Research Square

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Comparative Analysis of Antimicrobial Resistance Patterns among Uropathogenic Escherichia coli and Klebsiella pneumoniae Isolates from Referral Hospitals in Chad and Cameroon

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Abstract

Background

Antimicrobial resistance among uropathogenic bacteria is a major public health concern worldwide, particularly in low- and middle-income countries where surveillance data remain limited. This study compared the antibiotic resistance profiles of *Escherichia coli* and *Klebsiella pneumoniae* isolated from urinary tract infections (UTIs) at the National Reference University Hospital Center (CHU-RN), Chad, and the Military Region Hospital N°1 (HMR1), Cameroon.

Methods

A prospective cross-sectional study was conducted from February to July 2025. Midstream urine specimens were collected from 300 patients at CHU-RN and 250 patients at HMR1. Only one isolate per patient was retained for analysis. Bacterial identification was performed using standard culture methods and the API 20E system. Antimicrobial susceptibility testing was carried out by Kirby–Bauer disk diffusion on Müller-Hinton agar and interpreted according to CA-SFM/EUCAST 2025 breakpoints.

Results

Among 300 urine samples analyzed at CHURN and 250 at HMR1, culture positivity rates were 31.7% and 22.0%, respectively. *E. coli* was the predominant pathogen, accounting for 19.3% of isolates at CHURN and 10.8% at HMR1, followed by *K. pneumoniae* at 6.7% and 6.0%, respectively. Most patients at CHU-RN were male (66.0%), whereas females predominated at HMR1 (64.4%). High resistance rates were observed for amoxicillin (70.5–95.0%) and amoxicillin–clavulanic acid (52.0–75.0%) in both bacterial species. Fluoroquinolone resistance was particularly elevated among *E. coli* isolates from CHURN, reaching 65.5% for ciprofloxacin and 63.8% for levofloxacin. Imipenem remained the most effective antibiotic, with resistance rates below 20.0% in all isolates. Significant differences in resistance patterns were observed between hospitals ($p < 0.001$).

Conclusion

Uropathogenic *E. coli* and *K. pneumoniae* exhibit high resistance to commonly prescribed antibiotics in both Chad and Cameroon. Continuous antimicrobial resistance surveillance and evidence-based antibiotic stewardship programs are urgently needed to improve UTI management and preserve the effectiveness of last-resort antibiotics in Central Africa.

Introduction

Antimicrobial resistance (AMR) has become one of the greatest global public health threats, compromising the effective treatment of infectious diseases and increasing morbidity, mortality, healthcare costs, and hospital stays [1]. The World Health Organization has identified AMR as one of the top ten global public health threats, and the burden falls disproportionately on low- and middle-income countries in Sub-Saharan Africa, where infectious diseases remain leading causes of morbidity and mortality. The convergence of high disease burden, inadequate diagnostic capacity, widespread over-the-counter antibiotic availability, and poor sanitation creates an environment highly conducive to the emergence and dissemination of resistant organisms [2].

Urinary tract infections (UTIs) remain among the most common bacterial infections worldwide, affecting nearly 250 million individuals annually. *E. coli* accounts for approximately 70–90% of community-acquired UTIs, whereas *K. pneumoniae* represents the second most frequent uropathogen 24% [3]. Previous African studies have reported a high burden of urinary tract infections, with considerable variation according to population characteristics and healthcare settings [4].

In Cameroon, *E. coli* represents 50.9% of uropathogenic isolates, compared with 16.4% for *K. pneumoniae* [5]. In Chad, similar proportions have been reported, with 64.5% for *E. coli* and 24.7% for *K. pneumoniae* [6]. These organisms therefore constitute a major burden in urinary infections in both countries However, antimicrobial susceptibility patterns vary substantially across countries and healthcare facilities because of differences in antibiotic prescribing practices, infection prevention measures, antimicrobial stewardship programmes, and laboratory capacity.

Despite the growing burden of AMR, comparative data from Central Africa remain scarce, particularly between neighbouring countries that share similar epidemiological and healthcare contexts [7]. Cameroon and Chad are confronted with increasing antimicrobial resistance, yet direct comparisons of resistance profiles among uropathogenic bacteria are lacking. Generating comparative evidence from referral hospitals in both countries is essential to improve empirical antibiotic therapy, strengthen antimicrobial resistance surveillance, and support evidence-based public health interventions. Therefore, this study aimed to compare the antimicrobial resistance profiles of *Escherichia coli* and *Klebsiella pneumoniae* isolated from urinary tract infections at the National Reference University Hospital Center (CHU-RN), Chad, and the Military Region Hospital N°1 (HMR1), Cameroon.

Methods

Study design and setting

This prospective, descriptive, cross-sectional study was conducted from February to July 2025 in N'Djamena, Chad, and Yaoundé, Cameroon. Clinical specimens were collected from patients attending the National Reference University Hospital Center (CHU-RN) in N'Djamena and the Military Region Hospital N°1 (HMR1) in Yaoundé.

Study population

The study population included patients older than 21 years of age, of both sexes, who submitted urine samples for routine microbiological investigation during the study period. A total of 300 patients were enrolled at CHURN and 250 at HMR1. Only one isolate per patient was retained for analysis.

Sample collection and processing

Urine samples were preferably collected in the morning or after at least 4 hours without urination, either at the laboratory or at home, under strict aseptic conditions. Samples were collected in sterile single-use containers, immediately sealed, labeled with the collection time, and transported by the patient to the laboratory at room temperature. Clinical information, including urinary symptoms and relevant medical history, was recorded by the attending clinician on the laboratory request form. Sociodemographic data were collected using a structured questionnaire. Cytobacteriological examination included macroscopic, cytological, and microscopic analysis after centrifugation, followed by Gram staining [8].

Bacterial isolation and identification

Gram-negative bacilli were isolated according to the laboratory's standard analytical protocol. Clinical specimens were cultured on CLED and MacConkey agar (bioMérieux, France), selective and differential media for Enterobacterales. After 18 to 24 h of incubation at 37°C, presumptive identification of *Escherichia coli* and *Klebsiella pneumoniae* was based on colony morphology on MacConkey agar, together with the oxidase test. The oxidase test was used to distinguish oxidase-positive from oxidase-negative Gram-negative bacilli. Suspected colonies were then purified by subculture onto Müller-Hinton agar (Laboratorios Conda S.A.) and incubated for an additional 18 to 24 h at 37°C. Final identification was performed using the API 20E system (bioMérieux, Marcy-l'Étoile, France). According to Kass criteria, bacterial growth of ≥ 10^5 CFU/mL was considered significant. Although several Enterobacterales species were isolated during routine bacteriological analysis, only *E. coli* and *K. pneumoniae* were included in the present study [9].

Antimicrobial susceptibility testing

Antimicrobial susceptibility testing was performed on Müller-Hinton agar (Bio-Rad, France) using the disk diffusion method, according to the recommendations of CA-SFM/EUCAST 2025. Plates were inoculated with a 0.5 McFarland bacterial suspension standardized with a densitometer (DENSIMAT, bioMérieux, France), and fourteen antibiotic discs were applied. After 18 to 24 h of incubation at 37°C, inhibition zone diameters were measured using the ADAGIO system (Bio-Rad, France). Results were interpreted as susceptible or resistant according to the CLSI/EUCAST clinical breakpoints for 2025 [10].

Statistical analysis

Data were entered into Excel 2016 and analyzed using SPSS version 27. The chi-square test was used to compare proportions, and statistical significance was set at $p < 0.05$.

Results

Sociodemographic profile

A total of 300 patients were enrolled at CHU-RN and 250 at HMRR1.

At Military Region Hospital N°1, 161 were female (64.4%) and 89 were male (35.6%), indicating a predominance of female participants, corresponding to a sex ratio of 0.55 in favor of females. The 61–70-year age group was the most represented, followed by the 71–80-year and 51–60-year age groups, whereas the 81–90-year age group was the least represented. Outpatients were the most frequent, accounting for 62.8% of the sample, compared with 37.2% inpatients.

At the National Reference University Hospital Center (CHU-RN), 198 participants were male (66%) and 102 were female (34%), corresponding to a sex ratio of 1.94 in favor of males. The 61–70-year age group was the most represented, followed by the 71–80-year and 51–60-year age groups, whereas the 81–90-year age group was the least represented. Outpatients predominated, representing 73% of the sample, compared with 27% hospitalized participants.

Table I

Characteristic of study participants who provided urines samples

Caractéristics	n (%) HMR1	n (%) CHU-RN
Sex		
female	161 (64,4)	102 (34)
male	89 (35,6)	198 (66)
Patient type		
Outpatients	157 (62,8)	219 (73)
Inpatients	93 (37,2)	81 (27)
Age groups		
21–30	35 (14)	42 (14)
31–40	23 (9,2)	27 (9)
41–50	27 (10,8)	32 (32)
51–60	36 (14,4)	45 (15)
61–70	79 (31,6)	97 (32,33)
71–80	37 (14,8)	47 (15,66)
81–90	13 (5,2)	10 (3,33)

Bacterial isolation

At Military Region Hospital N°1, 55 urine cultures were positive. *Escherichia coli* was isolated in 27 samples, corresponding to 49.09% of positive cultures and a prevalence of 10.8% among all samples. *Klebsiella pneumoniae* was isolated in 15 samples, corresponding to 27.27% of positive cultures and a prevalence of 6.0%. The remaining 13 positive cultures (23.63%) yielded other Enterobacterales.

At the National Reference University Hospital Center (CHU-RN), 95 urine cultures were positive. *E. coli* was isolated in 58 samples, corresponding to 61.70% of positive cultures and a prevalence of 19.33% among all samples. *K. pneumoniae* was isolated in 20 samples, corresponding to 21.28% of positive cultures and a prevalence of 6.67%. The remaining 17 positive cultures (17.02%) yielded other Enterobacterales

Table II

Prevalence of isolates identified during the study

setting		HMR1	CHU-RN
Culture	**Isolats**	**n (%)**	**n (%)**
Positive	*E. coli*	27 (10,5)	58 (19,33)
	K. pneumoniae	15 (6)	20 (6,67)
	Autres entérobactéries	13 (5,2)	17 (5,67)
Négative	/	195 (78)	205 (68,33)
Total	/	250 (100)	300 (100)

Antimicrobial resistance

Antimicrobial resistance in E. coli

At Military Region Hospital N°1, the 27 *E. coli* isolates showed high resistance to amoxicillin (85%), ceftriaxone (55.55%), amoxicillin-clavulanic acid (52%), and cefepime (44%). Resistance to ciprofloxacin and levofloxacin was 37.03% and 22.22%, respectively. Gentamicin and imipenem showed lower resistance rates of 22.22% and 18.51%, respectively.

At CHURN, the 58 *E. coli* isolates showed resistance to amoxicillin in 70.51% of cases and to cotrimoxazole in 67.24%. Resistance to amoxicillin-clavulanic acid reached 60.25%. Ceftriaxone and cefepime resistance rates were 65.51% and 32.75%, respectively. Ciprofloxacin and levofloxacin resistance was particularly high, at 65.51% and 63.79%, respectively. Gentamicin and imipenem showed the lowest resistance rates, both at 7.40%, while nitrofurantoin resistance was 39.65%.

For *E. coli*, resistance to amoxicillin was higher at Military Region Hospital N°1 than at CHU-RN, whereas resistance to amoxicillin-clavulanic acid was slightly higher at CHURN. Fluoroquinolone resistance was markedly higher at CHURN, especially for ciprofloxacin and levofloxacin. Ceftriaxone resistance was also higher at CHURN, while cefepime resistance was higher at Military Region Hospital N°1.

Antimicrobial resistance in K. pneumoniae

Among the 15 *K. pneumoniae* isolates from Military Region Hospital N°1, resistance to amoxicillin was 86.88% and to amoxicillin-clavulanic acid 66.66%. Resistance to ceftriaxone and cefepime was 22.22% and 37.03%, respectively. Imipenem remained the most active agent, with only 15.51% resistance. Ciprofloxacin and levofloxacin showed low resistance rates of 9.62% each. Gentamicin, nitrofurantoin, and cotrimoxazole showed resistance rates of 27.58%, 18.51%, and 14.81%, respectively.

Among the 20 *K. pneumoniae* isolates from CHU-RN, resistance to amoxicillin was 95% and to amoxicillin-clavulanic acid 75%. Resistance to cotrimoxazole, ceftriaxone, ciprofloxacin, levofloxacin, and nitrofurantoin was 24.13%, 22.41%, 22.41%, 20.68%, and 20.68%, respectively. Cefepime, gentamicin, and imipenem showed the lowest resistance rates, at 13.79%, 12.06%, and 8.62%, respectively.

For *K. pneumoniae*, resistance to amoxicillin and amoxicillin-clavulanic acid was high in both hospitals, but the highest values were observed at CHU-RN. Imipenem remained effective at both sites, with resistance below 16%. Resistance to fluoroquinolones was lower at Military Region Hospital N°1 than at CHU-RN, while resistance to cefepime was lower at CHU-RN.

The chi-square test showed a significant difference in resistance distribution across antibiotics for both bacterial species in both hospitals, with $p < 0.001$ in all cases. This indicates that resistance patterns were not homogeneous and varied according to the antibiotic tested and the hospital setting.

Discussion

The present study showed marked differences in the sociodemographic characteristics of participants between the two hospitals. At HMR1, women were more frequently represented, whereas men predominated at CHU-RN. This discrepancy may reflect differences in consultation patterns between the two settings, particularly a higher attendance of men at CHU-RN, where urological consultations are more common. In contrast, women are generally more affected by urinary tract infections because of the shorter female urethra, its proximity to the anal region, and hygiene-related factors that facilitate ascending bacterial contamination. The female predominance observed at HMR1 is consistent with the findings of Bayaba *et al.* in western Cameroon, whereas the male predominance observed at CHU-RN is similar to that reported by Garba *et al.* in Niger [10, 11].

The most represented age group in both hospitals was 61–70 years. This finding may be explained by the increased susceptibility of older adults to uropathogenic infections, which is often associated with reduced immune function, a higher burden of chronic diseases, and a greater frequency of urinary catheter use, particularly in patients with prostatic disorders and urinary stasis. These results differ from those reported by Assouma *et al.* in Benin, where the highest frequency of urinary tract infections was observed in the 21–30-year age group [3].

Non-hospitalized participants were the most common in both hospitals. This may be explained by the fact that most patients sought consultation without requiring admission. Our findings are higher than those reported by Ouchar *et al.* in Chad, who observed a lower proportion of non-hospitalized participants [13].

Among the isolated bacteria, *Escherichia coli* was the most common species at both CHU-RN and HMR1, with a prevalence of 19.33% and 10.8% respectively, followed by *Klebsiella pneumoniae* with a prevalence of 6.67% and 6%. These variations may reflect epidemiological, health, and socioeconomic differences between the regions studied, as well as variations in diagnostic practices and the profile of the patients included. The results obtained are consistent with those reported by Bayaba in Cameroon, who observed a prevalence of 79.41% and 14.70% for *E. coli* and *K. pneumoniae*, respectively [14]. Our results are higher than those reported by Mouanga-Ndzime in Gabon, who found a prevalence of 21% for *E. coli* and 14% for *K. pneumoniae* [15].

At the Military Region Hospital N°1 (HMR1), the rates of resistance of *E. coli* to amoxicillin and the combination of amoxicillin and clavulanic acid were 85% and 52%, respectively, and at the National Reference University Hospital Center in N'Djamena (CHU-RN), resistance rates were higher, at 70.51% for amoxicillin and 60.25% for the combination of amoxicillin and clavulanic acid, suggesting a gradual loss of efficacy of this combination in the treatment of urinary tract infections in these settings.

These high levels of resistance to aminopenicillins are acquired and are thought to be the result of selection pressure linked to the excessive use of these antibiotics. These results are similar to those obtained by Foka at the Yaoundé University Hospital, which found resistance rates of 97.7% for amoxicillin and 89.2% for amoxicillin-clavulanic acid [16].

The rates of *Escherichia coli* resistance to cephalosporins at Military Region Hospital N°1 are 55.55% for ceftriaxone and 44.44% for cefepime. In contrast, the resistance rates observed at the CHURN in N'Djamena are high for ceftriaxone at 65.51% and lower for cefepime at 32.75%. These data show significant heterogeneity in resistance depending on location, and these resistance rates could be linked to excessive or inappropriate empirical use of these antibiotics, which are often prescribed without prior antibiogram testing. In addition, easy and sometimes uncontrolled access to antibiotics for self-medication could exacerbate this situation. These results are similar to those reported in Chad by Yandai, who obtained the same resistance rate to cefepime and ceftriaxone of 33.33% [17].

For carbapenems, the lowest resistance rates observed in both hospitals were for imipenem, at 18.51% at HMR1 and 7.4% at CHURN.

These low levels of resistance suggest that carbapenems remain the most effective antibiotics for treating severe infections caused by these enterobacteria. These results are consistent with those reported by Goita in Mali, which had a resistance rate of 9.10% [18].

The results showed resistance to gentamicin at a rate of 22.22% for *Escherichia coli* at the Military Region Hospital N°1 in Yaoundé. In contrast, an increase in sensitivity was observed at CHURN, with a gentamicin resistance rate of 7.4%, demonstrating the effectiveness of this antibiotic. These regional disparities highlight the need to strengthen local surveillance of bacterial resistance and to adapt antibiotic therapy policies to the specific epidemiological realities of each region.

At the Military Region Hospital N°1, *Escherichia coli* shows 37.03% resistance to ciprofloxacin and 22.22% resistance to levofloxacin, and at CHU-RN, a notable increase in resistance is observed, particularly in *E. coli*, with rates of 65.51% to ciprofloxacin and 63.79% to levofloxacin. These data highlight the growing threat of fluoroquinolone resistance in the subregion, requiring increased surveillance and adaptation of antibiotic treatments. These results are similar to those reported by Gamougam in Chad, who reported resistance rates of 88.13% to ciprofloxacin and 81.35% to levofloxacin [19].

For sulfonamides, the resistance of isolates to the antibiotic trimethoprim/sulfamethoxazole is 25.92% for *Escherichia coli* at HMR1 and 67.24% at CHU-RN. As for resistance to nitrofurans, nitrofurantoin showed resistance of 33.33% for *Escherichia coli* at HMR1 and 39.65% at CHU-RN. These results reflect strong antibiotic pressure in this region, requiring increased monitoring and a review of treatment protocols in healthcare facilities. These results are below those reported by Yandai, who found *Escherichia coli* resistance to trimethoprim-sulfamethoxazole of 65%, and those reported by Abderrahim and Salem, who found *Escherichia coli* resistance to nitrofurantoin of 15% [20].

At HMR1, the resistance rates of *K. pneumoniae* to amoxicillin and the combination of amoxicillin and clavulanic acid were 86.88% and 66.66%, respectively. In contrast, at CHURN, resistance rates were 95% for amoxicillin and 75% for the combination of amoxicillin and clavulanic acid. These data show very high resistance of *K. pneumoniae* to penicillins in both hospitals, with particularly alarming rates at CHU-RN. These results are similar to those obtained in Mali, where resistance rates for *K. pneumoniae* were recorded at 88.8% for amoxicillin and 78.26% for amoxicillin-clavulanic acid [18].

Klebsiella pneumoniae resistance to cephalosporins is marked as follows: 22.22% to ceftriaxone and 37.03% to cefepime at HMR1, and a higher rate for ceftriaxone (22.41%) and a lower rate for cefepime (13.79%) at CHU-RN. These results are lower than those reported by Yandai in Chad, who obtained the same resistance rate to cefepime and ceftriaxone of 56.52% [17].

For carbapenems, the lowest resistance rates of *Klebsiella pneumoniae* observed in both hospitals were noted for imipenem at 15.51% at HMR1 and 8.62% at CHU-RN, highlighting the effectiveness of carbapenems in both Central African cities.

These results showed an emergence of resistance to gentamicin, with 27.58% for Klebsiella pneumoniae at HMR1 and 12.06% at CHU-RN. These results are well below those reported by Bayaba who found resistance rates of 71.43% for *K. pneumoniae* [14].

At Military Region Hospital N°1, *Klebsiella pneumoniae* resistance was 9.62% for ciprofloxacin and levofloxacin, respectively, and at CHU-RN, a notable increase in resistance was observed, particularly in *K. pneumoniae*, with rates of 22.41% for ciprofloxacin and 20.68% for levofloxacin. In Chad, the data reported by Gamougam are higher than those obtained, with *K. pneumoniae* resistance of 71.42% for ciprofloxacin and 42.85% for levofloxacin[19]. These results could be explained by the fact that, due to poverty in Africa, people choose self-medication rather than undergoing a normal consultation at the hospital and also obtain their medicines at a lower cost on the street rather than at the pharmacy.

For sulfonamides, the resistance of isolates during our study to the antibiotic trimethoprim/sulfamethoxazole was 14.81% for *Klebsiella pneumoniae* at HMR1 and 24.13% for *Klebsiella pneumoniae* at CHU-RN. These results are lower than those reported by Yandai, who found *Klebsiella pneumoniae* resistance to trimethoprim-sulfamethoxazole of 95.65% [17].

As for resistance to nitrofurans, nitrofurantoin showed a resistance rate of 18.51% for *Klebsiella pneumoniae* at HMR1 and 20.68% for *Klebsiella pneumoniae* at CHU-RN. Resistance rates were generally higher at CHU-RN, particularly for ciprofloxacin (*E. coli*: 65.51% vs. 37.03%), trimethoprim/sulfamethoxazole (67.24% vs. 25.92%), and amoxicillin. However, HMR1 showed more marked resistance to amoxicillin/clavulanic acid and cefepime. Carbapenems remain effective, especially at CHU-RN. Gentamicin and nitrofurantoin show generally satisfactory sensitivity profiles in both centers. These results highlight the urgent need to optimize antibiotic prescriptions, improve the supervision of their use, and strengthen microbiological surveillance strategies to limit the progression toward therapeutic deadlock in these two hospital settings.

Conclusion

This study compared the antibiotic resistance profiles of *Escherichia coli* and *Klebsiella pneumoniae* isolates responsible for urinary tract infections in two hospitals in Central Africa: CHU-RN in Chad and HMR1 in Cameroon. The results show significant disparities between the two facilities in terms of both positivity rates and resistance profiles. Both bacteria show high resistance to beta-lactams, particularly amoxicillin and amoxicillin-clavulanic acid, with percentages reaching up to 95% for *K. pneumoniae*. On the other hand, carbapenems (imipenem) remain effective overall, confirming their place as antibiotics of last resort. Certain molecules such as gentamicin and nitrofurantoin also retain good activity. These differences highlight the need for continuous local monitoring of bacterial resistance and adaptation of treatment protocols to hospital contexts. They also underscore the urgent need to strengthen antibiotic stewardship policies, particularly in Central Africa. Larger-scale studies incorporating antibiotic exposure factors, local medical practices, and molecular data are recommended to better understand and curb the progression of antibiotic resistance.

Abbreviations

MH
Müller-Hinton
GNB
Gram-negative bacilli
EUCAST
European Committee of Antimicrobial Susceptibility Testing
CHURN
National Reference University Hospital Center
HMR1
Military Region Hospital N°1

Declarations

Ethical approval and consent to participate

The study was conducted in accordance with the Declaration of Helsinki. Ethical approval was obtained from the CRESH, the Ethics Committee of the Center for Health Research, and written authorization for sample and data collection was also obtained from the administrative authorities of both hospitals. Informed consent was obtained from all participants, or from their legal guardians when applicable.

Competing interests

The authors declare no competing interests.

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Author Contribution

TLJ (TINKOMTA LAOBÉRÉ Junior) conceived the study, contributed to data collection, performed data analysis, interpreted the results, and drafted the first version of the manuscript. AB (Alain BODERING) contributed to the study design, scientific supervision, and critical revision of the manuscript. NO (NISSO Ouangkaké) participated in microbiological investigations, data collection, and validation of the results. KG (KHADIDJA Gamougam) contributed to data management, statistical analysis, and manuscript revision. YFH (YANDAI FISSOU Henry) contributed to the interpretation of results and critical review of the manuscript. MNE (MAKUE NGUIFFO Elsa) contributed to the literature review, data analysis, and scientific revision of the manuscript. MNDF (MONI NDEDDI Del Florence) contributed to supervision, validation of results, and final revision of the manuscript.All authors read and approved the final version of the manuscript and agreed to be accountable for all aspects of the work.

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Data availability

The data generated and analyzed during the current study are included in this article and its supplementary materials.

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Figures

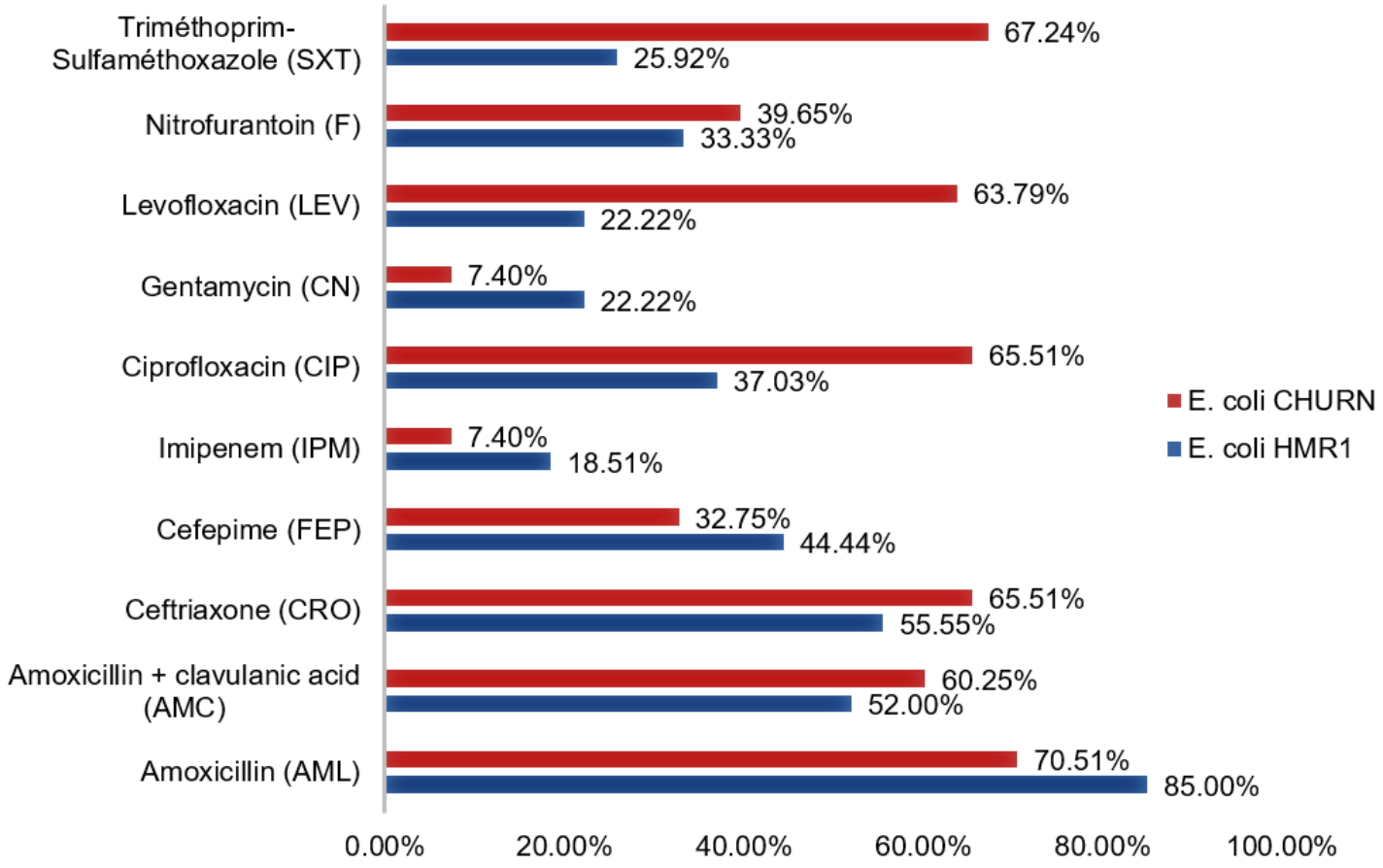


Figure 1

Antibiotic Resistance in Uropathogenic *Escherichia coli*

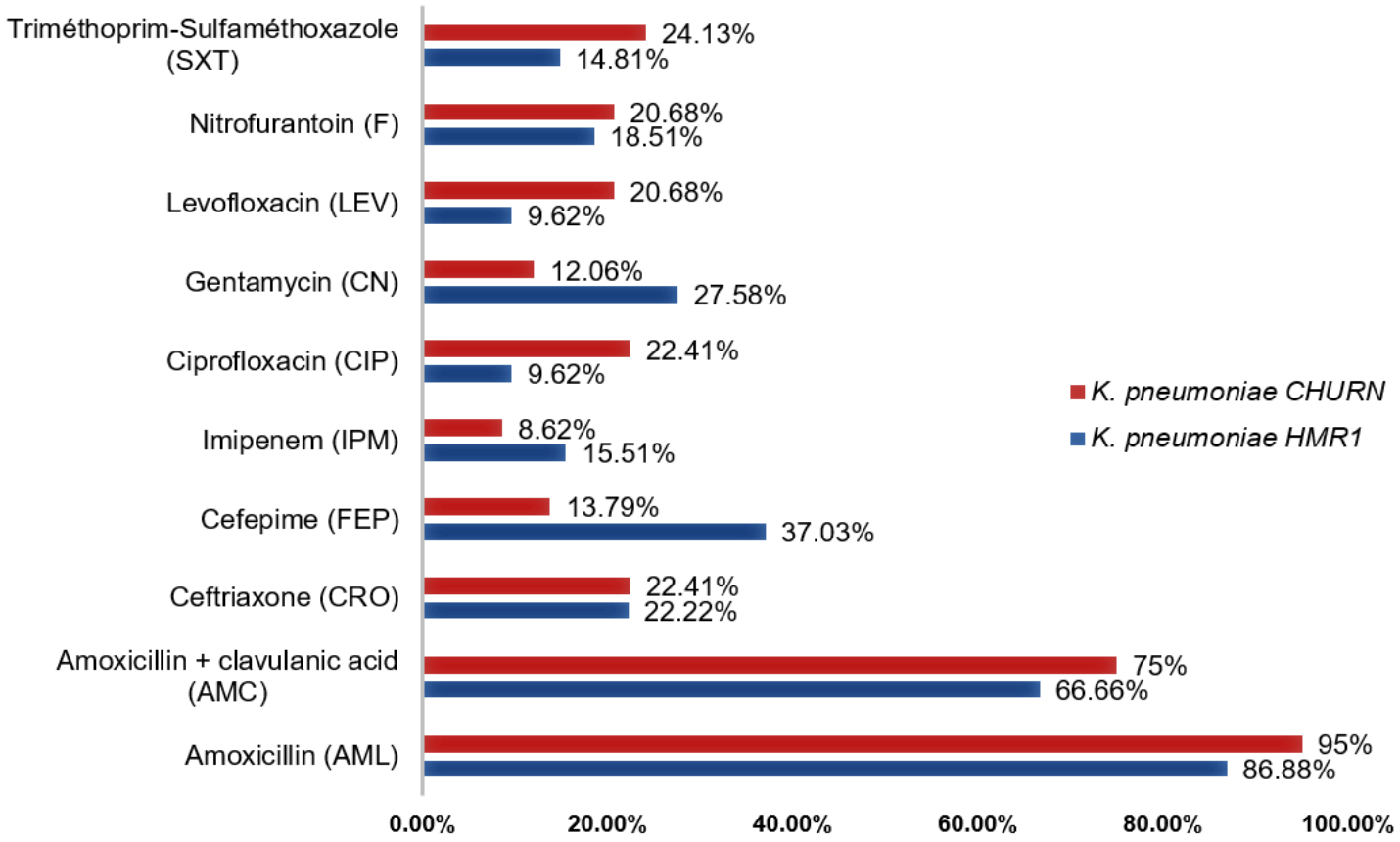


Figure 2

Antibiotic Resistance in Uropathogenic *Klebsiella pneumoniae*