

PREVALENCE AND FACTORS OF COMMUNITY-ACQUIRED URINARY TRACT INFECTIONS IN CHILDREN CAUSED BY DRUG-RESISTANT MICROORGANISMS AT NAKHON PATHOM HOSPITAL

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Abstract

Background: Urinary tract infections (UTIs) are a common pediatric condition and a growing concern due to increasing antimicrobial resistance. Identifying risk factors for drug-resistant pathogens and evaluating empirical antibiotic susceptibility are essential for improving treatment outcomes.

Objectives: The study aimed to determine the prevalence of drug-resistant microorganisms causing community-acquired UTIs in children, identify associated risk factors, and assess the susceptibility of empirical antibiotics recommended by Thai national guidelines.

Methods: This retrospective study included children aged 0–15 years with community-acquired UTIs from January 2021 to February 2025. Demographic and clinical data were collected. Categorical variables were summarized as frequencies and percentages. Multivariable logistic regression analysis was performed to identify independent risk factors.

Results: Among 165 patients, *Escherichia coli* was the most common pathogen (66.7%). Drug-resistant microorganisms were identified in 124 cases (75.2%). Among Enterobacteriaceae isolates, 37% were extended-spectrum β -lactamase producers and 40.9% were multidrug-resistant. Younger age (OR 0.99; 95% CI 0.99–0.99) and a history of recurrent UTIs (OR 6.88; 95% CI 1.57–30.22) were independent risk factors for drug-resistant infections. Male sex and a history of antibiotic treatment within the preceding 30 days were associated with resistance to ceftriaxone and cefotaxime. Amikacin showed the highest susceptibility rate (92.1%), while amoxicillin-clavulanate had the highest susceptibility among oral agents (67.3%).

Conclusions: Drug-resistant microorganisms are highly prevalent in pediatric community-acquired UTIs. Younger age and recurrent UTIs are key risk factors, while male sex and recent antibiotic treatment are associated with resistance to commonly used third-generation cephalosporins. Amikacin demonstrated the highest susceptibility rate among the empirical antibiotic options.

Keywords: Urinary tract infection, children, antimicrobial resistance, risk factors, ESBL, community-acquired infection

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Introduction

Urinary tract infections (UTIs) are common bacterial infections in children. In the first year of life, UTIs are more common in boys than girls, but thereafter, UTIs are significantly more prevalent in girls than boys.⁽¹⁾ In children younger than 24 months presenting with fever, 7% are found to have UTIs.⁽²⁾ Among children under 5 years old with acute illness, 5.9% are diagnosed with UTIs.⁽³⁾ A study in Thailand conducted at a tertiary hospital outpatient department found that 21% of children under 2 years old presenting with fever of unknown origin were diagnosed with UTIs⁽⁴⁾, indicating that UTIs are common problems among Thai children.

Despite UTIs being common in children, symptoms vary, with older children reporting dysuria and abdominal pain. In comparison, younger children often show nonspecific signs such as fever, irritability, poor feeding, vomiting, drowsiness, or jaundice⁽⁵⁾, which can delay diagnosis. This delay is serious, as UTIs can cause kidney scarring, resulting in long-term issues⁽⁶⁾ such as hypertension or chronic kidney disease, in up to 15% of cases.⁽⁷⁾ Immediate and proper antibiotic treatment is crucial to prevent kidney damage and complications.⁽⁸⁾

The most common pathogens implicated in UTIs are *Escherichia coli* and *Klebsiella pneumoniae*.⁽⁹⁾ Less frequently encountered pathogens include *Proteus mirabilis*, *Enterobacter* spp., *Pseudomonas aeruginosa*, *Citrobacter* spp., *Serratia* spp., *Streptococcus agalactiae*, and *Staphylococcus saprophyticus*.⁽⁶⁾ However, there is a global increase in UTIs caused by drug-resistant microorganisms.⁽¹⁰⁾ This issue is also observed in Thailand; a study at a tertiary hospital between 2011 and 2017 revealed that about 19.8% of microorganisms causing UTIs in children are resistant to common antibiotics.⁽¹¹⁾ The national guidelines in Thailand, specifically the “Clinical Practice Guideline for Urinary Tract Infection in Children Aged 2 Months to 5 Years”, Updated in 2022,⁽¹²⁾ recommend empirical treatment for pediatric UTIs with third-generation cephalosporins, aminoglycosides, or amoxicillin-clavulanate. Consequently, this rising resistance poses a significant challenge to the efficacy of these currently recommended antibiotics.

Drug-resistant UTIs not only complicate treatment, leading to prolonged hospital stays and increased costs, but also elevate the risk of severe complications such as bloodstream infections and acute kidney injury.^(10,13) Therefore, appropriate initial antibiotic selection is vital to reduce adverse outcomes. Furthermore, data on risk factors for community-acquired urinary tract infections in children caused by drug-resistant microorganisms in Thailand remain scarce. Accordingly, this research aims to determine the prevalence of community-acquired drug-resistant UTIs in children, identify associated risk factors, and assess the in vitro susceptibility of empirical antibiotics recommended by the Thai national guidelines.

Methods

Research design and participants

This retrospective study included pediatric patients diagnosed with urinary tract infections from January 2021 to February 2025. This study was approved by the Ethics Committee of the Clinical Research Center, Nakhon Pathom Hospital, Thailand (COE No. 002/2025). Children aged 0-15 years who were hospitalized or seen in the Outpatient Department with a confirmed diagnosis of UTI based on urine culture results were included. Individuals with asymptomatic bacteriuria, those who developed a urinary tract infection during their hospital stay, or patients who had been discharged from the hospital no more than 7 days prior were not included. We also excluded patients whose urine cultures showed no growth, whose urine samples were collected incorrectly, or who had urinary catheters.

Data assessment

Data were collected from electronic medical records of subjects who met the inclusion and exclusion criteria. These data focused on several key areas: demographic characteristics; patient history, including underlying diseases, kidney and urinary tract anomalies, recurrent urinary tract infections, a history of antibiotic treatment within the preceding 30 days, previous antibiotic prophylaxis, previous hospitalization within 30 and 90 days prior to the UTI, constipation, and

intermittent urethral catheterization. We also recorded clinical presentation and physical examination findings, such as phimosis in boys, labial adhesion in girls, and abnormal neurological examination. The collected data also included urine culture with antibiogram results, kidney and urinary tract ultrasound, voiding cystourethrography (as indicated by Thai national guidelines), and admission duration for hospitalized patients.

Relying on the Thai clinical practice guidelines⁽¹²⁾, uropathogens, regardless of quantity. For urethral catheterization, a positive culture was defined as the presence of the diagnosis of urinary tract infection is established based on the urine collection method for culture. For patients unable to control their urination, urine cultures were obtained by suprapubic aspiration or urethral catheterization. A positive urine culture via suprapubic aspiration was defined as the presence of a single colony $\geq 5 \times 10^4$ CFU/mL or $\geq 10^4$ CFU/mL if white blood cells were present in the urine. In patients able to control urination, a urine culture was obtained by midstream clean catch, and a positive diagnosis was defined as $\geq 10^5$ CFU/mL. The isolated pathogens were described for their susceptibility/resistance to specific antibiotics. Extended-spectrum beta-lactamases (ESBLs) are enzymes produced by Gram-negative organisms that inactivate most penicillins, cephalosporins, and aztreonam, but generally remain susceptible to carbapenems. ESBLs do not inactivate non-beta-lactam agents.⁽¹⁴⁾ In this study, ESBL was defined based on the minimum inhibitory concentration (MIC) thresholds for ceftriaxone or cefotaxime, with an MIC > 2 μ g/mL considered indicative of ESBL production. AmpC beta-lactamases (AmpC) are enzymes produced by certain Gram-negative bacteria, including Enterobacterales and non-fermenting organisms such as *Pseudomonas aeruginosa*. These enzymes hydrolyze penicillins and third-generation cephalosporins and are not inhibited by beta-lactamase inhibitors. However, AmpC-producing organisms typically remain susceptible to cefepime and carbapenems.⁽¹⁴⁾ In this study, AmpC beta-lactamase production was identified using routine phenotypic methods, including antimicrobial susceptibility testing and

inhibitor-based tests with boronic acid, where an increased inhibition zone was considered indicative of AmpC beta-lactamase production. Carbapenem-Resistant Enterobacterales (CRE) are Enterobacterales that are resistant to at least one carbapenem antibiotic (e.g., ertapenem, meropenem, imipenem, doripenem) or that produce a carbapenemase enzyme.⁽¹⁴⁾ Multidrug-resistant (MDR) bacteria are organisms non-susceptible to at least one agent in three or more antimicrobial classes. Extensively drug-resistant (XDR) bacteria are organisms that are non-susceptible to at least one agent in all but 2 or fewer antimicrobial categories. Pandrug-resistant (PDR) bacteria are organisms non-susceptible to all antimicrobial agents tested.⁽¹⁵⁾ In this study, organisms were categorized as drug-resistant if they were resistant to at least one tested antibiotic, and as non-resistant if they were susceptible to all tested antibiotics.

We analyzed demographic characteristics, underlying disease, and physical examinations to identify risk factors for drug-resistant microorganisms causing community-acquired UTIs. We also analyzed susceptibilities to recommended empiric antibiotic regimens—amoxicillin-clavulanate, ceftriaxone, cefotaxime, amikacin, gentamicin, ciprofloxacin, and trimethoprim-sulfamethoxazole—to determine in vitro antimicrobial susceptibility according to Thai national guidelines.

Statistical analysis

Data were analyzed using SPSS version 23.0. Descriptive statistical analysis was performed; data with a normal distribution were reported as mean standard deviation. Categorical variables were reported as percentages of participants with the characteristic of interest. Pearson's chi-square test and Fisher's exact test were used to assess differences in categorical variables. Independent-samples t-test and Wilcoxon-Mann-Whitney test were used to compare the distributions of continuous variables. Multivariable logistic regression analysis was performed to identify risk factors for drug-resistant microorganisms causing community-acquired UTIs. The following variables were considered for inclusion in the mul-

tivariable model: age, sex, history of recurrent UTIs, kidney and urinary tract anomalies, a history of antibiotic treatment within the preceding 30 days, prior antibiotic prophylaxis, previous hospitalization within 30 and 90 days prior to the index UTI, constipation, intermittent urethral catheterization, neurogenic bladder, history of myelomeningocele, phimosis, and labial adhesions. We selected variables with p -values < 0.10 in the univariable analysis, along with clinically relevant factors, as candidate variables for the multivariable model. Age was included as a continuous variable. A two-sided p -value ≤ 0.05 was considered statistically significant.

Results

Patient characteristics

Patient characteristics of the 165 enrolled patients are summarized in **Table 1**. The majority of participants were male (54.5%), with a mean age of 2.3 ± 3.4 years. Among these, 26.7% had hydronephrosis, which was the most common underlying urinary tract abnormality observed in this study. The prevalence of vesicoureteral reflux was also notable at 6.7%. Most patients with congenital anomalies of the kidney and urinary tract (CAKUT) had combined anomalies, such as vesicoureteral reflux (VUR) with hydronephrosis

or double collecting systems. Seven patients (4.2%) had a neurogenic bladder. Two patients (1.2%) had a renal abscess as a complication of UTI. Thirty-seven patients (22.4%) had recurrent UTI, and 5.5% were on antibiotic prophylaxis. Thirty-six patients (21.8%) had received prior antibiotic treatment within 30 days before presentation. In this study, 27.9% of patients were hospitalized within 30 days, and 11.5% within 90 days; however, all patients had been discharged more than 7 days prior to enrollment. Two patients (1.2%) had undergone clean intermittent catheterization.

The most common presentation of UTIs in this study was fever (68.4%), which included both fever with specific symptoms (53.9%) and fever without localizing signs (14.5%), followed by nausea and vomiting (18.2%), dysuria (15.8%), and poor intake (14.5%). Among boys, 66.7% had phimosis, while 5.3% of girls had labial adhesion. Overall, 25.5% of all patients experienced constipation. Five patients (3%) had myelomeningocele, and four of these had weakness in their lower extremities. Most patients (77%) were treated as outpatients, while 23% required hospitalization, with a mean admission duration of 193.8 ± 147.9 hours.

Table 1. Clinical and demographic data of the patients (n=165)

Characteristics	Participants (total = 165) N (%)
Mean age, years (Mean $\pm$ SD)	2.3 $\pm$ 3.4
Sex	
Male	90 (54.5)
Female	75 (45.5)
CAKUT	
Yes	53 (32.1)
No	112 (67.9)
Hydronephrosis	44 (26.7)
Hydroureter	8 (4.8)
Vesicourethral reflux	11 (6.7)
Double collecting system	4 (2.4)
Ureterovesical junction obstruction	1 (0.6)
Multicystic dysplastic kidney	1 (0.6)
Renal dysplasia	1 (0.6)
Ureterocele	2 (1.2)
Renal cortical cyst	1 (0.6)

Table 1. Clinical and demographic data of the patients (n=165) (Cont.)

Characteristics	Participants (total = 165) N (%)
Renal abscess	2 (1.2)
Renal scar	1 (0.6)
History of recurrent UTIs	37 (22.4)
Antibiotic prophylaxis	9 (5.5)
History of antibiotic treatment within the preceding 30 days	36 (21.8)
Previous hospitalization	
No	100 (60.6)
Hospitalization in the 30 days before enrolment	46 (27.9)
Hospitalization in the 90 days before enrolment	19 (11.5)
Constipation	42 (25.5)
Neurogenic bladder	7 (4.2)
History of myelomeningocele	5 (3.0)
Clean intermittent catheterization (CIC)	2 (1.2)
Clinical presentations	
Fever with specific symptoms	89 (53.9)
Nausea or vomiting	30 (18.2)
Dysuria	26 (15.8)
Fever without localizing signs	24 (14.5)
Poor intake	24 (14.5)
Diarrhea	22 (13.3)
Drowsiness	17 (10.3)
Gross hematuria	12 (7.3)
Prolong jaundice	9 (5.5)
Febrile convulsion	7 (4.2)
Cloudy urine	6 (3.6)
Others (flank pain, urgency, frequent voiding, dripping, oliguria, genital pain, smelling urine, bloating)	22 (13.3)
Physical examination	
Phimosis in males (N = 90)	60 (66.7)
Labial adhesion in females (N=75)	4 (5.3)
Weakness of the lower extremities' muscles	4 (2.4)
Admission	
No	127 (77.0)
Yes	38 (23.0)
Mean duration of admission, hours (Mean $\pm$ SD)	193.8 $\pm$ 147.9

CAKUT: Congenital Anomalies of the Kidney and Urinary Tract; SD: standard deviation

Etiology of community-acquired urinary tract infection in children and resistance pattern.

Figure 1 shows the etiology of community-acquired urinary tract infection in children. The most prevalent uropathogen identified was Enterobacteriaceae, with *E. coli* (66.7%) the most common, followed by *K. pneumoniae* (17.6%) and *P. mirabilis* (4.2%), respectively. Other isolates, belonging to the non-Enterobacteriaceae group, included predominantly *P. aeruginosa* (1.2%) and *Enterococcus* spp., primarily *E. faecalis* (3%).

Figure 2 illustrates the antibiotic resistance patterns within the Enterobacteriaceae group. Of the 34 patients in this group (34/154; 22%), all were susceptible to all tested antibiotics. The predominant resistance pattern observed was a combination of ESBL production and MDR, affecting 45 out of 154 patients (29.2%). In this study, 57/154 (37%) patients had resistance to extended-spectrum beta-lactamase antibiotics, and 63/154 (40.9%) had MDR infections. Only one patient with CRE was identified. Notably, this study found no XDR or PDR bacteria. For non-Enterobacteriaceae isolates, two *P. aeruginosa* isolates were susceptible to all tested antibiotics. Among *Enterococcus* species, most *E. faecalis* isolates (4/5; 80%) were susceptible to both

ampicillin and vancomycin, with only 1 isolate resistant to ampicillin. Furthermore, no vancomycin resistance was detected among the Gram-positive bacteria group.

Overall, 41 of 165 cases (24.8%) were caused by organisms susceptible to all tested antibiotics. **Table 2** compares infections caused by organisms susceptible to all tested antibiotics with those resistant to at least one tested antibiotic in children with community-acquired UTIs. A history of recurrent UTIs showed a significant difference between the groups ($p = 0.007$), and the drug-resistant group tended to be younger ($p = 0.064$). Based on these findings and clinical relevance, we included the following variables in the multivariable logistic regression model: history of recurrent UTIs ($p = 0.007$), history of antibiotic treatment within the preceding 30 days ($p = 0.085$), and age ($p = 0.064$). In the multivariable analysis, younger age (OR = 0.99; 95% CI 0.99–0.99) and a history of recurrent UTIs (OR = 6.88; 95% CI 1.57–30.22) were independently associated with an increased risk of drug-resistant community-acquired UTIs. The findings highlight a critical need for age-specific and history-informed approaches to empirical antibiotic selection to combat rising resistance in pediatric urinary tract infections.

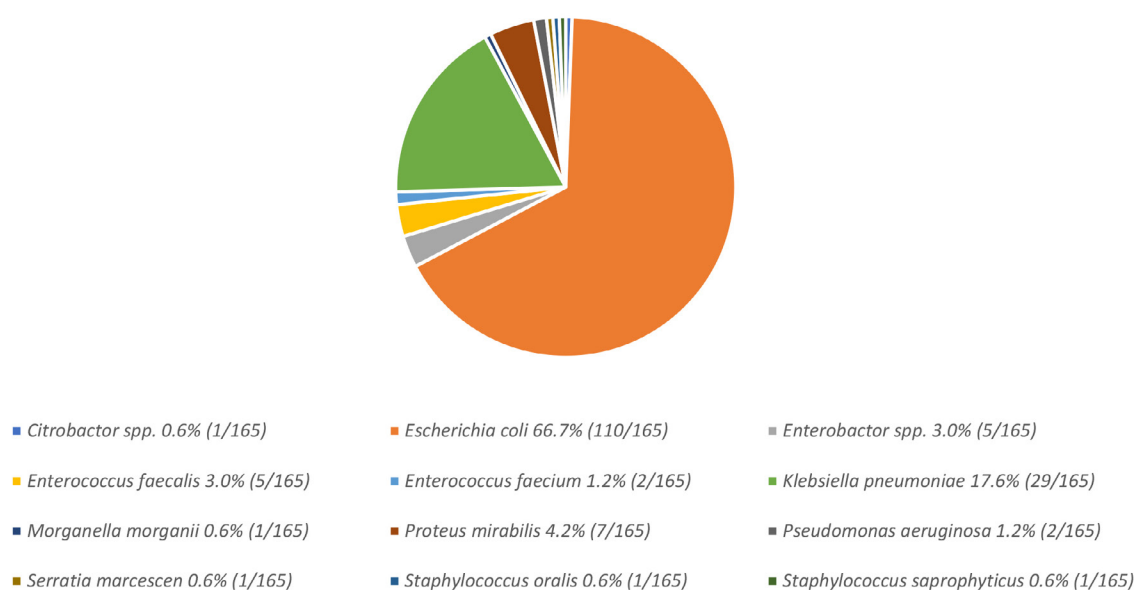


Figure 1. Etiology of community-acquired urinary tract infection in children

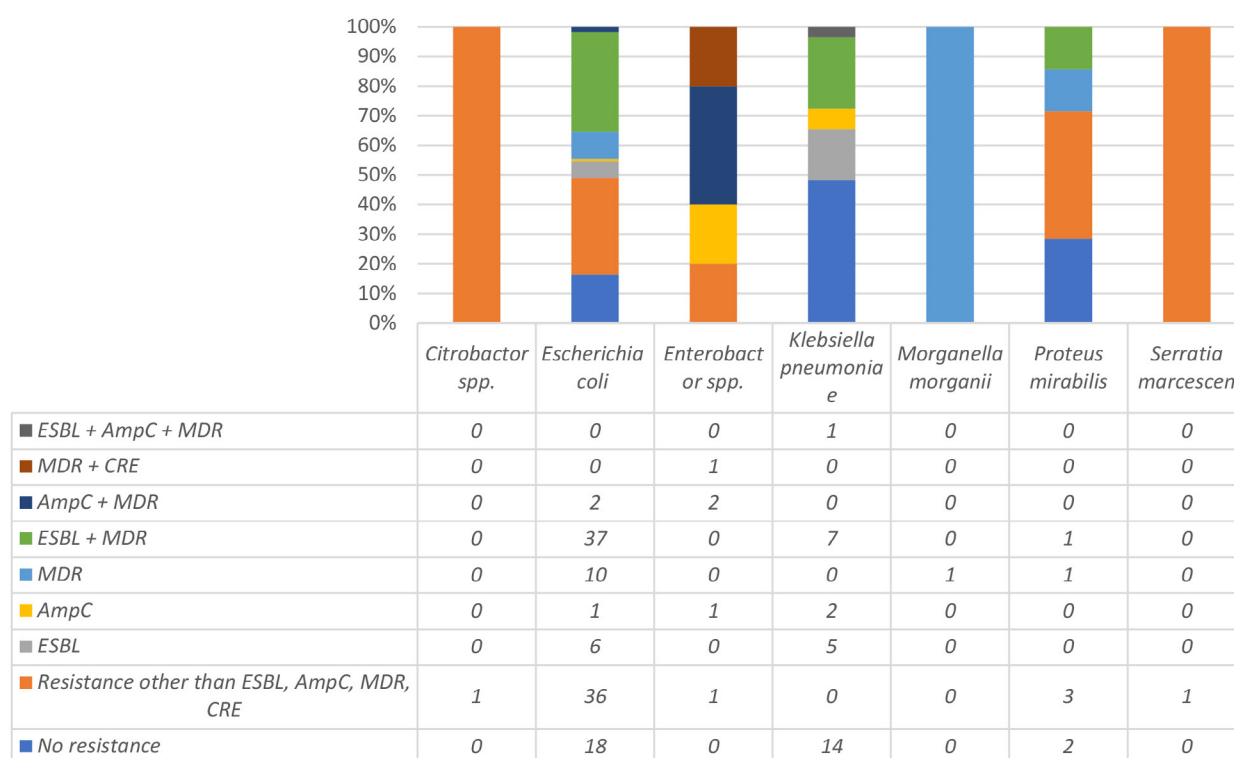


Figure 2. Antibiotic resistance patterns among Enterobacterales

Table 2. Comparison of characteristics between infections caused by organisms susceptible to all tested antibiotics and those resistant to at least one tested antibiotic in children with community-acquired UTIs

Risk factors	Susceptible to all tested antibiotics N=41, 24.8% (N, %)	Resistant to at least one tested antibiotic N=124, 75.2% (N, %)	p-value
Mean age, years (Mean ± SD)	3.7 ± 4.3	1.9 ± 2.9	0.064
Sex			
• Male	20 (48.8)	70 (56.5)	0.392
• Female	21 (51.2)	54 (43.5)	
CAKUT	10 (24.3)	47 (37.9)	0.102
• Hydronephrosis	7 (17.1)	37 (33.9)	0.101
• Hydroureter	-	8 (6.5)	0.201
• Vesicourethral reflux	2 (4.9)	9 (7.3)	0.732
• Double collecting system	1 (2.4)	3 (2.4)	0.999
• Ureterovesical junction obstruction	-	1 (0.8)	0.999
• Multicystic dysplastic kidney	-	1 (0.8)	0.999
• Renal dysplasia	-	1 (0.8)	0.999
• Ureterocele	-	2 (1.6)	0.999
• Renal cortical cyst	-	1 (0.8)	0.999
History of recurrent UTIs	3 (7.3)	34 (27.4)	0.007
Antibiotic prophylaxis	-	9 (7.3)	0.114
History of antibiotic treatment within the preceding 30 days	5 (12.2)	31 (25.0)	0.085

Table 2. Comparison of characteristics between infections caused by organisms susceptible to all tested antibiotics and those resistant to at least one tested antibiotic in children with community-acquired UTIs (Cont.)

Risk factors	Susceptible to all tested antibiotics N=41, 24.8% (N, %)	Resistant to at least one tested antibiotic N=124, 75.2% (N, %)	p-value
Previous hospitalization			0.411
• No	28 (68.3)	70 (57.4)	
• Hospitalization in the 30 days before enrolment	10 (24.4)	36 (29.5)	
• Hospitalization in the 90 days before enrolment	3 (7.3)	16 (13.1)	
Constipation	13 (31.7)	29 (23.4)	0.274
Neurogenic bladder	-	2 (1.7)	0.999
History of myelomeningocele	1 (2.4)	4 (3.2)	0.999
Clean intermittent catheterization (CIC)	-	2 (1.6)	0.999
Clinical presentation			
• Fever	23 (56.1)	66 (53.7)	0.786
Physical examination			
• Phimosis in male	13 (65.0)	47 (67.1)	0.662
• Labial adhesion in female	-	4 (7.7)	0.570
• Sacral dimple	1 (2.4)	2 (1.6)	0.999
• Weakness of lower extremities muscle	1 (2.4)	4 (3.2)	0.999

CAKUT: Congenital Anomalies of the Kidney and Urinary Tract, SD: standard deviation

Table 3. Multivariate analysis of risk factors for community-acquired drug-resistant UTIs in children

Risk factor	Adjusted OR	95% CI	p-value
Age	0.999	0.999-0.999	0.009
Recurrent UTI	6.89	1.57-30.22	0.011

OR = odds ratio

In vitro antimicrobial susceptibility of uropathogens according to the Thai national guidelines

According to the “Clinical Practice Guideline for Urinary Tract Infection in Children Aged 2 Months to 5 Years”, updated in 2022⁽¹²⁾, empirical treatment for pediatric UTIs is recommended with third-generation cephalosporins, aminoglycosides, or amoxicillin-clavulanate. **Table 4** summarizes the *in vitro* antimicrobial susceptibility of uropathogens according to Thai national guidelines. This study found that amikacin (92.1%) was the most susceptible antibiotic for community-acquired UTIs in pediatric patients, followed by amoxicillin-clavulanate (67.3%) and ciprofloxacin (61.8%).

Ceftriaxone, routinely selected for inpatient UTI treatment because of its widespread use, low cost, and established safety profile,⁽¹⁶⁾ showed 54.6% susceptibility. To identify risk factors associated with ceftriaxone-resistant organisms, we performed logistic regression analysis (**Table 5**). Univariable analysis identified sex ($p < 0.001$), age ($p = 0.005$), antibiotic prophylaxis ($p = 0.012$), history of antibiotic treatment within the preceding 30 days ($p < 0.001$), previous hospitalization within 30 days ($p = 0.006$), and constipation ($p = 0.062$) as potential risk factors. We then included these variables in the multivariable logistic regression model. In the multivariable analysis, male sex (odds ratio 3.77; 95% CI 1.81,

Table 4. In vitro antimicrobial susceptibility of uropathogens according to Thai national guidelines

Therapy	Total	Susceptible N (%)	Intermediate N (%)	Not susceptible N (%)	Unknown N (%)
Amoxicillin-clavulanate	165	111 (67.3)	19 (11.52)	32 (19.39)	3 (1.82)
Ceftriaxone	165	90 (54.6)	2 (1.2)	73 (44.2)	-
Cefotaxime	165	83 (50.3)	3 (1.8)	74 (44.6)	5 (3.0)
Amikacin	165	152 (92.1)	-	11 (6.7)	2 (1.2)
Gentamicin	165	93 (56.4)	-	65 (39.4)	7 (4.24)
Ciprofloxacin	165	102 (61.8)	22 (13.3)	40 (24.2)	1 (0.6)
Trimethoprim-sulfamethoxazole	165	72 (43.6)	-	86 (52.2)	7 (4.2)

Table 5. Multivariate analysis of risk factors for ceftriaxone-resistant organisms

Risk factor	Adjusted OR	95% CI	p-value
Male sex	3.77	1.81-7.86	<0.001
History of antibiotic treatment within the preceding 30 days	3.19	1.24-8.23	0.017
Antibiotic prophylaxis use	9.21	0.999-84.99	0.05

OR = odds ratio

7.86) and antibiotic treatment within the preceding 30 days (odds ratio 3.19; 95% CI 1.24, 8.23) were strong independent risk factors for ceftriaxone resistance. Antibiotic prophylaxis use (odds ratio 9.21; 95% CI 0.99, 84.99) showed a borderline association with ceftriaxone resistance and may remain clinically relevant.

Cefotaxime, frequently prescribed for early-onset sepsis due to its broad-spectrum coverage of neonatal sepsis pathogens⁽¹⁷⁾, showed 50.3% susceptibility in this study. To identify risk factors associated with cefotaxime-resistant organisms, logistic regression analysis was performed (**Table 6**). Univariable analysis identified sex ($p < 0.001$), age ($p = 0.008$), antibiotic prophylaxis ($p = 0.029$), antibiotic treatment within the preceding 30 days ($p < 0.001$), and hospitalization within 30 days ($p = 0.003$) as potential risk factors. These variables were subsequently included in the multivariable logistic regression model. In the multivariable analysis, male sex (odds ratio 2.98; 95% CI 1.44, 6.15) and antibiotic treatment within the preceding 30 days (odds ratio 2.95; 95% CI 1.13, 7.74) were strong independent risk factors for cefotaxime resistance.

Among patients with ESBL-producing and/or multidrug-resistant uropathogens, 13 cases were successfully treated with ceftriaxone or cefotaxime. In this study, one case of septicemia was identified, caused by an ESBL-producing and multidrug-resistant *K. pneumoniae*. In addition, one patient developed acute kidney injury associated with ESBL-producing *K. pneumoniae*. Two cases of renal abscess were observed: one caused by *E. faecalis* in the setting of inappropriate empirical antibiotic therapy, and another caused by *E. coli* associated with partial treatment.

Discussion

The findings of this study reveal an increasing prevalence of community-acquired urinary tract infections in children due to drug-resistant microorganisms. This study reports a prevalence of any drug-resistant uropathogens of 75.2%, higher than a previous study from Italy (46.7%) during 2012–2020.⁽¹⁸⁾ However, this study also reported an increase in the prevalence of drug-resistant microorganisms from 42% during 2012–2015 to 56.7% during 2016–2020. This evidence demonstrates the increasing prevalence of drug-resistant

Table 6. Multivariate analysis of risk factors for cefotaxime-resistant organisms

Risk factor	Adjusted OR	95% CI	<i>p</i> -value
Male sex	2.98	1.44-6.15	0.003
History of antibiotic treatment within the preceding 30 days	2.95	1.13-7.74	0.028

OR = odds ratio

microorganisms worldwide. Especially in Southeast Asia, this region may constitute the highest global risk zone for the dissemination of antimicrobial resistance in human populations. Systematic reviews regarding antimicrobial resistance among children in Southeast Asia, which collected studies published between 2010–2023, found that when evaluating *E. coli* and *Klebsiella* spp., two of the most common pathogens for UTIs, high rates of non-susceptibility to cotrimoxazole were observed for both pathogens (59% [IQR 38 to 75] for *Klebsiella* spp. and 67% [IQR 50 to 75] for *E. coli*).⁽¹⁹⁾ This phenomenon was also observed in adults; a systematic review of antimicrobial resistance among uropathogens in the Asia-Pacific region reported that the prevalence of resistance to trimethoprim/sulfamethoxazole, ciprofloxacin, and ceftriaxone ranged from 33% to 90%.⁽²⁰⁾ The problem of antimicrobial resistance has worsened in this region due to widespread overuse and misuse of antibiotics in humans and animals, easy over-the-counter access, weak regulations, poor sanitation, and dense populations, which have led to rapid bacterial evolution and spread, further exacerbated by factors such as intensive farming and weak infection control in healthcare.^(21–23)

As previously documented, the most frequent community-acquired uropathogens in this study are *E. coli*, followed by *K. pneumoniae*, *Enterobacter* spp., and *E. faecalis*, consistent with global trends in pediatric UTIs.⁽²⁴⁾ The prevalence of ESBL-producing Enterobacteriaceae in this study was 37%, which is comparable to other studies from regions such as the Middle East (>40%)⁽²⁵⁾ and Indonesia (42%).⁽²⁶⁾ Consistent with a recent multicenter survey of pediatric nephrologists from 232 centers in 77 countries, the prevalence of UTIs caused by ESBL-producing

Enterobacteriaceae varies across continents, with a relatively higher estimated prevalence (>20%) of ESBL-producing bacteria in Asia, the Middle East, and Africa.⁽²⁷⁾ Data on MDR pathogens are scarce; this study found a prevalence of 40.9%, consistent with published rates ranging from 5% to 90% across different settings.⁽²⁸⁾ This high variability is noteworthy; for instance, studies in Bangladesh reported rates of 55%–72.3%,⁽²⁹⁾ and in India, 75.4%.⁽³⁰⁾ An incremental increase has also been reported in Korea, where the rate of MDR UTIs rose from 35.7% in 2006 to 51.9% in 2016.⁽³¹⁾ This escalating trend of drug-resistant microorganisms may lead to multiple consequences, including inappropriate empirical antibiotic use before urine culture results are available, prolonged hospital stays, increased mortality, higher healthcare costs, and challenges in selecting appropriate prophylactic agents.^(13,32)

Early identification of patients at risk of antibiotic resistance reduces the failure of empirical antimicrobial therapy. This study found that younger age and a history of recurrent UTIs were risk factors associated with community-acquired drug-resistant UTIs in children. Regarding age-related risk factors, many studies have yielded similar results. For instance, Kizilca et al. identified age < 1 year as a significant risk factor for ESBL-positive UTIs in pediatric populations.⁽¹³⁾ Similarly, the study by Jakovljevic et al. revealed a higher prevalence of antibiotic-resistant *E. coli* in infants and toddlers compared to older children and adolescents.⁽³³⁾ The possible explanations include that younger children are disproportionately exposed to empirically prescribed broad-spectrum antibiotics early in life, increasing the risk of antimicrobial resistance.⁽³⁴⁾ Neonates, with their immature immune systems, are more vulnerable to infection and more likely

to receive empiric antibiotics, which in turn fosters resistance selection. Furthermore, a lack of research on appropriate dose prescribing for younger children can lead to under- or overdosing, where suboptimal dosing increases the potential for antimicrobial resistance selection.^(35,36) A history of recurrent UTI was also identified as a significant risk factor for drug-resistant UTIs in this study, consistent with findings from systematic reviews⁽³⁷⁾ and reports from the USA,⁽³⁸⁾ Korea,⁽³⁹⁾ Turkey,⁽¹³⁾ and Italy.⁽¹⁸⁾ This can be explained by the fact that children with recurrent UTIs often undergo repeated antibiotic treatments and previous hospitalizations, and may have underlying anatomical or functional abnormalities of the kidney and urinary tract, which increase susceptibility to infections caused by resistant organisms.⁽⁴⁰⁾

For ceftriaxone and cefotaxime, commonly used as empirical therapy for community-acquired urinary tract infections, multivariable logistic regression analysis showed that male sex and a history of antibiotic treatment within the preceding 30 days were independent risk factors for antimicrobial resistance. These findings are consistent with previous studies. Pérez Heras I et al. reported that both factors were associated with extended-spectrum β -lactamase (ESBL)-producing *E. coli* infections in children.⁽⁴¹⁾ Similarly, Shaikh N et al. identified male sex, particularly in uncircumcised males, as a risk factor for antimicrobial-resistant urinary tract infections.⁽⁴²⁾ The association between male sex and resistant UTI may be explained by the higher likelihood of underlying structural or functional urinary tract abnormalities in males, which can lead to recurrent infections, difficulty in eradicating pathogens, and increased antibiotic exposure, thereby promoting the development of resistance.⁽⁴³⁾ In addition, a history of antibiotic treatment within the preceding 30 days is a well-established risk factor, as prior antibiotic exposure promotes the growth of resistant organisms.^(18,44-47)

Interestingly, our study successfully treated 13 cases of UTI caused by ESBL-producing and/or multidrug-resistant organisms with ceftriaxone or cefotaxime. This finding highlights a potential discrepancy between in vitro antimicrobial sus-

ceptibility and clinical outcomes in urinary tract infections. The inconsistency between in vitro resistance and clinical outcomes may be explained by beta-lactam antibiotics' ability to achieve high urinary concentrations that can exceed the minimum inhibitory concentration at the site of infection, facilitating bacterial clearance despite laboratory-reported resistance.⁽⁴⁸⁾ These findings suggest that in vitro resistance may not always accurately predict clinical outcomes in UTIs; however, this observation should be interpreted with caution and requires further validation in larger prospective studies.

According to the Thai national guideline "Clinical Practice Guideline for Urinary Tract Infection in Children Aged 2 Months to 5 Years", updated in 2022⁽¹²⁾, the most promising empirical antibiotic identified in this study was amikacin (92.1% susceptibility), an intravenous antibiotic. These findings correspond with results from other studies. Kilic et al. analyzed urine cultures from pediatric outpatient clinics and found that amikacin had the lowest resistance rate among uropathogens.⁽⁴⁹⁾ Similarly, Samanci et al. reported that amikacin had the lowest resistance rates against uropathogens in children, even lower than meropenem, colistin, ertapenem, and imipenem.⁽⁵⁰⁾ Regarding oral antibiotics, this study found that amoxicillin-clavulanate had the highest susceptibility (67.3%) among oral options. This finding is consistent with a study by Rodríguez-Lozano et al. in Spain, which reported a susceptibility rate of 75.3% to amoxicillin-clavulanate in pediatric urinary tract infections.⁽⁵¹⁾

This study encountered some limitations. First, its retrospective design means it relies on existing medical records, which may be incomplete. Second, the study was conducted in a tertiary-care hospital, which may have preferentially included more complicated cases. Patients managed in this setting are more likely to have underlying conditions such as CAKUT, recurrent UTIs, difficult-to-treat infections, or UTI-related complications. In contrast, less severe community-acquired UTI cases are often managed in primary care settings. Therefore, this study's findings may not fully represent the overall distribution of pathogens in the general community.

Nevertheless, this study provides a detailed view of the resistance landscape affecting children in the metropolitan area. It demonstrates the real-life effectiveness of antibiotics recommended by the Thai national guidelines.

Conclusion

Despite extensive research on urinary tract infections in children, this topic remains clinically challenging, and the present study contributes valuable insights into its management. The findings highlight the increasing prevalence of drug-resistant uropathogens in pediatric patients, underscoring the critical need to encourage appropriate antibiotic use in Thai children. Younger age and a history of recurrent urinary tract infections were identified as risk factors for drug-resistant microorganisms. Furthermore, male sex and a history of antibiotic treatment within the preceding 30 days were associated with resistance to ceftriaxone and cefotaxime. These findings underscore the importance of careful empirical antibiotic selection in patients with these risk factors. Amikacin proved to be the most susceptible empirical antibiotic in this study. Although amoxicillin-clavulanate was the oral antibiotic with the lowest resistance, susceptibility was still only approximately 67%.

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