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Research Article

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Antibiotic Resistance Characteristics of Escherichia Coli, Staphylococcus Aureus, and Pseudomonas Aeruginosa Isolated from Patients with Urinary Tract Infections

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Abstract: Background: Antimicrobial resistance among urinary tract pathogens is a growing global threat. Objective: To evaluate antibiotic susceptibility patterns of *Escherichia coli*, *Staphylococcus aureus*, and *Pseudomonas aeruginosa* isolated from UTIs in Tay Nguyen University Hospital. Methods: From March to May 2025, 139 positive urine cultures were analyzed. Antibiotic susceptibility testing was performed using the Kirby–Bauer disk diffusion method according to CLSI guidelines. Results: *E. coli* isolates showed high resistance to Ampicillin (66.7%) and Tetracycline (41.3%), but remained susceptible to Amikacin (95.2%) and Piperacillin/Tazobactam (82.5%). *S. aureus* exhibited high resistance to Erythromycin (87.0%) but retained sensitivity to Amikacin (97.8%) and Levofloxacin (73.9%). *P. aeruginosa* isolates were resistant to most tested antibiotics but susceptible to Colistin (92.3%) and Piperacillin/Tazobactam (84.6%). Conclusion: Rising resistance rates highlight the urgent need for routine antimicrobial surveillance and rational antibiotic use in clinical practice.

Keywords: Antibiotic resistance, *E. coli*, *S. aureus*, *P. aeruginosa*, Urinary tract infection.

INTRODUCTION

Urinary tract infections (UTIs) are among the most common bacterial infections in both community and hospital settings, with an estimated 150 million new cases annually worldwide (Flores-Mireles, A. L. *et al.,* 2015). The treatment of UTIs mainly relies on antibiotics; however, antimicrobial resistance is increasing rapidly, particularly in common pathogens such as *Escherichia coli*, *Staphylococcus aureus*, and *Pseudomonas aeruginosa* (Gupta, K. *et al.,* 2011).

According to the World Health Organization (WHO), UTIs are included in the group of infectious diseases that require strict monitoring of antibiotic resistance due to the widespread emergence of multidrug-resistant (MDR) strains. These strains complicate treatment, increase the risk of complications, and escalate healthcare costs (World Health Organization. 2023). In Vietnam, several studies have reported that the resistance rates of *E. coli* to Ampicillin and Tetracycline usually range from 50–70% (Nguyen, T. T. *et al.,* 2024). Nevertheless, research data from the Central Highlands remain limited.

Given this context, we conducted a study to describe the antibiotic resistance profiles of *E. coli*, *S. aureus*, and *P. aeruginosa* isolated from patients with UTIs at Tay Nguyen University Hospital in 2025, thereby providing practical evidence to guide appropriate antibiotic selection in clinical practice.

SUBJECTS AND METHODS

Study subjects

Patients clinically suspected of having urinary tract infections (UTIs) who presented for examination and treatment at Tay Nguyen University Hospital during the study period. *Inclusion criteria:* Patients with symptoms suggestive of UTI (dysuria, urinary frequency/urgency, fever, flank pain); midstream urine samples collected under aseptic conditions; positive urine culture with bacterial count ≥10^5 CFU/ml. *Exclusion criteria:* Patients who had received antibiotics within 48 hours prior to sample collection; specimens deemed inadequate (contaminated with numerous epithelial cells or suspected of mixed contamination).

Study period and setting

The study was conducted from March 2025 to May 2025 at the Department of Microbiology, Tay Nguyen University Hospital.

Study design: A descriptive cross-sectional study.

Sample size

The required sample size nnn was estimated using the single-proportion formula:

$$n = Z^{2}_{(1-\alpha/2)} \frac{p(1-p)}{d^2}$$

where $Z^{2}_{(1-\alpha/2)}$ =1.96 for a 95% confidence level, the allowable margin of error d=0.05, and the expected prevalence p=0.179 based on Le Dinh Khanh (2018) (Khanh, L. D. *et al.,* 2018). The calculated minimum sample size was n=225participants.

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Sample Collection and Processing

The specimens were midstream urine samples, collected in the morning, stored in sterile containers, and transported to the laboratory within 2 hours after collection.

Samples were cultured on blood agar, MacConkey agar, and CLED agar.

Bacterial identification was based on:

Colony morphology.

Gram staining.

Biochemical reactions: IMViC, oxidase, catalase, coagulase, urease, etc.

The main bacterial strains isolated included *Escherichia coli*, *Staphylococcus aureus*, and *Pseudomonas aeruginosa*.

Antimicrobial Susceptibility Testing

Antibiotic susceptibility testing was performed using the Kirby–Bauer disk diffusion method on Mueller–Hinton agar, according to CLSI M100 guidelines, 2024 edition (Flores-Mireles, A. L. *et al.*, 2015).

The antibiotic groups tested included:

β-lactams: Ampicillin, Amoxicillin/Clavulanate, Ceftriaxone, Ceftazidime, Piperacillin/Tazobactam.

Aminoglycosides: Amikacin, Gentamicin.

Quinolones: Ciprofloxacin, Levofloxacin.

Macrolide: Erythromycin (for *S. aureus*).

Others: Tetracycline, Colistin (for *P. aeruginosa*).

Results were interpreted and classified as susceptible (S), intermediate (I), or resistant (R).

Data Processing and Analysis

Data were entered and processed using SPSS version 22.0.

Qualitative variables were presented as frequencies and percentages.

Comparison of resistance rates between bacterial strains was performed using the Chi-square test, with statistical significance set at $p < 0.05$.

RESULTS

Overall prevalence of urinary tract infection

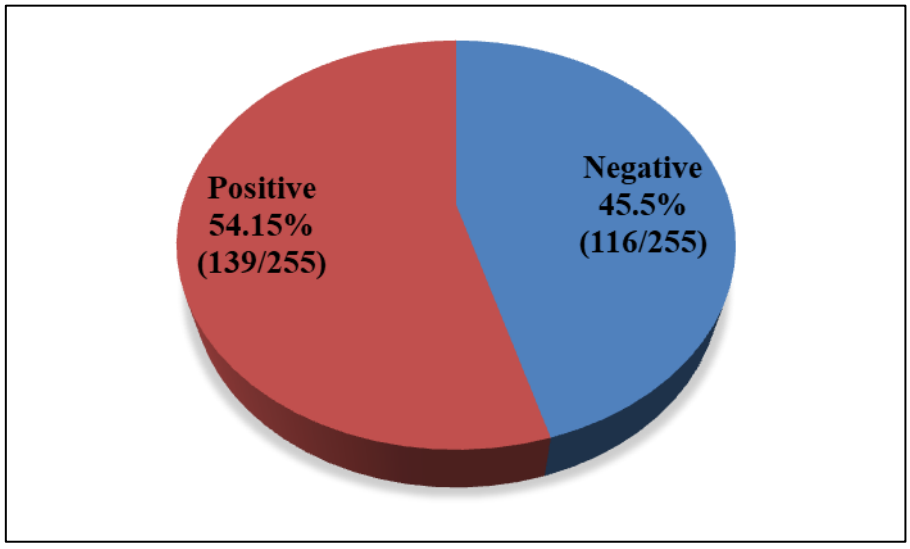

Figure 1. Prevalence of urinary tract infection among patients

Out of 255 patients with suspected urinary tract infection, 139 cases (54.5%) were culture-positive, while 116 cases (45.5%) were culture-negative.

Table 1. Distribution of bacterial isolates from urine specimens

Microorganism	Number of isolates	Percentage (%)
Escherichia coli	63	45.3
Staphylococcus aureus	46	33.1
Pseudomonas aeruginosa	13	9.4
Yeast (*Candida* spp.)	17	12.2
Total	**139**	**100**

Based on the results in Table 1, among 139 culture-positive urine samples: *Escherichia coli* accounted for 45.3%; *Staphylococcus aureus* accounted for 33.1%; *Pseudomonas aeruginosa* accounted for 9.4% and yeasts (mainly *Candida* spp.) were isolated in 12.2% of samples.

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Antibiotic resistance characteristics of Escherichia coli

Table 2. Antibiotic resistance profile of *Escherichia coli*

Antibiotic	Susceptible (%)	Intermediate (%)	Resistant (%)
Amikacin	1 (1,6)	2 (3,2)	60 (95,2)
Ampicillin	42 (66,7)	15 (23,8)	6 (9,5)
Gentamicin	16 (25,4)	27 (42,9)	20 (31,7)
Levofloxacin	2 (3,2)	18 (28,6)	43 (68,3)
Ofloxacin	4 (6,3)	17 (27,0)	42 (66,7)
Piperacillin/Tazobactam	0 (0)	11 (17,5)	52 (82,5)
Tetracycline	26 (41,3)	12 (19,0)	25 (39,7)

Antibiotic susceptibility test results of 63 *E. coli* isolates *E. coli* exhibited resistance to commonly used antibiotics such as Ampicillin (66.7%) and Tetracycline (41.3%). The highest susceptibility rates of *E. coli* were observed with Amikacin (95.2%), Piperacillin/Tazobactam (82.5%), and Levofloxacin (68.3%).

Antibiotic Resistance Characteristics of Staphylococcus aureus

Table 3. Antibiotic Resistance Characteristics of *Staphylococcus aureus*

Antibiotic	Susceptible (%)	Intermediate (%)	Resistant (%)
Amikacin	45 (97,8)	1 (2,2)	0 (0)
Erythromycin	1 (2,2)	5 (10,9)	40 (87,0)
Gentamicin	25 (54,3)	10 (21,7)	11 (23,9)
Levofloxacin	34 (73,9)	7 (15,2)	5 (10,9)
Ofloxacin	30 (65,2)	15 (32,6)	1 (2,2)
Tetracycline	14 (30,4)	16 (34,8)	16 (34,8)
Vancomycin	40 (87,0)	0 (0)	6 (13.0)

Antibiotic susceptibility test results of 46 *S. aureus* isolates: *S. aureus* strains were resistant to most commonly used antibiotics, with the highest resistance observed against Erythromycin (87.0%). The susceptibility rates of *S. aureus* were relatively high for Amikacin (97.8%), Vancomycin (87.0%), Levofloxacin (73.9%), and Ofloxacin (65.2%).

Antibiotic Resistance Characteristics of Pseudomonas aeruginosa

Table 4. Antibiotic Resistance Characteristics of *Pseudomonas aeruginosa*

Antibiotic	Susceptible (%)	Intermediate (%)	Resistant (%)
Amikacin	10 (79,9)	0 (0)	3 (23,1)
Colistin	7 (53,8)	0 (0)	6 (46,2)
Gentamicin	9 (69,2)	2 (15,4)	2 (15,4)
Levofloxacin	11 (84,6)	2 (15,4)	0 (0)
Ofloxacin	9 (69,2)	3 (23,1)	1 (7,7)
Piperacillin/Tazobactam	11 (84,6)	2 (15,4)	0 (0)
Tetracycline	4 (30,8)	6 (46,2)	3 (23,1)

Antibiotic susceptibility test results of 46 *P. aeruginosa* isolates: The *P. aeruginosa* isolates showed good susceptibility to Piperacillin/Tazobactam (84.6%), Levofloxacin (84.6%), and Amikacin (79.9%). Other antibiotics also demonstrated high susceptibility rates.

DISCUSSION

Proportion of Bacteria Causing Urinary Tract Infections

The present study conducted at Tay Nguyen University Hospital showed that the prevalence of urinary tract infections (UTIs), as confirmed by urine culture, was 54.5%. This rate is higher than that reported by Pham Hien Anh (2022) (27.33%) (Huy, T. Q. *et al.*, 2023) and Le Dinh Khanh (2018) (45.5%) (Anh, P. H., & Hưng, P. M. 2022), but lower than the findings of Tran Quoc Huy (2022) (75.5%) (Ha, P. T. Y. *et al.*, 2022). These discrepancies may be attributed to differences in epidemiological characteristics, demographic profiles, and risk factors among the studied populations.

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From a clinical perspective, UTIs present with diverse manifestations and may lead to various complications. Although diagnostic methods and microbial identification techniques have advanced, routine urine culture and bacterial isolation still face certain limitations in daily practice. Currently, diagnosis primarily relies on a combination of clinical symptoms, biochemical tests, and microbiological confirmation. Notably, the increasing trend of antimicrobial resistance among uropathogens poses challenges in selecting effective treatment regimens and underscores the urgent need for continuous surveillance and rational antibiotic use.

In our study, a total of 139 microbial isolates were obtained from urine samples. Among these, *Escherichia coli* accounted for the highest proportion (45.3%), followed by *Staphylococcus aureus* (33.1%) and *Pseudomonas aeruginosa* (9.4%). In addition, 17 yeast isolates were identified; however, fungal pathogens were not the primary focus of this research.

Our findings are consistent with previous reports. Pham Thuy Yen Ha (2022) recorded *E. coli* (43.4%), *P. aeruginosa* (11.3%), and *S. aureus* (1.9%) (Sa, N. T., & Binh, T. D. 2024); while Le Dinh Khanh (2018) documented *E. coli* (45.88%), *S. aureus* (9.43%), and *P. aeruginosa* (8.24%) (Anh, P. H., & Hưng, P. M. 2022). Collectively, these results confirm that at Tay Nguyen University Hospital, *E. coli* and *S. aureus* remain the principal causative agents of UTIs, whereas *P. aeruginosa* also plays a significant role, particularly in cases associated with hospital-acquired infections.

Antibiotic Susceptibility of E. coli

Our findings showed that *E. coli* exhibited high resistance to several commonly used antibiotics, with the highest resistance observed against Ampicillin (66.7%), followed by Tetracycline (41.3%). In contrast, the bacterium maintained high susceptibility to Amikacin (95.2%), Piperacillin/Tazobactam (82.5%), and Levofloxacin (68.3%). This pattern reflects a clinical reality in which traditional antibiotics are becoming increasingly ineffective, whereas some newer agents or combination therapies still retain therapeutic efficacy.

When compared with the study by Pham Thuy Yen Ha (2022), the susceptibility rates of *E. coli* to Amikacin and Piperacillin/Tazobactam were both above 90%, which is consistent with our results. However, susceptibility to Levofloxacin in that study was only 43.5% (Sa, N. T., & Binh, T. D. 2024), markedly lower than the 68.3% observed in our study. This discrepancy may be attributed to differences in epidemiological characteristics, patterns of antibiotic usage, or patient populations between the two investigations.

In summary, our results confirm a concerning trend of resistance to Ampicillin and Tetracycline, while Amikacin and Piperacillin/Tazobactam continue to play an important role in treatment. Levofloxacin demonstrates intermediate effectiveness with variability across studies, highlighting the need for continuous surveillance of antibiotic resistance at individual healthcare facilities to guide appropriate therapeutic strategies.

Antibiotic Susceptibility of S. aureus

Our study revealed that *S. aureus* exhibited resistance to most commonly used antibiotics, with the highest resistance rate observed for Erythromycin (87.0%), highlighting a worrisome resistance profile among Gram-positive bacteria. Nevertheless, *S. aureus* remained highly susceptible to Amikacin (97.8%) and Vancomycin (87.0%), and showed moderate susceptibility to Levofloxacin (73.9%) and Ofloxacin (65.2%).

Compared to the findings of Le Dinh Khanh (2018), in which susceptibility rates to Amikacin and Vancomycin both reached 100% (Anh, P. H., & Hưng, P. M. 2022), the current results are lower. This suggests that some *S. aureus* strains have begun developing resistance to Amikacin and Vancomycin, which are considered critical treatment options for severe *S. aureus* infections. Such findings serve as an early warning of the potential spread of multidrug-resistant (MDR) *S. aureus* strains in both community and hospital settings. Furthermore, our results regarding Erythromycin resistance (87.0%) are consistent with the report by Nguyen Truong Sa (2023), which recorded resistance rates of 84% in Khanh Hoa and 86.5% in Thua Thien Hue (Phuong, L. T. *et al.,* 2023). This consistency indicates that macrolide resistance in *S. aureus* has become widespread across multiple regions, underscoring the broad epidemiological nature of this phenomenon. Although Amikacin and Vancomycin still maintain high therapeutic efficacy against *S. aureus*, the emerging trend of resistance is concerning. This underscores the urgent need for continuous surveillance, rational antibiotic stewardship, and the exploration of

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alternative therapeutic strategies to curb the spread of drug-resistant *S. aureus* strains.

Antibiotic susceptibility of P. aeruginosa

Our results showed that *P. aeruginosa* remained relatively susceptible to several antibiotics, with susceptibility rates of 84.6% for Piperacillin/Tazobactam and Levofloxacin, 79.9% for Amikacin, and 69.2% for Gentamicin. These findings indicate that certain antibiotics still retain considerable efficacy against *P. aeruginosa*, a pathogen well known for its intrinsic resistance and propensity to develop multidrug resistance.

In contrast, the study by Le Thi Phuong (2023) reported markedly higher resistance rates to Levofloxacin (94.12%), Piperacillin/Tazobactam (93.33%), and Amikacin (93.75%) (Hai, L.H. L. & Nga, L. T. 2022), which is strikingly different from our findings. This discrepancy may be attributable to differences in study settings, patterns of antibiotic use, and patient populations. In particular, healthcare facilities with extensive use of broad-spectrum antibiotics may face higher resistance rates.

On the other hand, our results are more consistent with those of Le Ha Long Hai (2022), who reported susceptibility rates of 82.8% for Piperacillin/Tazobactam, 73.6% for Amikacin, and 73.6% for Gentamicin . This similarity suggests that resistance patterns of *P. aeruginosa* may vary geographically, reflecting differences in antibiotic stewardship and prescribing practices across hospitals and regions.

Taken together, these findings underscore that although *P. aeruginosa* still demonstrates considerable susceptibility to key antibiotics, the variability across studies highlights the risk of rapidly emerging multidrug resistance. Therefore, regular antimicrobial surveillance and judicious use of Piperacillin/Tazobactam, Amikacin, and fluoroquinolones are crucial to preserving their long-term effectiveness.

CONCLUSION

The study revealed that the prevalence of urinary tract infections (UTIs) at Tay Nguyen University Hospital was relatively high (54.5%). Among the isolated pathogens, *Escherichia coli* was the most common (45.3%), followed by *Staphylococcus aureus* (33.1%) and *Pseudomonas aeruginosa* (9.4%). Our findings highlight an alarming situation of antimicrobial resistance (AMR) and multidrug resistance (MDR) among uropathogens. Many isolates exhibited resistance to commonly prescribed antibiotics, posing significant challenges for treatment and infection control. Specifically: - *E. coli* showed high resistance to Ampicillin (66.7%) and Tetracycline (41.3%), but remained highly susceptible to Amikacin (95.2%) and Piperacillin/Tazobactam (82.5%). - *S. aureus* demonstrated marked resistance to Erythromycin (87.0%) and Tetracycline (58.7%), yet retained high susceptibility to Amikacin (97.8%) and Levofloxacin (73.9%). - *P. aeruginosa* exhibited multidrug resistance, with high resistance rates to Ceftriaxone (61.5%) and Ciprofloxacin (53.8%), while still showing good susceptibility to Colistin (92.3%) and Piperacillin/Tazobactam (84.6%).

These results indicate that traditional first-line antibiotics such as Ampicillin, Erythromycin, and Tetracycline are no longer appropriate for empirical treatment of UTIs in this setting. Conversely, Amikacin and Piperacillin/Tazobactam remain highly effective and may be considered as priority options, particularly for severe infections or patients at high risk of antibiotic resistance.

Recommendations

Antibiotic susceptibility testing should be performed prior to initiating treatment in order to select appropriate antibiotics and minimize the risk of resistance. Hospitals should develop and regularly update treatment guidelines for UTIs based on local antimicrobial resistance data.Periodic surveillance of antimicrobial resistance should be strengthened, particularly for *E. coli*, *S. aureus*, and *P. aeruginosa*.

Implementation of an antibiotic stewardship program is essential, coupled with education and awareness campaigns for healthcare professionals and the community to promote rational antibiotic use. Future studies should expand sample size, extend study duration, and incorporate molecular analyses of resistance mechanisms to provide a more comprehensive understanding of antimicrobial resistance.

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