

Bacterial Uropathogens and Antimicrobial Susceptibility Patterns among Children at a Cambodian Tertiary Pediatric Hospital, January 2023 – June 2025

Research Article

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Abstract: Antimicrobial resistance complicates empirical treatment of pediatric urinary tract infection (UTI), and local data from Cambodia remain limited. This study aimed to describe bacterial isolates from urine cultures in children with suspected UTI and their antimicrobial susceptibility patterns. This retrospective descriptive study was conducted at the National Pediatric Hospital, Cambodia, between January 2023 and June 2025. Children aged 0-15 years with suspected UTI and positive bacterial urine cultures were included. Fungal isolates were excluded because the study focused on bacterial uropathogens and antibacterial susceptibility patterns. Clinical, microbiological, susceptibility, and antibiotic-use data were extracted from medical records and microbiology reports. Among 3,209 children who underwent urine culture testing, 80 (2.5%) had positive cultures. After excluding 21 fungal isolates, 59 children (1.8%) with positive bacterial cultures were analyzed. The mean age was 5.9 years, and females predominated (38/59, 64.4%). Gram-negative bacteria accounted for 58/59 isolates (98.3%). *Escherichia coli* was the most common pathogen (48/59, 81.4%), followed by *Klebsiella* spp. (7/59, 11.9%). *E. coli* showed high resistance to ampicillin (44/48, 91.7%), trimethoprim-sulfamethoxazole (36/42, 85.7%), ceftriaxone (36/48, 75.0%), ceftazidime (31/44, 70.5%), ciprofloxacin (31/46, 67.4%), amoxicillin/clavulanic acid (27/47, 57.4%), and gentamicin (25/47, 53.2%). Lower resistance was observed to nitrofurantoin (1/37, 2.7%), amikacin (4/47, 8.5%), meropenem (7/44, 15.9%), and imipenem (8/44, 18.2%). Ceftriaxone was the most frequently used antibiotic during hospitalization (43/59, 72.9%), despite high ceftriaxone resistance among *E. coli* isolates. Gram-negative bacteria, mainly *E. coli* followed by *Klebsiella* spp., predominated among children with positive bacterial urine cultures. Frequent ceftriaxone use despite high *E. coli* resistance highlights the need for culture-guided treatment adjustment, ongoing local surveillance, and periodic review of empirical antibiotic recommendations. These findings should be interpreted as baseline surveillance data.

1. Introduction

Urinary tract infection (UTI) is one of the most common bacterial infections in children and an important cause of pediatric morbidity (Fitzgerald et al., 2012). Diagnosis can be challenging because symptoms are often nonspecific, particularly in infants and young children, and the clinical distinction

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between cystitis and pyelonephritis may be unreliable (Hoberman et al., 2003; National Institute for Health and Care Excellence, 2022; Gnech et al., 2026).

Delayed or inappropriate treatment may increase the risk of recurrence and long-term renal complications, especially in children with underlying urinary tract abnormalities, who are vulnerable to progressive renal damage, hypertension, and chronic kidney disease (Conway et al., 2007). *Escherichia coli* is the predominant uropathogen in pediatric UTI, followed by organisms such as *Klebsiella*, *Pseudomonas*, *Proteus*, and *Enterobacter* species (Robinson et al., 2014). Although empirical antibiotics are commonly initiated before culture results are available, treatment should be guided by local pathogen distribution and antimicrobial resistance patterns (National Institute for Health and Care Excellence, 2022; Gnech et al., 2026; Abdullah et al., 2012).

The increasing burden of antimicrobial resistance highlights the need for updated local microbiological surveillance (Farajnia et al., 2009). However, data on pediatric UTI pathogens and their antimicrobial susceptibility patterns in Cambodian tertiary care settings remain limited, potentially affecting empirical treatment decisions. This study aimed to describe the microbiological profile of pediatric UTI and determine the antimicrobial susceptibility patterns of bacterial isolates at a tertiary pediatric hospital in Cambodia.

2. Materials and Methods

2.1. Study design and setting

This retrospective descriptive study was conducted at the National Pediatric Hospital, Phnom Penh, Cambodia, a national tertiary pediatric referral hospital. The study included children who underwent urine culture testing for suspected urinary tract infection from January 2023 to June 2025.

2.2. Study population, inclusion, and exclusion criteria

Children aged 0–15 years with suspected UTI and at least one positive bacterial urine culture were included. The unit of analysis was the first positive bacterial urine culture per patient. If multiple positive cultures were available from the same patient during the same admission or UTI episode, only the first positive bacterial isolate was included. Fungal-only cultures, cultures reported as contamination, and records with insufficient microbiological data were excluded.

2.3. Clinical definition of suspected UTI

Suspected UTI was defined as a clinician-requested urine culture based on compatible clinical features, including fever, dysuria, urinary frequency, urgency, abdominal or flank pain, vomiting, poor feeding, lethargy, or other nonspecific illness suggestive of UTI. Because of the retrospective design, the study relied on documented clinical suspicion and requests for urine cultures rather than a standardized prospective case definition.

2.4. Urine specimen collection and culture processing

Urine specimens were collected by clean-catch midstream, catheterization, or urine bag according to routine hospital practice. Cultures were performed on MacConkey and blood agar plates and incubated at 35–37°C for 18–24 hours. Positive culture was defined as bacterial growth of $\geq 10^5$ CFU/mL. Mixed growth, growth below this threshold, or growth of three or more bacterial species was considered possible contamination, and repeat urine collection was recommended when clinically indicated.

2.5. Microbiological identification

Bacterial isolates were identified using conventional biochemical methods and the API (Analytical Profile Index) identification system, in accordance with the laboratory’s standard operating procedures.

2.6. Antimicrobial susceptibility testing

Antimicrobial susceptibility testing was performed using the Kirby–Bauer disk diffusion method. Results were interpreted according to the Clinical and Laboratory Standards Institute Performance Standards for Antimicrobial Susceptibility Testing, 32nd edition, CLSI supplement M100, 2022 (Clinical and Laboratory Standards Institute, 32nd, 2022). Antibiotics tested were based on the routine laboratory panel, organism type, and antimicrobial availability; therefore, not all isolates were tested against every antibiotic. Intermediate results were reported separately and were not combined with resistant results. Missing susceptibility results were not imputed. Quality control was performed according to laboratory procedures using ATCC reference strains.

2.7. Data collection and quality control

Data were extracted from microbiology and medical records using a standardized checklist, including demographic characteristics, clinical features, culture results, antimicrobial susceptibility patterns, blood culture findings, and antibiotics used during hospitalization. Blood culture results and organisms with potential for contamination or colonization, including *Bacillus* spp., *Acinetobacter* spp., and *Burkholderia cepacia*, were interpreted descriptively in relation to the available clinical context.

2.8. Statistical analysis

Data were analyzed descriptively using Microsoft Excel 2016. Categorical variables are presented as frequencies and percentages, and continuous variables as means and ranges. Antimicrobial resistance percentages were calculated using the number of isolates tested for each antibiotic as the denominator. Where reported, 95% confidence intervals for resistance proportions were calculated using the Wilson method. No multivariable analysis was performed because of the small sample size.

3. Results

Of 3,209 children who underwent urine culture testing, 80 had positive cultures, yielding an overall positivity rate of 2.5%. After excluding 21 fungal isolates, 59 children with positive bacterial urine cultures were included in the final analysis, representing 1.8% of all children tested (Figure 1).

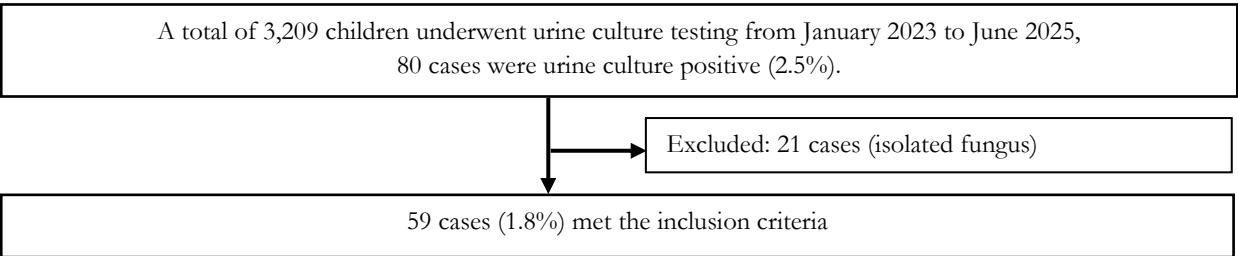


Figure 1. Flow diagram of study inclusion and exclusion

3.1. Sociodemographic features

Patients ranged in age from 1 day to 15 years, with a mean age of 5.9 years. They were classified into three age groups, with 12 patients (20.3%) aged under 2 years, 19 (32.2%) aged 2–5 years, and 28 (47.5%) aged over 5 years. Of the 59 patients, 21 (35.6%) were male and 38 (64.4%) were female, giving a male-to-female ratio of 1:1.8.

3.2. Clinical characteristics

Fever was the most common presenting complaint, occurring in 48 patients (81.4%). Other presenting symptoms included dysuria, pallor, cough, dyspnea, headache, sore throat, abdominal pain, rhinorrhea, somnolence, convulsions, arthralgia, asthenia, rash, and vomiting. The duration of hospitalization ranged from 2 to 63 days, with a mean length of stay of 10.3 days.

3.3. Microbiological profiles

Of the 59 cases with positive urine cultures, Gram-negative bacteria accounted for 98.3% (n = 58). The most frequently isolated organism was *Escherichia coli* (81.4%, n = 48), followed by *Klebsiella* spp. (11.9%, n = 7), *Acinetobacter* spp. (3.4%, n = 2), and *Proteus mirabilis* (1.7%, n = 1). Gram-positive bacteria (*Enterococcus* spp.) were identified in 1 case (1.7%).

Among *E. coli* isolates, resistance was most frequent to ampicillin (44/48, 91.7%), trimethoprim-sulfamethoxazole (36/42, 85.7%), ceftriaxone (36/48, 75.0%), ceftazidime (31/44, 70.5%), ciprofloxacin (31/46, 67.4%), amoxicillin/clavulanic acid (27/47, 57.4%), and gentamicin (25/47, 53.2%). In contrast, low resistance was observed to nitrofurantoin (1/37, 2.7%), followed by amikacin (4/47, 8.5%), meropenem (7/44, 15.9%), and imipenem (8/44, 18.2%) (Table 1).

Table 1. Antimicrobial susceptibility patterns of *E. coli* (n = 48)

Antibiotics	Susceptible, n (%)	Intermediate, n (%)	Resistant, n/N (%)	95% CI	Total
Amoxicillin/Clavulanic Acid	18 (38.3)	2 (4.3)	27/47 (57.4)	43.3–70.5	47
Ampicillin	3 (6.3)	1 (2.1)	44/48 (91.7)	80.4–96.7	48
Amikacin	41 (87.2)	2 (4.3)	4/47 (8.5)	3.4–19.9	47
Ceftazidime	8 (18.2)	5 (11.4)	31/44 (70.5)	55.8–81.8	44
Ceftriaxone	12 (25.0)	-	36/48 (75.0)	61.2–85.1	48
Ciprofloxacin	10 (21.7)	5 (10.9)	31/46 (67.4)	53.0–79.1	46
Gentamicin	22 (46.8)	-	25/47 (53.2)	39.2–66.7	47
Imipenem	31 (70.5)	5 (11.4)	8/44 (18.2)	9.5–32.0	44
Meropenem	35 (79.5)	2 (4.5)	7/44 (15.9)	7.9–29.4	44
Nitrofurantoin	35 (94.6)	1 (2.7)	1/37 (2.7)	0.5–13.8	37
Trimethoprim/Sulfamethoxazole	6 (14.3)	-	36/42 (85.7)	72.2–93.3	42

Percentages are based on the number of isolates tested for each antibiotic. The 95% confidence intervals for resistance proportions were calculated using the Wilson method.

Although based on only seven isolates, *Klebsiella* spp. Showed a concerning resistance pattern, with complete resistance to ampicillin (100.0%) and high resistance to trimethoprim-sulfamethoxazole (83.3%, n = 5/6), amoxicillin/clavulanic acid (71.4%, n = 5/7), ceftriaxone (57.1%, n = 4/7), and gentamicin (57.1%, n = 4/7). Lower resistance was observed for nitrofurantoin (0.0%), amikacin (14.3%, n = 1/7), meropenem (14.3%, n = 1/7), and imipenem (16.7%, n = 1/6) (Table 2).

Table 2. Antimicrobial susceptibility patterns of *Klebsiella* spp. (n = 7)

Antibiotics	Susceptible, n (%)	Intermediate, n (%)	Resistant, n/N (%)	95% CI	Total
Amoxicillin/Clavulanic Acid	2 (28.6)	-	5/7 (71.4)	35.9–91.8	7
Ampicillin	0 (0.0)	-	7/7 (100.0)	64.6–100.0	7
Amikacin	6 (85.7)	-	1/7 (14.3)	2.6–51.3	7
Ceftazidime	4 (57.1)	1 (14.3)	2/7 (28.6)	8.2–64.1	7
Ceftriaxone	3 (42.9)	-	4/7 (57.1)	25.0–84.2	7
Ciprofloxacin	3 (42.9)	1 (14.3)	3/7 (42.9)	15.8–75.0	7
Gentamicin	3 (42.9)	-	4/7 (57.1)	25.0–84.2	7
Imipenem	5 (83.3)	-	1/6 (16.7)	3.0–56.4	6
Meropenem	6 (85.7)	-	1/7 (14.3)	2.6–51.3	7
Nitrofurantoin	6 (100.0)	-	0/6 (0.0)	0.0–39.0	6
Trimethoprim/Sulfamethoxazole	1 (16.7)	-	5/6 (83.3)	43.6–97.0	6

Percentages are based on the number of isolates tested for each antibiotic. The 95% confidence intervals were calculated using the Wilson method. Estimates should be interpreted cautiously because of the small sample size (n = 7).

The 95% confidence intervals for resistance estimates are shown in Tables 1 and 2; estimates for *Klebsiella* spp. Should be interpreted cautiously because of the small number of isolates.

In addition to *Escherichia coli* and *Klebsiella* spp., two isolates of *Acinetobacter* spp. Were identified. Both isolates were resistant to ceftazidime, ciprofloxacin, gentamicin, meropenem, and trimethoprim–sulfamethoxazole, while one isolate remained susceptible to amikacin. A single isolate of *Proteus mirabilis* was detected. This isolate was resistant to ampicillin, ceftriaxone, ciprofloxacin, and gentamicin, but susceptible to amoxicillin–clavulanic acid, amikacin, and meropenem. One isolate of *Enterococcus* spp. Was also identified. This isolate was resistant to ciprofloxacin and penicillin, but susceptible to ampicillin and nitrofurantoin. Because of the very small number of these isolates, these findings should be interpreted descriptively and cautiously.

Blood cultures were performed in 39 patients (66.1%), of whom 6 had positive results. *Escherichia coli* was isolated in 3 cases, while the remaining isolates were *Klebsiella pneumoniae* (n = 1), *Bacillus* spp. (n = 1), and *Burkholderia 5epacian* (n = 1).

3.4. Distribution of antibiotics used during hospitalization

Antibiotic therapy was administered to all patients included in the study. Monotherapy was used in 18 of 59 cases (30.5%), whereas the remaining patients received combination therapy, most commonly dual therapy, which was prescribed in 32 cases (54.2%). Triple therapy was used less frequently, accounting for 9 cases (15.3%). Ceftriaxone was the most commonly prescribed antibiotic during hospitalization, administered in 43 of 59 cases (72.9%), followed by gentamicin in 26 cases (44.1%) and ciprofloxacin in 23 cases (39.0%). Detailed antibiotic utilization is shown in Table 3.

Table 3. Distribution of Antibiotics Used During Hospitalization (n = 59)

Antibiotics	Number of cases	Percentage (%)
Ceftriaxone	43	72.9
Gentamicin	26	44.1
Ciprofloxacin	23	39.0
Ceftazidime	7	11.9
Trimethoprim/sulfamethoxazole	5	8.5

Cloxacillin	4	6.8
Azithromycin	3	5.1
Amoxicillin/clavulanic acid	2	3.4
Amikacin	2	3.4
Nitrofurantoin	2	3.4
Meropenem	1	1.7
Erythromycin	1	1.7

Percentages use n = 59 as the denominator; totals exceed 100% due to combination therapy.

4. Discussion

4.1. Sociodemographic features

The mean age of children in our study was 5.9 years, which was higher than that reported in several previous studies (Moore et al., 2016; Vélez Echeverri et al., 2014; Han et al., 2015; Mohd Nor et al., 2015), where the corresponding mean ages were 1.7 years, 2.3 years, 5 months, and 3.9 years, respectively. More than half of our cases occurred in children older than 5 years. This difference may reflect variations in study population, referral patterns, health-seeking behavior, and local clinical practice. As the National Pediatric Hospital is a tertiary referral center, older children with more complicated or persistent infections may be more likely to undergo urine culture testing.

Females were more frequently affected than males, with a male-to-female ratio of 1:1.8. This finding is consistent with the female predominance classically reported in pediatric UTI, especially beyond infancy, and is comparable to the results of Moore CE et al. (2016) and Velez Echeverri et al. (2014), who found male-to-female ratios of 1:1.9 and 1:2, respectively. In contrast, some studies reported a male predominance, particularly in younger age groups (Mohd Nor et al., 2015; Mirsoleymani et al., 2016). The sex distribution observed in our study may therefore be partly explained by the relatively older age of the study population.

4.2. Clinical characteristics

Fever was the most common presenting complaint, occurring in 81.4% of patients. This is consistent with previous studies reporting fever in 79.9%, 48.0%, and 50.0% of pediatric UTI cases, respectively (Vélez Echeverri et al., 2014; Mohd Nor et al., 2015; Sharef et al., 2015). Clinical presentations were otherwise heterogeneous, reflecting the well-known nonspecific nature of UTI in children. This supports the importance of microbiological confirmation, especially in younger children and in those presenting with atypical symptoms.

The mean duration of hospitalization was 10.3 days, suggesting that many patients required prolonged inpatient management. Although the present study was not designed to identify the causes of longer admission, this finding may reflect disease severity, associated comorbidities, complicated UTI, underlying urinary tract abnormalities, or treatment modification after microbiological results became available.

4.3. Microbiological profile and antimicrobial susceptibility patterns

Gram-negative organisms predominated in our study, with *Escherichia coli* as the leading pathogen and *Klebsiella* spp. As the second most common bacterial isolate. This pattern is consistent with the established

epidemiology of pediatric UTI (Robinson et al., 2014; Moore et al., 2016; Vélez Echeverri et al., 2014; Han et al., 2015; Mohd Nor et al., 2015).

The low bacterial culture positivity rate should be interpreted cautiously. This may reflect urine culture testing in children with nonspecific symptoms or low pre-test probability of UTI, prior antibiotic exposure before specimen collection, specimen collection or transport issues, and strict laboratory reporting criteria. Because the denominator included all children who underwent urine culture testing rather than only those meeting a standardized prospective UTI case definition, the positivity rate should not be interpreted as the prevalence of pediatric UTI, but rather as the proportion of positive bacterial urine cultures among children tested in this hospital setting.

E. coli isolates showed high resistance to several commonly used antibiotics, including ampicillin, trimethoprim-sulfamethoxazole, ceftriaxone, ceftazidime, ciprofloxacin, amoxicillin/clavulanic acid, and gentamicin. In contrast, nitrofurantoin, amikacin, and carbapenems retained relatively good activity. High resistance to third-generation cephalosporins may suggest possible extended-spectrum beta-lactamase (ESBL)-producing isolates; however, ESBL confirmatory testing was not available in this retrospective dataset. Although carbapenem resistance was less frequent, resistance to imipenem and meropenem was still observed, which is concerning because carbapenems are usually reserved for severe or multidrug-resistant Gram-negative infections. Future studies should include confirmatory testing for ESBL, carbapenem resistance, and other resistance mechanisms.

The varying denominators across antibiotics reflect routine clinical laboratory testing rather than a standardized prospective research panel. Antibiotic panels may differ according to organism type, laboratory workflow, antimicrobial availability, and reporting practice. Therefore, resistance estimates for antibiotics tested in fewer isolates, such as nitrofurantoin, should be interpreted cautiously. No imputation was performed for missing antimicrobial susceptibility results.

Although based on only seven isolates, *Klebsiella* spp. Also showed high resistance to several commonly used antibiotics, including ampicillin, trimethoprim-sulfamethoxazole, amoxicillin/clavulanic acid, ceftriaxone, and gentamicin. Resistance remained lower to amikacin, meropenem, imipenem, and nitrofurantoin, although these estimates should be interpreted cautiously because of the small number of isolates.

Other organisms, including *Acinetobacter* spp., *Proteus mirabilis*, and *Enterococcus* spp., were identified infrequently, limiting meaningful comparison of their antimicrobial susceptibility patterns. The two *Acinetobacter* spp. Isolates showed resistance to multiple antibiotics, suggesting possible multidrug resistance. Because these organisms were uncommon and the study could not distinguish community-acquired from hospital-acquired UTI, these findings should be interpreted with caution.

Overall, these findings highlight the importance of ongoing local microbiological surveillance and antimicrobial susceptibility testing to guide empirical treatment and support antimicrobial stewardship in pediatric UTI.

4.3. Relationship between susceptibility findings and antibiotic use

A clinically important finding was the mismatch between commonly used empirical antibiotics and the observed resistance profile of *E. coli*. Ceftriaxone was administered in 72.9% of cases, despite ceftriaxone resistance in 75.0% of *E. coli* isolates. Gentamicin and ciprofloxacin were also frequently used, despite resistance rates of 53.2% and 67.4%, respectively. This mismatch likely reflects empirical prescribing before urine culture and antimicrobial susceptibility results were available. These findings

highlight the need for timely review of culture results, adjustment of therapy according to susceptibility findings, and periodic revision of local empirical antibiotic protocols.

4.4. Blood culture findings

Blood cultures were performed in 66.1% of patients, of whom 6 had positive results. *Escherichia coli* was the most frequently identified bloodstream isolate. Although the number of positive blood cultures was small, these findings suggest that bacteremia occurred in a minority of patients.

Some isolates, particularly *Bacillus* spp. In blood culture and non-fermenting Gram-negative organisms such as *Acinetobacter* spp. And *Burkholderia cepacia*, may represent contamination, colonization, healthcare-associated infection, or true infection, depending on specimen quality and clinical context. Because retrospective data were insufficient for standardized adjudication, these organisms were interpreted descriptively and cautiously.

4.5. Strengths and limitations

This study provides local baseline data on pediatric uropathogens and antimicrobial susceptibility patterns from a Cambodian tertiary pediatric hospital, where such evidence remains limited. These findings may help guide empirical antibiotic review and support antimicrobial stewardship.

Limitations include the retrospective single-center design, small sample size, incomplete susceptibility testing with varying denominators, and inability to distinguish community-acquired from hospital-acquired UTI. Clinical response, antibiotic modification after susceptibility results, prior antibiotic exposure, and treatment details were not assessed. Fungal isolates were excluded; therefore, candiduria could not be evaluated. These findings may not be generalizable to community-based populations or other Cambodian healthcare settings.

5. Conclusion

Among children with positive bacterial urine cultures at a Cambodian tertiary pediatric hospital, Gram-negative organisms predominated, mainly *Escherichia coli* followed by *Klebsiella* spp. *E. coli* showed high resistance to commonly used antibiotics, including ampicillin, trimethoprim-sulfamethoxazole, ceftriaxone, ceftazidime, ciprofloxacin, amoxicillin/clavulanic acid, and gentamicin, while resistance was lower to nitrofurantoin, amikacin, and carbapenems. Although limited by few isolates, *Klebsiella* spp. also showed high resistance to several commonly used antibiotics. Frequent ceftriaxone use despite high *E. coli* resistance highlights the need for culture-guided treatment adjustment, antimicrobial stewardship, continued local surveillance, and periodic review of empirical treatment recommendations.

Learning points:

- *Escherichia coli* and *Klebsiella* spp. were the predominant bacterial uropathogens among children with positive urine cultures in this setting.
- High resistance to third-generation cephalosporins may suggest possible ESBL-producing isolates, but confirmatory testing was not available in this retrospective dataset.
- Frequent ceftriaxone use despite high *E. coli* resistance highlights the need for timely review of urine culture results and adjustment of therapy according to susceptibility findings.
- Nitrofurantoin may remain useful for uncomplicated lower UTI when clinically appropriate, but it should not be used for suspected pyelonephritis or systemic infection.

- Continued local surveillance is needed to guide empirical treatment protocols and support antimicrobial stewardship.

Author contributions

All authors contributed to data analysis, drafting, and revising of the paper and agreed to be responsible for all the aspects of this work.

Data availability

Data are available upon reasonable request.

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Conflicts of interest

The authors declare no competing interests.

Ethical statement

The requirement for informed consent was waived because of the retrospective nature of the study and use of anonymized data. Ethical approval was obtained from the National Ethics Committee for Health Research, Phnom Penh, Cambodia (approval no. 156 NECHR, March 2026).

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