause of the difference in resistance patterns among the study population (Table 5).

Table 5. Correlation Analysis Between Antibiotic Utilization and Resistance

Variables	Correlation Coefficient (r)	p-value
Antibiotic Utilization Score vs Antimicrobial Resistance	-0.039	0.730

3.6 Logistic Regression Analysis for Predicting Antimicrobial Resistance

The use of logistic regression analysis was done to evaluate whether the antibiotic utilization score would be predictive of antimicrobial resistance between bacterial isolates. The analysis showed that the regression coefficient (0 = -0.0273) of antibiotic utilization score had a negative value and a standard error of 0.078. This association was however not statistically significant (p = 0.726). The regression model showed that the explanatory power (Pseudo R 2 0.001) of antibiotic utilization alone was not very high to predict antimicrobial resistance (Table 6).

Table 6. Logistic Regression Analysis for Predicting Antimicrobial Resistance

Variable	Coefficient (β)	Standard Error	p-value

Constant	0.0569	0.501	0.910
Antibiotic Utilization Score	-0.0273	0.078	0.726

4. Discussion

The study assessed the use of antibiotics and the resistance to antimicrobials in patients who were taking antibiotic therapy in a tertiary care hospital. The demographic study revealed that male patients were the largest portion of the study population, and more of them belonged to the middle-age groups. The trend could be an indication of an augmented healthcare consumption by economically active age groups who have a more regular exposure to environmental and occupational risk factors of infections. Some clinical studies investigating the occurrence of the infectious diseases have reported the prevalence of middle-aged patients in hospital-based studies. The patterns of antibiotic prescription were analyzed, and it was proven that there was a tendency to prescribe cephalosporins and fluoroquinolones as the most common classes of antibiotics. The popularity of these broad-spectrum antibiotics impose the idea that they are significant in empirical treatment of suspected bacterial infection in hospital settings. Nonetheless, the common use of this type of antibiotics can also be a factor in the process of selection that facilitates antimicrobial resistance. To keep the antibiotic consumption practices reasonable and prevent the unwarranted exposure to broad-spectrum agents, it is, nevertheless, important to continue to monitor the patterns of the antibiotic use.

The microbiological results were that Escherichia coli was most frequently isolated amongst bacteria, followed by Staphylococcus aureus and Klebsiella pneumoniae. These are the pathogens that are highly known as the major causative agents of hospital-acquired and community-acquired infections. The preponderance of Gram-negative bacteria in the present research notes the increasing significance of Gram-negative bacteria in clinical infections and the possibility of them being a contributing factor to the rising antimicrobial resistance. The analysis of resistance showed that the resistance was moderate in all antibiotic classes, but the statistical analysis did not reveal the significant correlation between the pattern of resistance and the antibiotic classes. Moreover, the correlation analysis on the intensity of antibiotic use and antimicrobial resistance showed that the correlation between the two was found to be very weak with a negative value. The results of the logistic regression analysis showed also that the score of antibiotic utilization was not a statistically significant predictor of the outcomes of resistance in this dataset. These results imply that antimicrobial resistance can be dependent on various influences other than antibiotic prescribing, such as practices of infection control, bacterial genetic mechanisms, and transmission through the environment.

The results of the study align with the existing literature on investigating the use and the trends of antibiotic use and resistance in hospitals. Other areas of research have also indicated that cephalosporins and fluoroquinolones are the most prescribed antibiotics in healthcare organizations because of their broad-spectrum action and efficacy in empirical treatment (Pauwels et al., 2021; Xu et al., 2020). The growth of antimicrobial resistance trends has been attributed to increased use of the antibiotics in the world. The high rate of Escherichia coli and Staphylococcus aureus among the bacterial isolates we reported in this study is also consistent with the previous reports in case of hospital-based surveillance studies. As an example, the retrospective studies that examined infected clinical samples have revealed them as the top causes of bacterial infection and contributors to antimicrobials resistance in healthcare settings (Puca et al., 2021; Tran et al., 2017). The outcomes of this research show that it is necessary to constantly monitor the fate of bacterial pathogens and their resistance patterns.

It has also been pointed out that the patterns of antimicrobial resistance difference in the context of healthcare settings and geographical areas has been stressed in the previous research because of the variations in the practice of antibiotic prescription and infection control (Pourmand et al., 2017; Tang et al., 2023). Hospital-based studies assessing the use and resistance patterns of antibiotics in hospitalized patients also reported similar observation, which revealed that the problem of antibiotic resistance is complex and multifactorial (Ramachandran, 2023). Furthermore, studies that have concentrated on policy issues regarding antibiotic use and resistance have shown how regulatory frameworks and stewardship programs can be put into use by regulating antibiotic resistance (Yevutsey et al., 2017).

The results of the current research emphasize the necessity to track the trends in the use of antibiotics and antimicrobial resistance in medical facilities. The knowledge of the prescribing habits may aid in recognizing the possible abuse of antibiotics and assist in the creation of specific antimicrobial stewardship initiatives. It is necessary to continuously observe bacterial isolates and their patterns of resistance in order to direct the empirical therapy and enhance the outcomes of treatment. The findings also highlight the importance of hospital setting based antibiotic policies that spur positive antibiotic prescribing habits and minimize the development of resistant pathogens. This study has a number of limitations although it offers important insights. To begin with, retrospective design depended on the past hospital records, and this can hinder the accessibility of some of the clinical variables. Second, the sample size is rather small, which might limit the ability to depict the results to other health care settings. Also, the research centered on the use and resistance patterns of antibiotics with little consideration of other aspects like infection control habits, comorbidities in patients, and dosage regime of antibiotics which can cause resistance.

To enhance the application of the results to other healthcare institutions, future research must factor in bigger sample sizes and multicenter data. Future research would also give additional information about the practice of prescribing antibiotics and clinical outcomes. Moreover, antimicrobial stewardship programs combined with regular monitoring of antibiotic use and resistance trends could also be used to maximize the use of antibiotics and limit the transmission of resistant organisms. Enhancement of infection control measures and advocacy of rational antibiotics prescriptions are some of the actions that can be taken to curb the increasing world menace of antimicrobial resistance.

5. Conclusion

The study was insightful on the use of the antibiotics and antimicrobial resistance of patients undergoing the antibiotic treatment in a tertiary care hospital. The demographic data analysis has revealed that the patients were of middle-aged age and male patients formed a bigger ratio of the study population. Analysis of the dosage pattern of antibiotic use showed that cephalosporins and fluoroquinol ones used the most common classes of antibiotics, which were used as a substitution when the cause of bacteria infections was suspected. Escherichia coli, Staphylococcus aureus and Klebsiella pneumoniae were the most common isolates of bacteria found in clinical infection. The resistance analysis showed moderate resistance in the antibiotic classes in the analysis. Nevertheless, statistical analysis proved that there were no statistically significant differences in terms of antibiotic class and resistance pattern, indicating that antimicrobial resistance can be conditioned by a set of clinical and environmental factors. Moreover, correlation and logistic regression calculations demonstrated that the antibiotic utilization score did not play a major role as a predictor of antimicrobial resistance in the research group. Such results underscore the multifaceted nature of the adverse issue of antimicrobial resistance and, in addition, underscore the significance of multifaceted interventions that cannot be limited to antibiotic prescriptions practice. Enhancing hospital antibiotic policy, promoting rational prescribing behavior, and effective infection control are important measures towards containing the growing menace of antimicrobial resistance and the effectiveness of antibiotic therapy in the long-term.

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