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Original Research Article

Distribution and antimicrobial susceptibility of pathogenic micro-organisms in pediatric urinary tract infections

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Abstract

Purpose: *To investigate the prevalence and distribution of pathogenic microorganisms and antimicrobial susceptibility in pediatric urinary tract infections (UTIs).*
Methods: *150 pediatric patients with UTI diagnosed and treated in Danyang People's Hospital of Jiangsu Province, China between January 2020 and December 2022 were enrolled. The distribution of pathogenic microorganisms was analyzed using microbial culture and antimicrobial susceptibility test results obtained for major gram-negative bacteria (Escherichia coli, Pseudomonas aeruginosa, and Klebsiella pneumonia). Based on adherence to antimicrobial susceptibility data, patients were divided into study (adhered to antimicrobial susceptibility) and control groups (did not adhere to antimicrobial susceptibility). The efficacy of treatments was compared.*
Results: *A total of 184 strains of pathogenic microorganisms were cultured from the urine of the 150 patients. Gram-negative bacteria accounted for 75.54 %, while gram-positive bacteria accounted for 24.46 %. Frequently encountered strains were Escherichia coli, Pseudomonas aeruginosa, and Enterococcus faecalis. Major gram-negative bacteria such as Escherichia coli and Pseudomonas aeruginosa showed higher sensitivity to cefotaxime, imipenem, furantoin, cefepime-tazobactam and amikacin, while major Gram-positive bacteria like Enterococcus faecalis showed higher sensitivity to vancomycin, imipenem and ampicillin-sulbactam. Clinical efficacy in the study group was significantly higher ($p < 0.05$) compared to the control group.*
Conclusion: *The distribution of pathogenic microorganisms in pediatric UTIs is diverse, with Gram-negative bacteria being the most common pathogens. Further studies should expand the sample size and broaden the scope of study subjects to comprehensively investigate the distribution of pathogenic microorganisms in pediatric urinary tract infections.*

Keywords: *Pediatric urinary tract infection, Pathogenic microorganisms, Antimicrobial susceptibility testing, Antimicrobial treatment*

INTRODUCTION

Pediatric urinary tract infection (UTI) is a common condition caused by bacterial infection in various parts of the urinary tract, including the bladder, urethra, and kidneys [1]. As a result of immature urinary tract anatomy, immune systems, and factors such as diaper usage, pediatric UTIs exhibit a relatively high incidence rate in clinical practice [2,3]. If left untreated, UTIs in children have serious consequences. The infection may spread to the kidneys, leading to conditions like pyelonephritis or kidney abscess, which present with severe symptoms such as high fever and abdominal pain. Untreated UTIs may also become chronic, causing recurrent symptoms like frequent urination and abdominal discomfort, affecting the daily activities of children. Additionally, long-term complications such as kidney damage, hypertension, and nephrotic syndrome may arise from untreated pediatric UTIs. Therefore, early identification of the causative microorganisms responsible for the infection, coupled with antimicrobial susceptibility testing, is of paramount importance in selecting appropriate infection treatment strategies.

In the management of pediatric UTIs, rational antibiotic use stands as a pivotal treatment strategy. However, rampant misuse and irrational utilization of antibiotics have contributed to the emergence of antibiotic resistance, posing challenges to the treatment of pediatric UTIs [4]. To effectively combat urinary tract infections and minimize the risk of antibiotic misuse, antimicrobial susceptibility testing has become an indispensable aspect of the treatment process.

Antimicrobial susceptibility testing involves testing the sensitivity of microorganisms to various antibiotics, which subsequently guides physicians in selecting the most appropriate antibiotics for treatment. This testing provides clinicians with scientifically accurate insights, allowing for personalized and targeted treatment plans that enhance treatment success rates, and decrease the likelihood of treatment failure. Furthermore, antimicrobial susceptibility testing assists in preventing infection relapse and reducing the occurrence of adverse antibiotic reactions, ultimately improving the quality of life for pediatric patients [5]. Nevertheless, it is important to note that antimicrobial susceptibility testing is not the sole determinant of treatment. A comprehensive treatment plan should also consider factors such as patient's age, severity of the condition, renal function, allergies and intolerances, and previous treatment history. This study therefore investigates the distribution of pathogenic microorganisms causing pediatric UTIs, and the effect of antimicrobial susceptibility testing on treatment efficacy in order to provide clinicians with more scientifically effective treatment strategies, thereby improving the health and recovery of pediatric patients.

METHODS

General information

This study enrolled a total of 150 pediatric patients with UTI between January 2020 and December 2022. All clinical pieces of information were documented. This study was approved by the Ethics Committee of Danyang People's Hospital of Jiangsu Province (approval no. 003902) and conducted in adherence to the principles outlined in the Declaration of Helsinki [6].

The distribution of pathogenic microorganisms was analyzed through microbial culture, and subsequent antimicrobial susceptibility testing was performed. By employing a random allocation method, the patients were divided into two groups: study group, comprising individuals who adhered to recommended antimicrobial susceptibility guidelines, and control group, consisting of non-adherent participants. Thorough explanations of the study protocols were provided to all patients and their legal guardians, who voluntarily provided informed consent by signing the appropriate consent forms.

Inclusion criteria

Pediatric patients diagnosed and treated for UTIs at the hospital, between 2 - 120 months old irrespective of gender, and with complete clinical data.

Exclusion criteria

Family history of mental illness, malignant tumors, organ dysfunction, or failure.

Treatments

Upon admission, patients received routine treatment. During antimicrobial therapy, participants were categorized into three groups based on the concordance between microbial examination reports and antimicrobial susceptibility data. The first group comprised participants who received antimicrobial agents matching both microbial examination reports and susceptibility data. The second group received antimicrobial agents differing from microbial examination reports and susceptibility data, with treatment adjusted according to the microbial report data while the third group received antimicrobial agents that did not align with the susceptibility results and physicians made no adjustments during treatment, indicating non-adherence.

Based on adherence to antimicrobial susceptibility data, patients were divided into equal groups comprising 75 cases each namely; study group (adherent group) and control group (non-adherent group). Simultaneously, to ensure standardized urine extraction and urinalysis, the process adhered to the guidelines outlined in the 3rd edition of National Clinical Laboratory Testing Procedures [7]. Midstream urine was collected from pediatrics and examined. The urine specimens were cultured, and the presence of urinary tract infection was determined using urine culture positivity criteria [7]. Gram-positive bacteria ≥ 10^4 colony forming unit/mL (CFU/mL), fungi ≥ 10^3 CFU/mL Gram-negative bacteria ≥10^5 CFU/mL.

Evaluation of parameters/indices

Distribution of pathogenic microorganisms

The distribution of different pathogenic microorganisms was investigated and reported in frequency and percentages.

Antimicrobial susceptibility test

Susceptibility test for Gram-positive (*Enterococcus faecalis* and *Staphylococcus aureus*) and Gram-negative organisms (*Escherichia coli*, *Pseudomonas aeruginosa*, and *Klebsiella pneumoniae*) was determined using the Kirby-Bauer disk diffusion test. Identification of major pathogens was performed using an automated biochemical analyzer (VITEK; Biomerieux, France), while other pathogenic microorganisms such as fungi and bacteria were identified using Analytical Profile Index (API) strips. To ensure accuracy, *Enterococcus faecalis* ATCC29212, *Pseudomonas aeruginosa* ATCC27853, *Escherichia coli* ATCC25922, and *Staphylococcus aureus* ATCC25923 were selected as quality control strains for antimicrobial susceptibility, all of which were obtained from the Ministry of Health Clinical Laboratory Center.

Efficacy

The efficacy of treatment was assessed over a 72-hour evaluation period. Efficacy was classified as significant (complete normalization of vital signs and disappearance of clinical symptoms), improvement (substantial improvement in vital signs and significant alleviation of symptoms), and ineffectiveness (lack of improvement or worsening of symptoms). Study and control groups were compared based on response to treatment, and efficacy was evaluated.

Statistical analysis

For image processing, analysis was carried out using GraphPad Prism 8.0 software (San Diego, CA, USA). Data compilation and statistical analysis were conducted using MS Excel and Statistical Packages for Social Sciences (SPSS) 26.0 software. Quantitative data were presented as mean ± standard deviation (SD), and *t*-test was used to determine statistical differences. Count data were presented as percentages (%), and statistical differences were assessed using the chi-squared test (χ^2). $P < 0.05$ was considered statistically significant.

RESULTS

Clinical information

The study group consisted of 75 patients, comprising 39 males and 36 females; average age of 4.96 ± 1.23 years and an average disease duration of 18.94 ± 9.65 days. Control group consisted of 75 patients, comprising 41 males and 34 females; the average age was 5.18 ± 1.41 years and the average disease duration was 19.08 ± 8.76 days. There was no significant difference in clinical characteristics between the two groups ($p > 0.05$; Table 1).

Table 1: Characteristics of the two groups of patients (N = 75)

Property	Characteristic	Study	Control	*T*-value	*P*-value
Gender	Male	39	41		
	Female	36	34		
Age (years)	Range	0.2-10	0.2-10		
	Mean ± SD	4.96±1.23	5.18±1.41	0.689	0.477
Disease duration (days)	Range	7-365	6-361		
	Mean ± SD	18.94±9.65	19.08±8.76	0.554	0.582
Type of illness	Shivering	68	69		
	High fever	62	65		
	General discomfort	72	70		
	Lethargy	59	60		
	Vomiting and diarrhea	61	55		

Distribution of pathogenic microorganisms

A total of 184 strains of pathogenic microorganisms were isolated, with Gram-negative bacteria accounting for 75.54 %. Among them, the top three isolated strains were *Escherichia coli* (30.98 %), *Pseudomonas aeruginosa* (25.00 %), and *Klebsiella pneumoniae* (10.87 %). Gram-positive bacteria accounted for 24.46 %, and the majority of strains were *Enterococcus faecalis* (18.48 %), *Staphylococcus aureus* (3.26 %), and *Streptococcus pneumoniae* (1.63 %; Table 2).

Antimicrobial susceptibility

Gram-negative bacteria

Escherichia coli exhibited higher sensitivity to furantoin, cefotaxime, imipenem, amikacin, and ceftazidime-tazobactam. *Pseudomonas aeruginosa* displayed higher sensitivity to cefotaxime, imipenem, and ceftazidime-tazobactam (Table 3).

Gram-positive bacteria

Enterococcus faecalis showed higher sensitivity to vancomycin, imipenem, and ampicillin-sulbactam (Table 4).

Efficacy

A total of 54 patients exhibited significant improvement, 18 showed improvement, and 3 showed no improvement in study group. In control group, 35 patients exhibited significant improvement, 11 showed improvement and 29 showed no improvement. The clinical effective rate of study group (96 %) was significantly higher compared to control group (61.33 %) ($p < 0.05$) (Figure 1).

Table 2: Distribution of pathogenic microorganisms in pediatric UTIs

Bacteria	Type	Strain	Proportion (%)
Gram-negative		139	75.54
	Escherichia coli	57	30.98
	Pseudomonas aeruginosa	46	25.00
	Klebsiella pneumoniae	20	10.87
	Klebsiella pneumoniae	11	5.98
	Pseudomonas aeruginosa	5	2.71
Gram-positive		45	24.46
	Enterococcus faecalis	34	18.48
	Staphylococcus aureus	6	3.26
	Streptococcus pneumonia	3	1.63
	Staphylococcus aureus	2	1.09

Table 3: Antimicrobial susceptibility of *Escherichia coli* and P*seudomonas aeruginosa*

Category	***Escherichia coli***		***Pseudomonas aeruginosa***	
	N	***Sensitivity (%)***	***N***	***Sensitivity (%)***
Furantoin	49	85.96	18	39.13
Cefotaxime	44	77.19	32	69.57
Imipenem	55	96.49	41	89.13
Amikacin	40	70.18	19	41.30
Tobramycin	20	35.09	14	30.43
Gentamicin	21	36.84	11	23.91
Compound Amoxicillin	22	38.60	15	32.61
Ceftazidime-tazobactam	39	68.42	40	86.96

Table 4: Antimicrobial susceptibility of *Enterococcus faecalis*

Category	Strain (N)	Sensitivity (%)
Vancomycin	32	94.12
Imipenem	27	79.41
Tobramycin	2	5.88
Gentamicin	10	29.41
Compound Amoxicillin	8	23.53
Ceftazidime-tazobactam	24	70.59

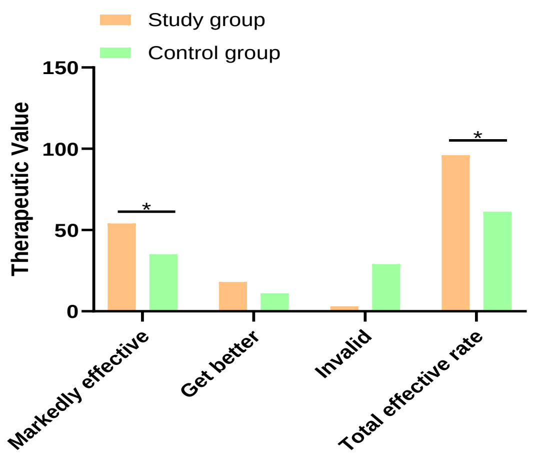

Figure 1: Efficacy of intervention in study and control groups. **P* < 0.05 compared to control group

DISCUSSION

Pediatric urinary tract infection refers to bacterial invasion of the urinary tract in children, causing infections in areas such as the bladder, urethra, and kidneys. It is a common pediatric condition, particularly prevalent in infancy and toddlerhood [1]. Urinary tract infections are notably common among female infants under the age of two, with higher incidence rates compared to male infants. This is primarily attributed to the shorter female urethra, which is closer to the anus, making it more susceptible to bacterial infections [8]. However, urinary tract infections also occur in male infants, especially in cases involving congenital abnormalities of the urinary system or urinary tract obstruction. Pediatric urinary tract infections are categorized into two types based on the affected site which include cystitis (bladder infection) and pyelonephritis (kidney infection). Cystitis is characterized by symptoms such as urinary frequency, urgency, dysuria, and even difficulties in urination.

Children with cystitis often experience frequent urges to urinate with poor urine output and the urine may appear cloudy or contain blood. Cystitis is generally milder and typically doesn't lead to fever or severe symptoms. On the other hand, pyelonephritis is a more severe form of pediatric urinary tract infection, especially if left untreated. It leads to complications and is associated with symptoms like high fever, chills, abdominal pain, vomiting, and loss of appetite. Additionally, children with pyelonephritis may also exhibit symptoms of cystitis, such as urinary frequency, urgency, and dysuria. Infants and non-verbal toddlers might manifest non-specific symptoms like irritability, restlessness, or decreased appetite [9].

Diagnosis of urinary tract infections primarily relies on urine examination and culture, often involving the collection of early morning urine samples for testing. In the treatment of pediatric urinary tract infections, oral antibiotics are commonly used to eradicate the infection, and in severe cases, hospitalization might be considered based on the severity of the condition. However, misuse and irrational use of antibiotics in urinary tract infection treatment have led to the global issue of antibiotic resistance [10]. Thus, rational antimicrobial susceptibility tests and rational antibiotic use have become crucial in the management of pediatric urinary tract infections. They provide scientific guidance to clinicians, help reduce antibiotic misuse, prevent the emergence of antibiotic resistance, and safeguard the health of affected children [11].

The results of this study demonstrated that Gram-negative bacteria, primarily *Escherichia coli*, constituted the predominant pathogen responsible for pediatric urinary tract infections. Previous related studies have indicated the diverse array of pathogenic microorganisms in pediatric urinary tract infections [12]. Common bacteria include *Escherichia coli, Klebsiella pneumoniae, Proteus mirabilis, and Streptococcus agalactiae.* Among these, *Escherichia coli* is the most common pathogen, accounting for over 80 % of urinary tract infections in children. Other bacterial strains also have varying distribution patterns, likely influenced by regional and seasonal variations [12,13], consistent with the findings of this study. Prevalence of *Escherichia coli* is attributed to its strong adhesive properties, allowing it to readily adhere to the surface of uroepithelial cells, leading to inflammatory reactions that significantly increase the risk and probability of urinary tract infections in children [14,15].

In cases of Gram-negative bacterial infections, the preferred treatment includes cefoperazone/sulbactam. For more severe cases, early administration of meropenem is recommended. Due to individual variability among patients, drugs prevalent in antimicrobial susceptibility test results, such as cefoperazone, cefoperazone/sulbactam, nitrofurantoin, meropenem, and ceftriaxone, are used for treatment. Furthermore, Gram-positive bacteria like *Enterococcus faecalis* and *Staphylococcus aureus* also play a role in infections. In Gram-positive bacterial infections, amoxicillin/clavulanate is the first choice. Expensive antibiotics like meropenem and vancomycin are reserved for critically ill patients to avoid the development of resistance [16,17]. Based on these results, doctors may accurately select antibiotics that the pathogen is sensitive to, thereby avoiding unnecessary antibiotic use and misuse, reducing the emergence of antibiotic resistance, and enhancing treatment efficacy [18,19]. The study therefore revealed that the highlighted treatment effect in study group (antimicrobial susceptibility adherence group) was significantly better compared to control group (non-adherence group). Patients in the adherence group exhibited gradual normalization of vital signs, significant improvement in clinical symptoms, and treatment efficacy. In contrast, patients in control group (non-adherence group) experienced less improvement in symptoms and even deterioration, indicating poorer treatment outcomes. This reaffirms the importance of antimicrobial susceptibility testing and interpretation in infection treatment.

This study underscores the fact that accurate antimicrobial susceptibility tests guide antibiotic selection, facilitate personalized treatment plans, enhance treatment success rates and outcomes, reduce infection recurrence and complication occurrences, and positively impact antibiotic cost-effectiveness and rational use [20]. However, it is crucial to recognize that susceptibility testing is not the sole determinant of treatment. Factors such as age, disease severity, renal function, and others must be integrated to formulate personalized treatment strategies for achieving the best therapeutic outcomes. With the ongoing advancements in medical technology, future efforts should further refine susceptibility testing techniques and promote widespread application. This will offer more scientifically and effectively supported solutions for treatment of pediatric urinary tract infections, thus enhancing the quality of life and health status of affected children.

Limitations of the study

This study has several limitations. First, the relatively small sample size may affect the reliability of the results. Also, the study only conducted antimicrobial susceptibility interpretation for a subset of pathogenic microorganisms in pediatric urinary tract infections. Other microorganisms also warrant further investigation.

CONCLUSION

The distribution of pathogenic microorganisms in pediatric urinary tract infections is diverse, with *Escherichia coli* being the most common causative agent. Antimicrobial susceptibility testing guides accurate antibiotic selection, improves individualized treatment plans, optimizes clinical outcomes, reduces antibiotic misuse, lowers the risk of resistance, and reduces healthcare costs. Future studies should expand the sample size and broaden the scope of study subjects to comprehensively investigate the distribution of pathogenic microorganisms in pediatric urinary tract infections.

DECLARATIONS

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Ethical approval

None provided.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Conflict of Interest

No conflict of interest associated with this work.

Contribution of Authors

The authors declare that this work was done by the authors named in this article and all liabilities pertaining to claims relating to the content of this article will be borne by them.

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