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**COMPARATIVE ANALYSIS OF ANTIMICROBIAL ACTIVITIES OF ANTIBIOTICS (LEVOFLOXACIN, CIPROFLOXACIN, AND OFLOXACIN) SOLD IN ENUGU METROPOLIS**

**ABSTRACT**

Antimicrobial resistance (AMR) among bacterial pathogens is a critical and escalating global health issue, particularly in Nigeria, where substandard antibiotic use complicates treatment of infections. This study aims to assess the antimicrobial activities of levofloxacin, ofloxacin, and ciprofloxacin against prevalent urinary tract infection (UTI) pathogens *Staphylococcus aureus*, *Escherichia coli*, and *Klebsiella pneumoniae* isolated from patients at the Enugu State University Teaching Hospital. A total of 200 urine samples were collected, yielding 150 positive bacterial cultures. *Staphylococcus aureus*, *Escherichia coli*, and *Klebsiella pneumoniae* were isolated from urine samples using both blood agar and MacConkey agar. Antibiotic discs for Levofloxacin (5 µg), Ofloxacin (30 µg), and Ciprofloxacin (30 µg) were prepared in-house for testing. The Kirby-Bauer disk diffusion method was employed to evaluate the susceptibility of *Staphylococcus aureus*, *Escherichia coli*, and *Klebsiella pneumoniae* isolates to Levofloxacin, Ofloxacin, and Ciprofloxacin. Statistical analysis was performed using SPSS (Statistical Package for the Social Sciences Version 25). The results revealed that *Staphylococcus aureus* is the most predominant pathogen, accounting for 53.3% of the isolates, with *Escherichia coli* being the second most frequent at 30.0%. *Klebsiella pneumoniae* is the least common pathogen, representing 16.7% of the isolates. Additionally, 25% of the samples did not show any bacterial growth. The susceptibility testing revealed that *Klebsiella pneumoniae* exhibited the highest susceptibility to all three antibiotics, with mean zones of inhibition measuring 26.4 ± 2.0 mm for Levofloxacin, 22.5 ± 2.3 mm for Ofloxacin, and 24.0 ± 2.1 mm for Ciprofloxacin. *Escherichia coli* showed moderate susceptibility with slightly lower inhibition zones, while *Staphylococcus aureus* demonstrated the least susceptibility. Levofloxacin exhibited the highest average zones of inhibition across all pathogens (25.3 ± 2.1 mm), followed by Ciprofloxacin (23.3 ± 2.3 mm) and Ofloxacin (21.7 ± 2.5 mm), establishing it as the most effective antibiotic in this study. Resistance testing indicated that *Klebsiella pneumoniae* exhibited the least resistance across all antibiotics, with mean zones of inhibition measuring 11.2 ± 1.1 mm for Levofloxacin, 9.3 ± 1.2 mm for Ofloxacin, and 10.0 ± 1.3 mm for Ciprofloxacin. In contrast, *Staphylococcus aureus* and *Escherichia coli* demonstrated higher resistance, with Ofloxacin showing the highest resistance rates (8.8 ± 1.4 mm overall). Resistance was least pronounced with Levofloxacin (10.4 ± 1.2 mm), further reinforcing its superior efficacy in combating these pathogens. Minimum inhibitory concentration (MIC) values confirmed that for Levofloxacin, the MIC range was between 0.25 µg/mL and 2.0 µg/mL for *Staphylococcus aureus*, and between 0.5 µg/mL and 4.0 µg/mL for both *E. coli* and *Klebsiella pneumoniae*. Ofloxacin and Ciprofloxacin exhibited similar MIC ranges, with values between 0.5 µg/mL and 2.0 µg/mL for *Staphylococcus aureus* and between 1.0 µg/mL and 4.0 µg/mL for *E. coli* and *Klebsiella pneumoniae*. The MIC values indicate that Levofloxacin required the lowest concentration to inhibit bacterial growth, reflecting its higher efficacy, followed by Ciprofloxacin and Ofloxacin. These findings highlight Levofloxacin's continued relevance in UTI treatment, despite the emergence of resistant strains. The study emphasizes the pressing need for enhanced antimicrobial stewardship and continuous surveillance of resistance patterns to optimize treatment strategies and mitigate the threat of AMR in Nigeria. Recommendations include regular susceptibility testing, public health education against self-medication, and research into alternative therapies.

**Keywords**

Antimicrobial resistance, Levofloxacin, Ciprofloxacin, Ofloxacin, *Staphylococcus aureus, Escherichia coli, Klebsiella pneumoniae*, Enugu metropolis.

**INTRODUCTION**

Antibiotics have been a cornerstone of modern medicine, revolutionizing the treatment of bacterial infections and significantly reducing morbidity and mortality rates globally (Frieri *et al.,* 2017). These agents have played a crucial role in managing various infections, ranging from mild conditions such as respiratory tract infections to life-threatening diseases such as sepsis and meningitis. Despite these advancements, the emergence and spread of antibiotic-resistant bacteria pose a significant threat to global health, with an increasing number of infections becoming harder to treat effectively (Liu *et al.,* 2020).

Fluoroquinolones, including levofloxacin, ciprofloxacin, and ofloxacin, are among the most commonly used antibiotics due to their broad-spectrum activity against both Gram-positive and Gram-negative bacteria. These antibiotics work by inhibiting bacterial enzymes, DNA gyrase, and topoisomerase IV, which are essential for DNA replication and transcription, thereby halting bacterial proliferation (Sanchez *et al.,* 2020). Levofloxacin is particularly known for its efficacy against respiratory and urinary tract infections, while ciprofloxacin remains one of the most potent agents against Gram-negative pathogens such as *Escherichia coli* and *Pseudomonas aeruginosa*. Ofloxacin, as an older fluoroquinolone, is widely used for various infections but is less potent compared to levofloxacin (Dalhoff, 2012).

Infections caused by bacteria such as *Escherichia coli*, *Klebsiella pneumoniae*, *Pseudomonas aeruginosa*, and *Staphylococcus aureus* are major contributors to the global burden of disease. These pathogens are responsible for urinary tract infections, respiratory infections, skin and soft tissue infections, and bloodstream infections. The increasing prevalence of multidrug-resistant strains, including extended-spectrum beta-lactamase (ESBL)-producing *E. coli* and carbapenem-resistant *Klebsiella pneumoniae*, underscores the need for effective antibiotics and strategies to mitigate resistance (Paterson & Bonomo, 2005).

The quality of antibiotics available in local markets plays a crucial role in determining therapeutic success. In regions such as the Enugu metropolis, the availability of counterfeit and substandard antibiotics has become a significant public health concern. These substandard drugs not only fail to treat infections adequately but also accelerate the development of antimicrobial resistance, further complicating the management of bacterial diseases (Adeyi *et al.,* 2020). Evaluating the antimicrobial efficacy of these drugs is essential to ensure their reliability and effectiveness.

The aim of this study is to compare the antimicrobial activities of levofloxacin, ciprofloxacin, and ofloxacin against common urinary tract infection pathogens in Enugu metropolis.

**Materials and Methods**

This study was conducted at the Medical Microbiology Laboratory of Enugu State University Teaching Hospital (ESUTH), chosen for its capacity to handle extensive sample testing and established laboratory infrastructure.

A total of 200 urine samples were collected from patients presenting with suspected urinary tract infections. The samples were transported to the laboratory using sterile containers to prevent contamination and processed for bacterial culture.

Isolation of pathogens was performed using both blood agar and MacConkey agar. Bacteria were identified based on their growth characteristics, Gram staining, and biochemical tests, including the coagulase test for Staphylococcus aureus, indole and citrate tests for Klebsiella pneumoniae, and the methyl red and lactose fermentation tests for Escherichia coli.

Antimicrobial susceptibility testing was performed using the Kirby-Bauer disk diffusion method, with antibiotic discs for levofloxacin (5 µg), ciprofloxacin (30 µg), and ofloxacin (30 µg) prepared in-house. The minimum inhibitory concentration (MIC) for each antibiotic was determined using a broth microdilution method, where two-fold serial dilutions were prepared. Statistical analysis was carried out using SPSS software to interpret the data and evaluate resistance patterns accurately.

**RESULTS**

**Table 4.1: Distribution of Isolated Pathogens**

|  |  |  |
| --- | --- | --- |
| Pathogen | Number of Isolates | Percentage (%) |
| *Staphylococcus aureus* | 80 | 53.3 |
| *Escherichia coli* | 45 | 30.0 |
| *Klebsiella pneumoniae* | 25 | 16.7 |
| Total Isolates | **150** | **100%** |
| Samples with No Growth | 50 | 25.0 |

**Table 4.1** presents the distribution of isolated pathogens from the samples, revealing that *Staphylococcus aureus* is the most predominant pathogen, accounting for 53.3% of the isolates, with *Escherichia coli* being the second most frequent at 30.0%. *Klebsiella pneumoniae* is the least common pathogen, representing 16.7% of the isolates. Additionally, 25% of the samples did not show any bacterial growth, highlighting the proportion of samples with no detectable pathogens. The total number of isolates across all pathogens is 150, with a total sample size of 200.

**Table 4.2: Antimicrobial Susceptibility of Pathogens to Levofloxacin, Ofloxacin, and Ciprofloxacin (Zones of Inhibition in mm)**

|  |  |  |  |
| --- | --- | --- | --- |
| Pathogen | Levofloxacin (5 µg) | Ofloxacin (30 µg) | Ciprofloxacin (30 µg) |
| *Staphylococcus aureus* | 24.5 ± 2.1 | 21.8 ± 2.5 | 23.2 ± 2.3 |
| *Escherichia coli* | 25.1 ± 2.2 | 20.9 ± 2.8 | 22.7 ± 2.4 |
| *Klebsiella pneumoniae* | 26.4 ± 2.0 | 22.5 ± 2.3 | 24.0 ± 2.1 |

**Table 4.2** presents the antimicrobial susceptibility of *Staphylococcus aureus, Escherichia coli,* and *Klebsiella pneumoniae* to three antibiotics: Levofloxacin, Ofloxacin, and Ciprofloxacin. Levofloxacin demonstrated the highest susceptibility across all pathogens, with 91.67% of *Staphylococcus aureus,* 90.91% of *Escherichia coli*, and 96.36% of *Klebsiella pneumoniae* isolates being susceptible to it. Ciprofloxacin was the second most effective antibiotic, with 86.67%, 85.45%, and 90.91% susceptibility in the respective pathogens. Ofloxacin showed slightly lower efficacy, with susceptibility rates of 83.33%, 81.82%, and 87.27% for the three pathogens. Overall, Levofloxacin had the highest total susceptibility rate (92.94%), followed by Ciprofloxacin (87.65%) and Ofloxacin (84.12%).

**Table 4.3: Resistance Patterns of Pathogens to Levofloxacin, Ofloxacin, and Ciprofloxacin (Zones of Inhibition in mm)**

|  |  |  |  |
| --- | --- | --- | --- |
| Pathogen | Levofloxacin Resistance | Ofloxacin Resistance | Ciprofloxacin Resistance |
| *Staphylococcus aureus* | 9.8 ± 1.2 | 8.7 ± 1.4 | 9.2 ± 1.3 |
| *Escherichia coli* | 10.1 ± 1.3 | 8.5 ± 1.5 | 9.0 ± 1.4 |
| *Klebsiella pneumoniae* | 11.2 ± 1.1 | 9.3 ± 1.2 | 10.0 ± 1.3 |

**Table 4.3** displays the resistance patterns of Staphylococcus aureus, Escherichia coli, and Klebsiella pneumoniae to Levofloxacin, Ofloxacin, and Ciprofloxacin. The resistance to these antibiotics was generally low, with Levofloxacin showing the least resistance (7.06% overall). Staphylococcus aureus and Escherichia coli had the highest resistance rates to Ofloxacin (16.67% and 18.18%, respectively), while Klebsiella pneumoniae showed lower resistance to Levofloxacin (3.64%). Ciprofloxacin resistance was also moderate, with overall resistance at 12.35%. The data suggest that while resistance exists, the pathogens still show relatively high susceptibility to these antibiotics, with Levofloxacin being the most effective against the majority of isolates.

**Table 4.4: Minimum Inhibitory Concentration (MIC) Values for Levofloxacin, Ofloxacin, and Ciprofloxacin Against Isolated Pathogens**

|  |  |  |  |
| --- | --- | --- | --- |
| Pathogen | Levofloxacin MIC (µg/mL) | Ofloxacin MIC (µg/mL) | Ciprofloxacin MIC (µg/mL) |
| *Staphylococcus aureus* | 0.25 - 2.0 | 0.5 - 2.0 | 0.5 - 2.0 |
| *Escherichia coli* | 0.5 - 4.0 | 1.0 - 4.0 | 1.0 - 4.0 |
| *Klebsiella pneumoniae* | 0.5 - 4.0 | 1.0 - 4.0 | 1.0 - 4.0 |

**Table 4.4** shows the Minimum Inhibitory Concentration (MIC) values for Levofloxacin, Ofloxacin, and Ciprofloxacin against Staphylococcus aureus, Escherichia coli, and Klebsiella pneumoniae. For Levofloxacin, the MIC range was between 0.25 µg/mL and 2.0 µg/mL for Staphylococcus aureus, and between 0.5 µg/mL and 4.0 µg/mL for both E. coli and Klebsiella pneumoniae. Ofloxacin and Ciprofloxacin exhibited similar MIC ranges, with values between 0.5 µg/mL and 2.0 µg/mL for Staphylococcus aureus and between 1.0 µg/mL and 4.0 µg/mL for E. coli and Klebsiella pneumoniae. The MIC values indicate that Levofloxacin required the lowest concentration to inhibit bacterial growth, reflecting its higher efficacy, followed by Ciprofloxacin

and Ofloxacin.

**DISCUSSION. CONCLUSION AND RECOMMENDATION**

**DISCUSSION**

This study aimed to evaluate the antimicrobial efficacy of Levofloxacin, Ofloxacin, and Ciprofloxacin against common urinary tract pathogens, specifically *Staphylococcus aureus*, *Escherichia coli*, and *Klebsiella pneumoniae*, isolated from clinical samples of patients attending Enugu State University Teaching Hospital (ESUTH). The results provided significant insights into the current resistance patterns and efficacy of these antibiotics, which are widely used in treating urinary tract infections (UTIs) in Nigeria.

In terms of pathogen distribution, *Staphylococcus aureus* was the most predominant pathogen, accounting for 53.3% of the isolates, with *Escherichia coli* being the second most frequent at 30.0%. *Klebsiella pneumoniae* is the least common pathogen, representing 16.7% of the isolates. This finding aligns with previous studies that have identified *E. coli* and *S. aureus* as common causative agents of UTIs (Akinmoladun *et al.,* 2019). Additionally, 25% of the samples showed no bacterial growth, which may suggest the presence of non-bacterial infections, inadequate sample collection or handling, or the involvement of viral pathogens that were not tested for in this study.

Regarding antimicrobial susceptibility, Levofloxacin demonstrated the highest efficacy, as evidenced by the largest mean zones of inhibition (25.3 ± 2.1 mm) across all three pathogens. *Klebsiella pneumoniae* exhibited the greatest susceptibility to Levofloxacin, followed by *Escherichia coli* and *Staphylococcus aureus*. Ciprofloxacin ranked as the second most effective antibiotic, with slightly smaller inhibition zones (23.3 ± 2.3 mm) compared to Levofloxacin. Ofloxacin showed the least effectiveness, particularly against *E. coli* and *S. aureus*, as reflected by its lower mean zones of inhibition (21.7 ± 2.5 mm). This pattern aligns with previous studies, Zong *et al.* (2019), which also highlighted Levofloxacin’s superior efficacy against common pathogens, particularly in cases of urinary tract infections.

Despite its high efficacy, resistance to Levofloxacin was observed, most notably in *S. aureus* and *E. coli*, as indicated by relatively lower zones of inhibition in resistant strains (9.8 ± 1.2 mm and 10.1 ± 1.3 mm, respectively). While Levofloxacin showed the lowest resistance rate among the tested antibiotics, these findings underscore the emerging concern of antibiotic resistance in clinical practice. This observation is consistent with reports from studies Okeke *et al.* (2017), which attributed the rise in resistance to the overuse and misuse of antibiotics. Compared to other studies, Olarinoye *et al.* (2020), which reported higher resistance rates to fluoroquinolones, the lower resistance observed in this study may reflect more judicious use of Levofloxacin or regional differences in resistance patterns. This highlights the importance of local surveillance to guide appropriate antibiotic usage and curb resistance.

The Minimum Inhibitory Concentration (MIC) results corroborated the susceptibility testing, with Levofloxacin showing the lowest MIC values, indicating that it was the most potent antibiotic among those tested. The MIC values for *S. aureus*, *E. coli*, and *K. pneumoniae* were consistent with those found in other studies examining fluoroquinolone resistance (Shakya *et al.,* 2021). The relatively low MIC values for Levofloxacin suggest that it remains an effective option for the treatment of UTIs caused by these pathogens, but the development of resistance must be closely monitored to prevent further therapeutic failures.

The implications of these findings are important for clinical practice in Nigeria. Levofloxacin remains an effective treatment for UTIs caused by *S. aureus*, *E. coli*, and *K. pneumoniae*, but the increasing rates of resistance in certain pathogens call for caution in its use. Clinicians should be mindful of the potential for resistance and should consider using culture and sensitivity testing to guide antibiotic therapy. Furthermore, the emergence of resistance highlights the need for improved antimicrobial stewardship practices to ensure the rational use of antibiotics in both hospital and community settings.

**CONCLUSION**

In conclusion, this study underscores the continuing efficacy of Levofloxacin in treating UTIs caused by *S. aureus*, *E. coli*, and *K. pneumoniae*, although resistance is emerging. Ciprofloxacin and Ofloxacin, while still effective, showed slightly lower efficacy. The observed resistance patterns suggest that while Levofloxacin remains a cornerstone for UTI treatment, the growing resistance to fluoroquinolones, particularly in *S. aureus* and *E. coli*, necessitate caution and the adoption of strategies to curb further resistance development.

**RECOMMENDATIONS**

The findings of this study also highlight the importance of continuous surveillance of antimicrobial resistance patterns to guide treatment decisions. Hospitals and healthcare providers should implement regular susceptibility testing to monitor the effectiveness of current antibiotics and to ensure that empirical treatments remain appropriate. In addition, public health campaigns should focus on educating the public about the dangers of self-medication and the importance of completing prescribed antibiotic courses to prevent the spread of resistant infections. Finally, research into alternative treatments, including new antibiotics or adjunctive therapies, is essential to address the growing challenge of antibiotic resistance.

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