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Bacteriological Profile and Antibiotic Sensitivity Patterns in Children with Urinary Tract Infection: A Cross-Sectional Study in the Northern Part of Bangladesh

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Methods: A single-center, cross-sectional study was conducted from February 2021 to January 2022 at the tertiary care hospital in Rangpur, Bangladesh's northernmost division. A total of 200 children aged 0 months to 12 years with clinically suspected UTIs were enrolled in the study. Researchers reviewed the study participants' medical records and sent the urine sample for routine and microscopic examination and culture sensitivity testing.

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Antibiotic Sensitivity in Children with UTIs

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Results: Out of 200 children,94 (47%) were identified as having presumptive UTIs due to significant pyuria, and 58 (29%) were diagnosed with confirmed UTIs. *Escherichia coli* was the most isolated (62%) pathogen. Among gram-negative bacteria, *Klebsiella species* (15.5%) were the second most common, and *Enterococcus faecalis species* (8.62%) were the most common among gram-positive bacteria. Nitrofurantoin (97%) was highly sensitive, followed by ciprofloxacin (93%). On the other hand, cefixime (97%), cotrimoxazole (81%), amoxicillin (72%), aztreonam (72%), and ceftriaxone (67%) were highly resistant to uropathogens.

Conclusions: In Bangladesh's northernmost regions, previously used amoxicillin and cephalosporin groups of drugs are no longer helpful in treating UTIs among children, as this study suggested nitrofurantoin and ciprofloxacin as the most appropriate antibiotics.

Keywords: urinary tract infection. children. bacteriological profile. antibiotic sensitivity.

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List of abbreviations

CFU: Colony forming units
CMH: Combined Military Hospital
CRF: Chronic renal failure
E. coli: Escherichia coli
ESRD: End-stage renal disease
HPF- High Power Field
UTI: urinary tract infection

Significance

What is already known on this subject?

- Traditionally, UTIs have been treated empirically with either injectable or oral antibiotics, such as the cephalosporin group of drugs, levofloxacin, trimethoprim-sulfamethoxazole (cotrimoxazole), and nitrofurantoin.

What this study adds?

- In the northernmost regions of Bangladesh, the amoxicillin and cephalosporin groups of drugs are highly resistant to uropathogens.
- Nitrofurantoin and ciprofloxacin are the most appropriate antibiotics for preventing long-term complications from UTIs.

I. Introduction

Urinary tract infection (UTI) is the clinical condition when bacteria enter the urethra to infect the different parts of the urinary tract (Centers for Disease Control and Prevention, 2021). It is a significant cause of morbidity and mortality in the pediatric age group (Foxman, 2002) and an essential indicator of underlying urinary tract anomalies (Laila et al., 2012). During the first year of life, males are affected frequently (Kanellopoulos et al., 2006), although the UTI incidence substantially increases among females with age (Al-Badr & Al-Shaikh, 2013; Harrington & Hooton, 2000; Moreno, 2016). Although the outcome of UTI is usually benign, it may be associated with long-term complications (Tan & Chlebicki, 2016). Therefore, prompt diagnosis and early initiation of appropriate antibiotics are required to reduce morbidities with

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devastating consequences such as chronic renal failure (CRF) and end-stage renal disease (ESRD) (Nazme et al., 2017; Saadeh & Mattoo, 2011; Shrestha et al., 2013; Spoorenberg et al., 2013).

Urine culture and sensitivity are the gold standards for diagnosing UTIs (Schmiemann et al., 2010). Antibiotic selection should depend on the pattern of uropathogens and their antimicrobial sensitivities in the local environment. Usually, antimicrobial vulnerability testing of urine is achieved within 48-36 hours of sampling (Akoachere et al., 2012). Therefore, in most UTI cases, treatment choice is empirical and experimental, influenced by available data reflecting antibiotic sensitivity and resistance in geographical regions. On culture, a group count of $>10^5$ colony forming units (CFU)/ml organisms of a single uropathogen in the midstream urine of girls and $>10^4$ CFU/ml organisms in boys are measured as confirmatory of UTI (Nazme et al., 2017; Srivastava & Bagga, 2016). A pure growth of $>10^5$ CFU/ml is considered 95% susceptibility, and 10^4-10^5 CFU/ml is categorized as 'infection likely' from catheterized urine samples (Cheng & Wong, 2005) or growth of any number of uropathogens from urine obtained by suprapubic aspiration is considered significant bacteriuria (Christopher D Doern & Susan E Richardson, 2016).

Escherichia coli (*E. coli*) has been reported to be the most common pathogen for symptomatic UTI (90%) in children. Other common bacteria are *Proteus, Klebsiella, Pseudomonas*, and *Enterobacter* (Akram et al., 2007; Islam et al., 2010; Nazme et al., 2017; Srivastava & Bagga, 2016). Viruses and fungi may also cause UTIs among children (Clark et al., 2010). Traditionally, UTI has been treated empirically with either injectable or oral antibiotics such as the cephalosporin group of drugs, levofloxacin, trimethoprim-sulfamethoxazole (cotrimoxazole), and nitrofurantoin (Wagenlehner et al., 2008). Several studies conducted in tertiary care hospitals located in the central region of Bangladesh found that these antibiotics are no longer beneficial to treat UTIs in children due to high resistance levels against causative uropathogens (Islam et al., 2019; Nazme et al., 2017; Shams et al., 2021).

To our knowledge, no study has been conducted in the Rangpur division, the northernmost part of Bangladesh, where the total number of children under 14 was 4,220,773 (ZhujiWorld, 2023). Therefore, the study objective was to determine the spectrum of causative agents of UTIs, their antimicrobial sensitivity, and resistance patterns in pediatric patients of a tertiary care hospital located in the northernmost part of Bangladesh so that pediatricians can predict the causative organisms before providing empirical treatment, thus preventing long-term complications from UTIs.

II. Materials and Methods

a) Study design and participants

It is a single-center, cross-sectional study conducted at the Combined Military Hospital (CMH), Rangpur, a tertiary care hospital located in the Rangpur division, Bangladesh's 7th and northernmost division (Wikiwand, 2023). This observational study was conducted between February 2021 and January 2022. A total of 200 children aged 0 months to 12 years with clinically suspected UTIs either attended the pediatric outpatient department or were admitted to the indoor department during the study period and were enrolled as the study participants after the researchers received either their parents' or caregivers' verbal informed consent.

b) Clinical data collection

Researchers reviewed the study participants' medical records to collect their demographic data (age & sex) and clinical data, including common, urinary, and general complaints. Thereafter, study participants' urine samples were sent for routine and microscopic examination and culture sensitivity testing. In the case of neonates, urine analysis was performed if patients presented clinical evidence of sepsis.

Before collecting urine samples, mothers or caregivers received brief training to follow the steps related to sample collection aseptically and properly before depositing them in the laboratory on time. Older children (7-12 years) were asked to collect early morning midstream urine samples after properly cleaning their external urethra and perineum with plain water without soap. In the case of young infant patients, the best way was to obtain urine for culture aseptically by urethral percutaneous supra-pubic bladder aspiration to avoid the potential chance of contaminated urine cultures that often happens from bag specimens. However, it was not possible to perform this, as the parents did not provide consent to this procedure. Hence, under the supervision of parents, these young children were advised to clean the perineum and peri-urethral area before collecting urine samples by using sterile plastic bags or wide-opened mouth containers supplied by the laboratory.

All samples were collected within 30 minutes of voiding urine. The collected urine samples were then transported to the pathology laboratory of the same hospital and stored at 4°C after adding a few drops of acetic acid, which prevented the growth of organisms. These urine samples were analyzed by microscopic examination followed by bacteriological culture and antibiotic sensitivity testing.

c) Statistical analysis

We analyzed the data in MS Excel 2010 and SPSS version 24.0 for Windows (SPSS Inc., Chicago). We conducted descriptive analysis and summarized the categorical data in counts and percentages.

III. Results

In this study, urine samples from 200 children with suspected UTIs were sent for routine microscopic analysis followed by bacteriological culture and antibiotic sensitivity testing. Among them, only 94 children (47%) were diagnosed with presumptive UTIs due to the presence of significant pyuria [>5 WBCs/high power field (HPF)](C. D. Doern & S. E. Richardson, 2016). In this results section, we present the study findings of these 94 presumptive UTI cases when the urinalysis result was positive for pyuria; among them, 35 (37%) were indoor admitted patients, 59 (62.7%) were outdoor department patients, 36 (38.3%) were male, and 58 (61.7%) were female. Out of 94 presumptive UTI cases, urine culture was positive due to significant organism growth in 58 cases (29% of all suspected cases and 62% of presumptive UTI cases), and these were considered "confirmed UTIs".

Table 1 shows the age and sex distribution analysis of the presumptive UTI cases, where we found the highest (57%) presumptive UTI cases among the younger age group (<5 years) and the lowest (17%) cases among the older age group (>10 years); the presumptive UTI cases were also higher among female children than among male children, leading to a male: female ratio of 0.62:1. We also found a similar age distribution among the urine culture-positive and urine culture-negative cases, i.e., the younger group (<5 years) suffered the most. Regarding the sex distribution analysis, the male: female ratio was 0.87:1 among 58 patients with uropathogens in their urine cultures (culture-positive), and the male: female ratio was 0.33:1 among 36 urine culture-negative cases.

Table 1: Distribution of presumptive UTI cases by sex and age

Age group	Presumptive UTI (n = 94)		Male (n=36)		Female (n=58)	
	Number	%	Number	%	Number	%
<5 years	54	57.45%	18	19%	36	38.3%
5-10 years	24	25.55%	11	11.7%	13	13.82%
>10 years	16	17%	7	7.45%	9	9.57%
	Urine culture positive (n=58)		Male (n=27)		Female (n=31)	
	Number	%	Number	%	Number	%
<5 years	26	44.83%	13	22.41%	13	22.41%
5-10 years	20	34.48%	9	15.52%	11	18.97%
>10 years	12	20.69%	5	8.62%	7	12.06%
	Urine culture negative (n=36)		Male (n=9)		Female (n=27)	
	Number	%	Number	%	Number	%
<5 years	28	77.78%	5	13.88%	23	63.88%
5-10 years	4	11.11%	2	5.56%	2	5.56%
>10 years	4	11.11%	2	5.56%	2	5.56%

Table 2 presents the prevalence of gram-negative and gram-positive pathogens that were isolated during urine cultures. *Escherichia coli (E. coli)* was the most isolated (62%) pathogen. Among gram-negative bacteria, *E. coli* was followed by *Klebsiella species* (15.5%), *Pseudomonas aeruginosa* (5.17%), and *Enterobacter species* (3.45%). Among gram-positive bacteria, *Enterococcus faecalis species* (8.62%) were the most common, followed by *Acinetobacter* (1.72%) and *Staphylococcus species* (1.72%).

Table 2: Prevalence of pathogens isolated on urine culture (n=58*)*

Name of Pathogens		Number (n=58)	Percentage (%)
Gram-negative	E. Coli	36	62.07%
	Klebsiella species	9	15.52%
	Pseudomonas aeruginosa	3	5.17%
	Enterobacter species	2	3.45%
	Proteus species	1	1.72%
Gram-positive	Enterococcus faecalis species	5	8.63%
	Staphylococcus species	1	1.72%
	Acinetobacter	1	1.72%

Table 3 presents the antibiotic sensitivity pattern of isolates among 58 confirmed UTI cases. We found that nitrofurantoin was highly sensitive in almost all cases (97%), followed by ciprofloxacin, which was sensitive in 93% of cases. The next most sensitive antibiotics were amikacin (88%), gentamycin (74%), and levofloxacin (66%). On the other hand, we found that uropathogens were highly resistant to cefixime (97%), cotrimoxazole (81%), amoxicillin (72%), aztreonam (72%), and ceftriaxone (67%).

Table 3: Antibiotic sensitivity pattern of isolates (n=58)

	Name of antibiotics	Sensitivity		Intermediate sensitivity		Resistant		Not done
		n	%	n	%	n	%	n
1	Amikacin	51	88	1	1.72	6	10.34	0
2	Amoxycillin	3	5.17	0	0	42	72.4	13
3	Azithromycin	17	29.3	1	1.72	35	62.0	5
4	Aztreonam	8	13.8	2	3.44	42	72.4	6
5	Ciprofloxacin	54	93	2	3.44	2	3.44	0
6	Cotrimoxazole	9	15.52	1	1.72	47	81.03	1
7	Cloxacin	7	12	0	0	2	3.44	49
8	Ceftriaxone	16	27.6	3	5.17	39	67.24	0
9	Cefixime	0	0	0	0	56	96.6	2
10	Cefuroxime	0	0	2	3.44	53	1.37	3
11	Cephalexin	26	44.83	0	0	12	20.7	20
12	Ceftazidime	1	1.72	0	0	10	17.24	47
13	Colistin	7	12	2	3.44	15	25.86	34
14	Erythromycin	16	27.6	1	1.72	4	6.89	37
15	Gentamicin	43	74	2	3.44	13	22.4	0
16	Imipenem	17	29.3	2	3.44	18	31.03	21
17	Levofloxacin	38	65.6	1	1.72	16	27.6	3
18	Meropenem	33	56.9	2	3.44	17	29.3	6
19	Netilmicin	13	22.4	0	0	23	39.66	22
20	Nalidixic acid	29	50	2	3.44	21	36.20	6
21	Nitrofurantoin	56	96.56	0	0	2	3.44	0
22	Penicillin	3	5.17	1	1.72	16	27.6	38
23	Vancomycin	5	8.62	0	0	0	0	53

Table 4 presents the detailed antibiotic sensitivity pattern of isolates by different types of bacteria, where we found that *E. coli* was highly sensitive (100%) to nitrofurantoin and highly resistant (100%) to amoxicillin and cefixime. *Klebsiella species* were highly sensitive (100%) to ciprofloxacin, gentamycin, levofloxacin, and nitrofurantoin and highly resistant (100%) to azithromycin, cotrimoxazole, ceftriaxone, cefixime, and cefuroxime. *Pseudomonas* isolates were highly sensitive (100%) to ciprofloxacin and levofloxacin and highly resistant (100%) to cotrimoxazole, cephalosporin group, and nalidixic acid. *Enterobacter species* were highly sensitive (100%) to aztreonam, ciprofloxacin, cotrimoxazole, cephalexin, gentamicin, and nitrofurantoin and highly resistant (100%) to amoxicillin. *Proteus species* were highly sensitive (100%) to amikacin, azithromycin, ciprofloxacin, cotrimoxazole, ceftriaxone, levofloxacin, meropenem, nitrofurantoin, and vancomycin; they were extremely resistant (100%) to amoxycillin, aztreonam, cefixime, cephalexin, cephalexin, cephradine, ceftazidime, colistin, gentamycin, imipenem, netilmicin, nalidixic acid, and penicillin.

Table 4: Antibiotic sensitivity pattern of isolates by distinct types of bacteria (n=58)

	Gram-Positive bacteria					Gram-Negative bacteria		
Antibiotics Sensitivity	E coli	Klebsiella	Pseudomonas	Enterobacter spp.	Proteus	Enterococcus	Acinetobacter	Staphylococcus spp
	(n=36)	(n=9)	(n=3)	(n=2)	(n=1)	(n=5)	(n=1)	(n=1)
	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)
Amikacin	S: 34 (94.45%) I:0 R:2 (5.56%)	S:7 (77.78%) I:1(11.11%) R:1(11.11%)	S:2 (66.7%) I:0 R:1(33.3%)	S:1 (50%) I:0 R:1 (50%)	S:1(100%) I:0 R:0	S:4 (80%) I:0 R:1(20%)	S:1 (100%) I:0 R:0	S:1 (100%) I:0 R:0
Amoxycillin	S:0 I:0 R:36 (100%)	ND	ND	S:0 I:0 R:2 (100%)	S:0 I:0 R:1(100%)	S:3 (60%) I:0 R:2 (40%)	ND	S:0 I:0 R:1 (100%)
Azithromycin	S:12 (33.33%)	S:0 I: 0	S:2 (66.7%) I:0	S:1(50%) I:0	S:1(100%)	ND	S:1 (100%) I:0	S:0 I:1 (100%)

	I:0 R:24 (66.7%)	R:9 (100%)	R:1(33.3%)	R:1(50%)	I:0 R:0		R:0	R:0
Aztreonam	S:3 (8.3%) I:2 (5.56%) R:31(86.1%)	S:2 (22.2%) I:0 R:7 (77.8%)	S:1(33.3%) I:0 R:2 (66.7%)	S:2 (100%) I:0 R:0	S:0 I:0 R:1(100%)	ND	S:0 I:0 R:1 (100%)	ND
Ciprofloxacin	S:33(91.7%) I:1 (2.78%) R:2(5.56%)	S:9 (100%) I:0 R:0	S:3 (100%) I:0 R:2 (66.7%)	S:2 (100%) I:0 R:0	S:1(100%) I:0 R:0	S:4 (80%) I:1 (20%) R:0	S:1 (100%) I:0 R:0	S:1 (100%) I:0 R:0
Cotrimoxazole	S:1(2.78%) I:1(2.78%) R:34 (94.44%)	S:0 I:0 R:9 (100%)	S:0 I:0 R:3 (100%)	S:2 (100%) I:0 R:0	S:1(100%) I:0 R:0	S:4 (80%) I:0 R:1 (20%)	ND	S:1 (100%) I:0 R:0
Cloxacin	S:4 (11.11%) ND 32	ND	ND	ND	ND	S:3 (60%) I:0 R:2 (40%)	ND	ND
Ceftriaxone	S:12 (33.33%) I:2(5.56%) R:22 (61.11%)	S:0 I:0 R:9 (100%)	S:0 I:0 R:3 (100%)	S:1(50%) I:0 R:1 (50%)	S:1(100%) I:0 R:0	S:1 (20%) I:0 R:4 (80%)	S:1 (100%) I:0 R:0	S:0 I:1 (100%) R:0
Cefixime	S:0 I:0 R:36 (100%)	S:0 I:0 R:9 (100%)	S:0 I:0 R:3 (100%)	ND	S:0 I:0 R:1 (100%)	S:0 I:0 R:5 (100%)	S:0 I:0 R:1 (100%)	S:0 I:0 R:1 (100%)
Cefuroxime	S:0 I:2 (5.56%) R:34 (94.44%)	S:0 I:0 R:9 (100%)	S:0 I:0 R:3 (100%)	ND	ND	S:0 I:0 R:5 (100%)	S:0 I:0 R:1 (100%)	S:0 I:0 R:1 (100%)
Cephalexin	S:22 (61.11%) I:0 R:4 (11.11%) ND 10	ND	S:0 I:0 R:3 (100%)	S:2(100%) I:0 R:0	S:0 I:0 R:1(100%)	S:2 (40%) I:0 R:2 (40%) ND 1	S:0 I:0 R:1(100%)	S:0 I: 0 R:1 (100%)
Cephradine	ND	ND	S:0 I:0 R:3 (100%)	S:0 I:0 R:1(50%) ND:1	S:0 I:0 R:1(100%)	ND	S:1 (100%) I:0 R:0	S:1 (100%) I:0 R:0
Ceftazidime	ND	ND	S:0 I:0 R:3 (100%)	ND	S:0 I:0 R:1(100%)	S:0 I:0 R:5 (100%)	S:1 (100%) I:0 R:0	S:0 I:0 R:1(100%)
Colistin	S:3 (8.33%) I:0 R:10 (27.78%) ND 23	ND	S:1 (33.3%) I:0 R:2 (66.7%)	ND	S:0 I:0 R:1(100%)	S:1 (20%) I:2 (40%) R:2 (40%)	S:1 (100%) I:0 R:0	S:1 (100%) I:0 R:0
Erythromycin	S:12 (33.33%) I:0 R:0 ND: 20	ND	ND	S:1 (50%) I:0 R:1 (50%)	ND	S:2 (40%) I:1 (20%) R:2 (40%)	ND	S:1 (100%) I:0 R:0
Gentamicin	S:24 (66.67%) I:2 (5.56%) R:12 (33.33%)	S:9 (100%) I:0 R:0	S:2 (66.7%) I:0 R:1 (33.3%)	S:2 (100%) I:0 R:0	S:0 I:0 R:1(100%)	S:4 (80%) I:0 R:1 (20%)	S:1 (100%) I:0 R:0	S:1 (100%) I:0 R:0
Imipenem	S:10 (27.78%) I:0 R:5 (13.89%) ND 21	S:1 (11.11%) I:0 R:8 (88.89%)	S:1(33.3%) I:0 R:2 (66.7%)	ND	S:0 I:0 R:1(100%)	S:3 (60%) I:0 R:2 (40%)	S:1 (100%) I:0 R:0	S:1 (100%) I:0 R:0
Levofloxacin	S:20 (55.56%) I:1(2.78%) R:15 (41.67%)	S:9 (100%) I:0 R:0	S:3 (100%) I:0 R:0	ND	S:1(100%) I:0 R:0	S:3 (60%) I:0 R:1 (20%) ND 1	S:1 (100%) I:0 R:0	S:1 (100%) I:0 R:0

Meropenem	S:20 (55.56%) I:2 (5.56%) R:14	S:5 (55.6%) I: 0 R:0 ND:4	S:2 (66.7%) I:0 R:1(33.3%)	ND	S:1(100%) I:0 R:0	S:4 (80%) I:0 R:1(20%)	S:0 I:0 R:1(100%)	S:1 (100%) I:0 R:0
Netilmicin	S:6 (16.7%) I:0 R:13 (36.11%) ND17	S:1(11.11%) I:0 R:5 (55.6%) ND:3	S:1 (33.3%) I:0 R:2 (66.7%)	ND	S:0 I:0 R:1 (100%)	S:3 (60%) I:0 R:2 (40%)	S:1 (100%) I:0 R:0	S:1 (100%) I:0 R:0
Nalidixic acid	S:22 (61.1%) I:2 (5.56%) R:12 (33.33%)	S:5 (55.6%) I:0 R:4 (44.4%)	S:0 I:0 R:3 (100%)	S:1 (50%) I:0 R:1 (50%)	S:0 I:0 R:1(100%)	ND	ND	S:1 (100%) I:0 R:0
Nitrofurantoin	S:36 (100%) I:0 R:0	S:9 (100%) I:0 R:0	S:1 (33.3%) I:0 R:2 (66.7%)	S:2 (100%) I:0 R:0	S:1(100%) I:0 R:0	S: 5 (100%) I:0 R:0	S: 1(100%) I:0 R:0	S:1 (100%) I:0 R:0
Penicillin	S: 0 I:2 (5.56%) R:14 (38.9%) ND:20	ND	ND	S:0 I:1(50%) R:1(50%)	S:0 I:0 R:1(100%)	S:3 (60%) I:1 (20%) R:1(20%)	ND	S:1 (100%) I:0 R:0
Vancomycin	ND	ND	ND	ND	S:1(100%) I:0 R:0	S:4 (80%) I:0 R:1(20%)	S:1 (100%) I:0 R:0	S:1 (100%) I:0 R:0

NB Name of antibiotics is listed alphabetically.
Here, S= sensitive, I= Intermediately sensitive, R=Resistance, 0 = no result
ND = not done

Regarding gram-positive bacteria, *Enterococcus faecalis species* were found to be extremely sensitive (100%) to nitrofurantoin and enormously resistant (100%) to cefixime, cefuroxime, and ceftazidime. The *Acinetobacter* isolate was found to be extremely sensitive (100%) to amikacin, azithromycin, ciprofloxacin, ceftriaxone, cephradine, ceftazidime, colistin, gentamicin, imipenem, levofloxacin, netilmicin, nitrofurantoin, and vancomycin; it was highly resistant (100%) to aztreonam, cefixime, cefuroxime, cephalexin, and meropenem. Staphylococcus species were extremely sensitive (100%) to amikacin, ciprofloxacin, cotrimoxazole, cephradine, colistin, erythromycin, gentamicin, imipenem, levofloxacin, meropenem, netilmicin, nalidixic acid, nitrofurantoin, penicillin, and vancomycin; they were enormously resistant (100%) to amoxycillin, cefixime, cefuroxime, cephalexin, and ceftazidime.

Out of 23 antibiotics, we found that the most effective antibiotics were nitrofurantoin, which was highly sensitive (100%) to seven out of eight bacteria (E. coli, Klebsiella, Enterobacter species, Proteus, Enterococcus, Acinetobacter, and Staphylococcus species), followed by ciprofloxacin, which was highly sensitive (100%) to six out of eight bacteria (*Klebsiella, Pseudomonas, Enterobacter species, Proteus, Acinetobacter, and Staphylococcus species*). Levofloxacin was highly sensitive (100%) to five out of eight bacteria (*Klebsiella, Pseudomonas, Proteus, Acinetobacter, and Staphylococcus species*), and gentamicin was highly sensitive (100%) to four out of eight bacteria (*Klebsiella, Enterobacter species, Acinetobacter, and Staphylococcus species*). However, gentamicin is highly resistant (100%) to *Proteus*.

Three antibiotics were highly sensitive (100%) to three bacteria: vancomycin (sensitive to *Proteus, Acinetobacter, and Staphylococcus species*), cotrimoxazole (sensitive to *Enterobacter species, Proteus, and Staphylococcus species*), and amikacin (sensitive to *Proteus, Acinetobacter, and Staphylococcus species*). However, Klebsiella and Pseudomonas were highly resistant (100%) to *cotrimoxazole*.

On the other hand, we found that the most resistant antibiotics were cefixime (highly resistant [100%] against seven bacteria: *E. coli, Klebsiella, Pseudomonas, Proteus, Enterococcus, Acinetobacter, and Staphylococcus species*); however, we did not conduct an antibiotic sensitivity test on *Enterobacter species* or cefuroxime (highly resistant [100%] against five bacteria: *Klebsiella, Pseudomonas, Enterococcus, Acinetobacter, and Staphylococcusspecies*), although we did not conduct an antibiotic sensitivity test on *Enterobacter species and Proteus*.

We also found that amoxycillin was highly resistant (100%) against four bacteria, *E. coli, Enterobacter species, Proteus, and Staphylococcus species*, although we did not conduct an antibiotic sensitivity test on *Klebsiella, Pseudomonas, and Acinetobacter*, and cephalexin was highly resistant (100%) against four bacteria, *Pseudomonas, Proteus, Acinetobacter, and Staphylococcus species*, although we did not conduct an antibiotic sensitivity test on

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Klebsiella. Cephalexin is highly (100%) sensitive only to *Enterobacter species.*

We found that ceftazidime was highly resistant (100%) against four bacteria, *Pseudomonas, Proteus, Enterococcus, and Staphylococcus species,* and highly (100%) sensitive to *Acinetobacter*, although we did not conduct an antibiotic sensitivity test on *E. coli, Klebsiella and Enterobacter species.*

IV. Discussion

Our study presents the bacteriological profile and antibiotic sensitivity patterns of urinary tract infections in children aged 12 years and below living in the northernmost part of Bangladesh. This study found that almost half (47%) of the suspected UTI study respondents (n=200) had significant pyuria. This study finding is lower than that of the studies that were conducted in other tertiary hospitals in Bangladesh, such as 92% in Mymensingh Medical College under the Dhaka division (Islam et al., 2010), 79% in Dhaka Shishu Hospital, Dhaka (Islam et al., 2019), and 67% in Combined Military Hospital, Dhaka (Nazme et al., 2017). This difference is because most patients prefer to visit tertiary hospitals located in the Dhaka division due to the high quality of services and the presence of skilled and efficient healthcare professionals. The prevalence of pyuria among children is also higher in other Asian countries, such as Nepal (95.6%) (Singh & Madhup, 2013).

These urine samples were further processed for urine culture, where we found that 58 samples had confirmed UTIs, i.e., 29% of suspected cases and 62% of presumptive UTI cases, due to positive urine culture. This study finding varies in other studies conducted in Bangladesh and Nepal; this may be attributed to the sample size and age of study respondents. Positive urine culture varies from 32% of suspected cases with children under 15 years (Nazme et al., 2017) to 84% of suspected cases with children under 18 years (Paul et al., 2019). Both studies were conducted in two different tertiary care hospitals located in Dhaka. A similar variation was also found in Nepal, ranging from 29% to 45% (Rai et al., 2008; Singh & Madhup, 2013).

The prevalence of UTIs varies with the age and sex of children. Almost half (45%) of the culture-positive cases were found in the age group below five years. This finding could be because younger children are not toilet trained, and ascending infection with fecal flora is more common in this age group. Similar findings are also reflected in other studies conducted in tertiary hospitals (Bay & Anacleto, 2010; Nazme et al., 2017; Singh & Madhup, 2013). Regarding gender differences, several studies reported a predominance of female children over males (Akram et al., 2007; Bay & Anacleto, 2010; Gautam & Pokhrel, 2012; Shrestha et al., 2013). We also found that UTIs were 1.6 times more frequent in females. The reasons behind this might be that a female child has a short urethra, is easily contaminated with fecal matter, and is not properly cleaned up after passing urine. These results are consistent with the study findings of Islam et al. (Islam et al., 2019) and Nazme et al. (Nazme et al., 2017). However, two studies conducted in India found males to be prevalent (Rai et al., 2008; Rekha et al., 2010); this may be due to an increase in seeking treatment for male children.

In this study, *E. coli* was the most isolated (62%) uropathogen. In different studies, the percentage of *E. coli* varies from 30% to 90% (Bay & Anacleto, 2010; Islam et al., 2010; Patel & Garala, 2014; Shrestha et al., 2013). The following common organisms in our study were *Klebsiella* (15.5%), *Enterococcus* (8.6%), and *Pseudomonas* (5.2%). Nazme et al. also found *Enterococcus* and *Klebsiella*to be the most common uropathogens after *E. coli* (Nazme et al., 2017). Islam et al. found that *Klebsiella, Pseudomonas, Enterococcus, Staphylococcus aureus*, and *Proteus species* were the most common uropathogens after *E. coli* (Islam et al., 2019).

This study found that *E. coli* was highly sensitive (100%) to nitrofurantoin and highly resistant (100%) to amoxicillin and cefixime; in contrast, Shrestha et al. (Shrestha et al., 2013) and Nazme et al. (Nazme et al., 2017) found that *E. coli* was most sensitive not only to nitrofurantoin but also to ciprofloxacin, levofloxacin, and amikacin. Das et al. reported that the sensitivity of E. coli to meropenem, amikacin, colistin, azithromycin, levofloxacin, cotrimoxazole, and ampicillin was high (Das et al., 2017). The next most common uropathogen was Klebsiella. This study found that *Klebsiella species* were highly sensitive (100%) to ciprofloxacin, gentamycin, levofloxacin, and nitrofurantoin and highly resistant (100%) to azithromycin, cotrimoxazole, ceftriaxone, cefixime, and cefuroxime. An Indian study reported that Klebsiella was the most sensitive to Ofloxacin, Amikacin, and Piperacillin+Tazobactum (Patel & Garala, 2014).

We found that *Pseudomonas* isolates were highly sensitive (100%) to ciprofloxacin and levofloxacin and highly resistant (100%) to cotrimoxazole, cephalosporin, and nalidixic acid. The findings of Nazme et al. (Nazme et al., 2017) are similar to those of this study, except that they found that Pseudomonas is also highly sensitive to *amikacin*. *Enterobacter species* were highly sensitive (100%) to aztreonam, ciprofloxacin, cotrimoxazole, cephalexin, gentamicin, and nitrofurantoin and highly resistant (100%) to amoxicillin. Villegas et al. also found similar results with Enterobacter (Villegas & Quinn, 2002).

In this study, *Proteus species* were highly sensitive (100%) to amikacin, azithromycin, ciprofloxacin, cotrimoxazole, ceftriaxone, levofloxacin, meropenem, nitrofurantoin, and vancomycin; they were extremely resistant (100%) to amoxycillin, aztreonam,

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cefixime, cephalexin, cephalexin, cephradine, ceftazidime, colistin, gentamycin, imipenem, netilmicin, nalidixic acid, and penicillin. A similar finding was found by Nazme et al. (Nazme et al., 2017).

Regarding gram-positive bacteria, *Enterococcus faecalis* species were found to be extremely sensitive (100%) to nitrofurantoin and enormously resistant (100%) to cefixime, cefuroxime, and ceftazidime. Nazme et al. (Nazme et al., 2017), Kauer et al. (Kaur et al., 2014), and Rossi et al. (Rossi et al., 2006) also found similar results. Our study found that the *Acinetobacter* isolate was extremely sensitive (100%) to amikacin, azithromycin, ciprofloxacin, ceftriaxone, cephradine, ceftazidime, colistin, gentamicin, imipenem, levofloxacin, netilmicin, nitrofurantoin, and vancomycin; it was highly resistant (100%) to aztreonam, cefixime, cefuroxime, cephalexin, and meropenem. This study's findings are similar to those of Nazme et al. (Nazme et al., 2017) and Urmi et al. (Urmi et al., 2019). *Staphylococcus species* were extremely sensitive (100%) to amikacin, ciprofloxacin, cotrimoxazole, cephradine, colistin, erythromycin, gentamicin, imipenem, levofloxacin, meropenem, netilmicin, nalidixic acid, nitrofurantoin, penicillin, and vancomycin; they were enormously resistant (100%) to amoxycillin, cefixime, cefuroxime, cephalexin, and ceftazidime. Shrestha et al. (Shrestha et al., 2013), Sorlozano et al.(Sorlózano-Puerto et al., 2017), and Baral et al. (Baral et al., 2012) also found similar study findings.

Nitrofurantoin is also recommended as the first choice among oral antibiotics for prophylaxis and treatment of UTIs in children due to its higher sensitivity (Laila et al., 2012; Randrianirina et al., 2007; Sanchez et al., 2014; Shrestha et al., 2013), and ciprofloxacin is a widely used fluoroquinolone with high bacterial activity against uropathogens irrespective of gram-negative or gram-positive group and well-established clinical efficacy in the treatment of UTIs (Belete et al., 2019; Blondeau, 2004). Our study also found that the most effective antibiotics are nitrofurantoin, which is highly sensitive (100%) to seven out of eight bacteria except for *Pseudomonas*, followed by ciprofloxacin, which is highly sensitive (100%) to six out of eight bacteria except for *E. coli and Enterococcus.*

Compared to another study conducted in Bangladesh (Nazme et al., 2017), this study found that levofloxacin was highly sensitive (100%) to five out of eight bacteria except for *E. coli and Enterococcus;* however, the sensitivity test was not performed on *Enterobacter.* Gentamicin was highly sensitive (100%) to four out of eight bacteria except for *E. coli, Pseudomonas, Enterococcus, and Proteus*, and a similar study finding was noticed in Yuksel et al.(Yüksel et al., 2006).

On the other hand, we found that the most resistant antibiotics were cefixime (highly resistant [100%] against seven bacteria: *E. coli, Klebsiella, Pseudomonas, Proteus, Enterococcus, Acinetobacter, and Staphylococcus species)*; however, we did not conduct an antibiotic sensitivity test on *Enterobacter species* or cefuroxime (highly resistant [100%] against five bacteria: *Klebsiella, Pseudomonas, Enterococcus, Acinetobacter, and Staphylococcus species*), although we did not conduct an antibiotic sensitivity test on *Enterobacter species and Proteus*. This high resistance profile was also confirmed by other studies (Ibeneme et al., 2014; Patel & Garala, 2014; Shrestha et al., 2013).

V. Conclusion

Our study concluded that pediatricians working in Bangladesh's northernmost regions should be cautious when treating and managing UTIs among children. Instead of prescribing amoxicillin and cephalosporin groups of drugs that are highly resistant to uropathogens, they should prescribe nitrofurantoin and ciprofloxacin as the most appropriate antibiotics for preventing long-term complications from UTIs.

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Data availability: All the data that were collected during this study are presented in the paper.

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