

# Urinary Tract Infections in Pediatric Age: A 5-Year Hospital-Based Retrospective Study

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## Abstract

**Introduction:** Urinary tract infections are the second most common bacterial infections in pediatric patients. Understanding local antibiotic resistance patterns is essential for appropriate therapeutic decision-making. This study aims to determine the prevalence and antibiotic susceptibility profile of microorganisms responsible for urinary tract infections in a Level II Hospital, to enhance empirical antibiotic prescription and prevent resistance.

**Methods:** A retrospective and descriptive study was conducted by reviewing the medical records of patients aged 0–17 years diagnosed with urinary tract infections, confirmed by urinary sediment with >5 leukocytes/field and microorganism identification in urine culture, between 2018 and 2022 in the Pediatric Department. Patients with nephro-urological malformations, positive urine cultures with inactive sediment, and asymptomatic bacteriuria were excluded. Urine samples collected using collection bags were also excluded.

**Results:** A total of 976 patients were included, with a predominance of females observed across all age groups, except during the first year of life, in which males exhibited a higher prevalence. *Escherichia coli* was the most frequently isolated microorganism across all age groups, with a sensitivity of 97.7% to cefuroxime-axetil and a resistance rate of 28.1% to amoxicillin-clavulanic acid. In the adolescent population, *Staphylococcus saprophyticus* demonstrated a prevalence similar to that of *Escherichia coli*. *Staphylococcus saprophyticus* exhibited nearly 94% sensitivity to amoxicillin-clavulanic acid and intrinsic resistance to fosfomicin.

**Conclusion:** *Escherichia coli* remains the primary etiological agent of urinary tract infections, with a prevalence nearly equivalent to that of *Staphylococcus saprophyticus* in adolescence, findings consistent with the literature. Considering the antimicrobial resistance pattern observed in our institution, empirical therapy should involve cefuroxime axetil until 12 years of age, followed by amoxicillin-clavulanic acid in older patients. Our findings highlight the importance of continuous monitoring of antibiotic susceptibility patterns to optimize empirical urinary tract infections management and reduce future resistance rates.

**Keywords:** Anti-Bacterial Agents; Child; Drug Resistance, Microbial; Microbial Sensitivity Tests; Urinary Tract Infections/ drug therapy

## INTRODUCTION

Urinary tract infection (UTI) is the second most common cause of bacterial infections in pediatric patients, often leading parents to seek emergency care. Its incidence is higher in males during the first year of life, after which it becomes more prevalent in females.<sup>1-4</sup>

The most common etiological agents of pediatric UTIs are Gram-negative bacteria, with *Escherichia coli* (*E. coli*) being the most prevalent microorganism, responsible for approximately 53%–83% of cases. Other pathogens include *Klebsiella* spp., *Proteus* spp., and *Enterococcus* spp.<sup>5-9</sup>

Despite variations in antibiotic susceptibility, a considerable resistance rate to commonly prescribed antibiotics remains a significant concern. *E. coli* exhibits significant resistance to ampicillin (69.8%–87%) and first-generation cephalosporins such as cefazolin (15%–62%). Resistance to trimethoprim-sulfamethoxazole is also high, ranging from 24% to 44%.<sup>5-9</sup>

Early empirical treatment should be initiated promptly to prevent renal parenchymal damage and potential long-term sequelae. The decision regarding empirical antibiotic therapy should consider the antibiotic susceptibility patterns of the most commonly isolated local bacteria and be adjusted based on urine culture and antimicrobial susceptibility test

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results.<sup>1-4,10,11</sup> The findings of this study may contribute to mitigating antimicrobial resistance and promoting a more evidence-based empirical prescription approach.

According to the European Centre for Disease Prevention and Control, Portugal is among the European countries with the highest antibiotic resistance rates.<sup>12</sup> The National Program for the Prevention of Antimicrobial Resistance, established in November 2009, aims to reduce antimicrobial resistance rates nationwide.<sup>13</sup>

The objective of this study was to assess the prevalence of etiological agents responsible for pediatric UTIs at Hospital do Divino Espírito Santo Ponta Delgada (HDES) in Azores, as well as their antibiotic susceptibility profiles, in order to reduce broad-spectrum antibiotic prescriptions and, consequently, minimize antimicrobial resistance.

## MATERIAL AND METHODS

This study is a retrospective analysis of pediatric patients diagnosed with urinary tract infections between 2018 and 2022 at the Pediatrics Department of HDES. The Ethical Committee authorized this study in accordance to institutional guidelines. Informed consent was waived, due to the retrospective and non-interventional nature of the study.

### Participants

All patients aged 0 to 17 years with UTI, confirmed by urinary sediment (US) with >5 leukocytes/field and a positive urine culture (UC). Cases with nephro-urological malformations, positive UC with inactive sediment, and asymptomatic bacteriuria were excluded. Urine samples collected using collection bags were also excluded.

### Variables and Outcomes

Data were collected from patients' medical records (Glint®) and the microbiology department of HDES. The analyzed variables included demographic data (age, gender), clinical data (personal nephro-urological history and symptomatology), laboratory data (urinalysis type II, urine culture, and antibiotic susceptibility testing), and therapeutic data (empirical antibiotic therapy). The primary outcome was antibiotic sensitivity.

### Definitions

Nephro-urological malformations included vesicoureteral reflux, neurogenic bladder, chronic catheterization, junction syndrome, pyelocaliceal duplication, nephrectomy, chronic renal failure, single kidney and ectopic kidneys. Inactive sediment is a sediment with < 5 leukocytes/field. Asymptomatic bacteriuria is the absence of signs or symptoms of a UTI in a patient whose urine culture meets the criteria for a UTI.<sup>11</sup>

### Statistical Methods

Categorical variables were summarized as absolute counts and corresponding percentages. Data analysis and the

generation of tables and figures were conducted using Microsoft Excel and Word 2010.

## RESULTS

Of the initial 1626 cases identified, 368 were excluded due to nephro-urological pathology and 282 due to normal urinary sediment or absence of urinary sediment analysis, resulting in a final cohort of 976 patients.

Females predominated overall (80.5%) across all age groups, except during the first three months of life, when UTIs were more frequent in males (79% vs 21%) (Table 1). Most cases were diagnosed in the emergency department (95%), followed by outpatient consultations (3.5%), while the remaining 1.5% originated from inpatient wards, the neonatal unit, the neonatal intensive care unit, and other services (Table 1).

Table 1. Baseline patient characteristics

Characteristics	Total
<b>Absolute number – n (%)</b>	976 (100)
2018	225 (23)
2019	256 (26)
2020	180 (18)
2021	194 (20)
2022	121 (13)
<b>Age (median in years)</b>	6,8
Age groups	n (%)
< 3 months	38 (3.9)
3- <12 months	84 (8.6)
12- 24 months	135 (13.8)
>24 months- 5 years	200 (20.5)
6-12 years	211 (21.6)
>12 years	308 (31.6)
<b>Female gender – n (%)</b>	786 (80.5)
Female gender by age groups	n (%)
< 3 months	8 (21)
3- <12 months	45 (53)
12- 24 months	104 (77)
>24 months- 5 years	168 (84)
6-12 years	180 (85)
>12 years	281 (91)
Origin of cases	n (%)
Emergency department	927 (95)
Outpatient consultation	34 (3.5)
Inpatient care	6 (0.6)
Neonatal unit	2 (0.2)
Neonatal intensive care unit	2 (0.2)
Others	5 (0.5)

Analysis of uropathogen distribution according to age and sex (Table 2) showed that *Escherichia coli* was the most frequently isolated microorganism, accounting for 59% of all cases, followed by *Proteus mirabilis* (15.9%) and *Staphylococcus saprophyticus* (13.5%). During the first three months

of life, UTIs were more common in males, with *E. coli* predominating in boys (75%) compared with girls (25%). Between 3 and 12 months of age, *E. coli* remained the leading pathogen in both sexes, although it was proportionally more frequent in females (70%) than in males (30%).

Table 2. Distribution of the pathogens by age groups

<i>E. coli</i>	PATHOGENS - n (%)								
	<i>P. mirabilis</i>	<i>S. saprophyticus</i>	<i>K. pneumoniae</i>	<i>P. aeruginosa</i>	<i>M. morgani</i>	<i>S. marcescens</i>	Others	Total	
	28 (2.9)	1 (0.1)	0	2 (0.2)	0	3 (0.3)	2 (0.2)	2 (0.2)	38 (3.9)
A 3-12 m	99 (10.1)	18 (1.8)	0	4 (0.4)	0	3 (0.3)	1 (0.1)	15 (1.5)	140 (14.3)
G >12- 24 m	37 (3.8)	36 (3.7)	0	1 (0.1)	3 (0.3)	0	0	2 (0.2)	79 (8.1)
E >24 m- 5 A	121 (12.4)	56 (5.7)	4 (0.4)	6 (0.6)	6 (0.6)	0	0	7 (0.7)	200 (20.5)
G 6-12 A	149 (15.3)	20 (2.1)	19 (1.9)	8 (0.8)	0	0	0	15 (1.5)	211 (21.6)
R >12 A	142 (14.5)	25 (2.6)	109 (11.2)	11 (1.1)	1 (0.1)	0	1 (0.1)	19 (1.9)	308 (31.6)
Total	576 (59)	156 (15.9)	132 (13.6)	32 (3.3)	10 (1)	6 (0.6)	4 (0.4)	60 (6.1)	976 (100)

Between 12 and 24 months, a clear sex-related difference emerged: *E. coli* remained the most frequent pathogen in females (55.9%), whereas *Proteus mirabilis* predominated in males (80.0%), exceeding *E. coli* (20.0%). This pattern persisted between 24 months and 5 years of age. In females, *E. coli* accounted for 66.7% of isolates and *P. mirabilis* for 22.0%; conversely, in males, *P. mirabilis* was the most common isolate (59.4%), followed by *E. coli* (28.1%). Thus, while *E. coli* remained dominant in girls between 12 months and 5 years, *P. mirabilis* was comparatively more prevalent in boys throughout the same period. In adolescence (>12 years), a marked sex-related difference was observed, with *Staphylococcus saprophyticus* becoming a prominent uropathogen, representing approximately 35% of isolates and occurring almost exclusively in females. *E. coli* remained prevalent in adolescents of both sexes but was proportionally less dominant in females due

to the increased contribution of *S. saprophyticus*. Other microorganisms, including *Klebsiella pneumoniae*, *Pseudomonas aeruginosa*, *Morganella morgani*, and *Serratia marcescens*, were infrequently isolated and showed no consistent sex-related distribution pattern. Regarding antimicrobial susceptibility, *E. coli* exhibited high sensitivity to cefuroxime-axetil (97.7%) and a resistance rate of 28.1% to amoxicillin-clavulanic acid. Cefuroxime-axetil demonstrated the highest overall sensitivity across most studied microorganisms (90%) (Table 3). In adolescents, *Staphylococcus saprophyticus* showed sensitivity to amoxicillin-clavulanic acid of nearly 94% and intrinsic resistance to fosfomicin (Table 4). Over the five-year study period, a significant increase in antimicrobial resistance was observed, with resistance to fosfomicin rising from 21.8% to 49.6% and resistance to ceftriaxone increasing from 0.4% to 10.7% (Table 5).

Table 3. Distribution of pathogens by antibiotic sensitivity

	Antibiotic - n (%)													
	Amoxicillin + clavulanic acid		Cefuroxime		Cefuroxime axetil		Fosfomicin		Nitrofurantoin		Ceftriaxone		Cefotaxime	
	R	S	R	S	R	S	R	S	R	S	R	S	R	S
<i>E. coli</i>	162 (28)	414 (72)	13 (2.3)	563 (97.7)	13 (2.3)	563 (97.7)	4 (1)	572 (99)	0	576 (100)	6 (1.1)	570 (98.9)	1 (0.2)	575 (99.8)
P <i>P. mirabilis</i>	11 (7.1)	145 (92.9)	1 (0.7)	155 (99.3)	1 (0.7)	155 (99.3)	24 (15.4)	132 (84.6)	118 (75.6)	38 (24.4)	0	156 (100)	1 (0.7)	155 (99.3)
T <i>S. saprophyticus</i>	7 (5.3)	125 (94.7)	3 (2.3)	129 (97.7)	1 (0.8)	131 (99.2)	132 (100)	0	0	132 (100)	3 (2.3)	129 (97.7)	3 (2.3)	129 (97.7)
O <i>K. pneumoniae</i>	13 (40.6)	19 (59.4)	1 (3.2)	31 (96.8)	1 (3.2)	31 (96.8)	4 (12.5)	28 (87.5)	1 (3.2)	31 (96.8)	1 (3.2)	31 (96.8)	1 (3.2)	31 (96.8)
E <i>P. aeruginosa</i>		N/A		N/A		N/A	2 (20)	-		N/A		N/A		N/A
S <i>M. morgani</i>	6 (100)	0		N/A	4 (66.7)	-	4 (66.7)	-	4 (66.7)	-	-	2 (33.3)	0	6 (100)
<i>S. marcescens</i>	4 (100)	0		N/A	2 (50)	-	-	2 (50)	2 (50)	-	-	2 (50)	2 (50)	2 (50)

Legend: R- resistance / S- sensitivity / N/A- not tested / - no results

Table 4. Distribution of most frequent pathogens by antibiotic sensitivity and age groups

		ANTIBIOTIC - n (%)														
		Amoxicillin + clavulanic acid		Cefuroxime		Cefuroxime axetil		Fosfomycin		Nitrofurantoin		Ceftriaxone		Cefotaxime		
		R	S	R	S	R	S	R	S	R	S	R	S	R	S	
<i>E. coli</i>	< 3 m	11 (39.3)	17 (60.7)	0	28 (100)	0	28 (100)	0	28 (100)	0	28 (100)	0	28 (100)	0	28 (100)	
	3-12 m	27 (27.3)	72 (72.7)	1 (1)	98 (99)	1 (1)	98 (99)	0	99 (100)	0	99 (100)	1 (1)	98 (99)	0	99 (100)	
		12 (32.4)	25 (67.6)	2 (5.4)	35 (94.6)	2 (5.4)	35 (94.6)	1 (2.7)	36 (97.3)	0	37 (100)	0	37 (100)	1 (2.7)	36 (97.3)	
	>24 m- 5A	32 (26.4)	89 (73.6)	0	121 (100)	0	121 (100)	1 (0.8)	120 (99.2)	0	121 (100)	0	121 (100)	0	121 (100)	
		48 (32.2)	101 (67.8)	5 (3.4)	144 (96.6)	5 (3.4)	144 (96.6)	1 (0.7)	148 (99.3)	0	149 (100)	3 (2)	146 (98)	0	149 (100)	
	>12 A	32 (22.5)	110 (77.5)	5 (3.5)	137 (96.5)	5 (3.5)	137 (96.5)	1 (0.7)	141 (99.3)	0	142 (100)	2 (1.4)	140 (98.6)	0	142 (100)	
P A T H O G E N S	<i>P. mirabilis</i>	< 3 m	0	1 (100)	0	1 (100)	0	1 (100)	-	-	-	-	0	1 (100)	0	1 (100)
			1 (5.6)	17 (94.4)	0	18 (100)	0	18 (100)	5 (27.8)	13 (72.2)	15 (83.3)	3 (16.7)	0	18 (100)	0	18 (100)
		>12- 24 m	3 (8.3)	33 (91.7)	0	36 (100)	0	36 (100)	3 (8.3)	33 (91.7)	26 (72.2)	10 (27.8)	0	36 (100)	0	36 (100)
		>24 m- 5A	3 (5.4)	53 (94.6)	0	56 (100)	0	56 (100)	11 (19.6)	45 (80.4)	45 (80.4)	11 (19.6)	0	56 (100)	0	56 (100)
			1 (5)	19 (95)	1 (5)	19 (95)	1 (5)	19 (95)	4 (20)	16 (80)	15 (75)	5 (25)	0	20 (100)	1 (5)	19 (95)
		>12 A	3 (12)	22 (88)	0	25 (100)	0	25 (100)	1 (4)	24 (96)	17 (68)	8 (32)	0	25 (100)	0	25 (100)
<i>S. saprophyticus</i>	< 3 m	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	3-12 m	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	>12- 24 m	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	>24 m- 5A	0	4 (100)	0	4 (100)	0	4 (100)	4 (100)	0	0	4 (100)	0	4 (100)	0	4 (100)	
	6-12 A	0	19 (100)	0	19 (100)	-	-	19 (100)	0	0	19 (100)	0	19 (100)	0	19 (100)	
	>12 A	7 (6.4)	102 (93.6)	3 (2.8)	106 (97.2)	1 (0.9)	108 (99.1)	109 (100)	0	0	109 (100)	3 (2.8)	106 (97.2)	3 (2.8)	106 (97.2)	

Legend: R- resistance / S- sensitivity / N/A- not tested /- no results

Table 5. Distribution of antibiotic sensitivity by years

		ANTIBIOTIC - n (%)													
		Amoxicillin + clavulanic acid		Cefuroxime		Cefuroxime axetil		Fosfomycin		Nitrofurantoin		Ceftriaxone		Cefotaxime	
		R	S	R	S	R	S	R	S	R	S	R	S	R	S
YEARS	2018	49 (21.8)	176 (78.2)	5 (2.2)	220 (97.8)	10 (4.4)	215 (95.6)	49 (21.8)	176 (78.2)	37 (16.4)	188 (83.6)	1 (0.4)	224 (99.6)	1 (0.4)	224 (99.6)
	2019	66 (25.8)	190 (74.2)	5 (2)	251 (98)	7 (2.7)	249 (97.3)	56 (21.9)	200 (78.1)	65 (25.4)	191 (74.6)	7 (2.7)	249 (97.3)	1 (0.4)	255 (99.6)
	2020	41 (22.8)	139 (77.2)	5 (2.8)	175 (97.2)	5 (2.8)	175 (97.2)	46 (25.6)	134 (74.4)	35 (19.4)	145 (80.6)	7 (3.9)	173 (96.1)	3 (1.7)	177 (98.3)
	2021	46 (23.7)	148 (76.3)	4 (2)	190 (98)	7 (3.6)	187 (96.4)	66 (34)	128 (66)	51 (26.3)	143 (73.7)	6 (3)	188 (97)	2 (1)	192 (99)
	2022	26 (21.5)	95 (78.5)	3 (2.5)	118 (97.5)	5 (4.1)	116 (95.9)	60 (49.6)	61 (50.4)	42 (34.7)	79 (65.3)	13 (10.7)	108 (89.3)	3 (2.5)	118 (97.5)

Legend: R- resistance / S- sensitivity / N/A- not tested /- no results

## DISCUSSION

Urinary tract infections (UTIs) remain a significant concern in pediatric patients, representing the second most common bacterial infection in this age group.<sup>14</sup> Our study confirms the predominance of *E. coli* (59%) as the leading causative microorganism, followed by *Proteus mirabilis* (15.9%) and *Staphylococcus saprophyticus* (13.6%). These findings are consistent with previous reports identifying *E. coli* as the most frequent etiological agent in pediatric UTIs, with prevalence rates ranging from 53% to 83%.<sup>14-15</sup>

A distinct sex-related distribution was observed. Although females predominated overall (80.5%), a higher prevalence of UTIs was found in males during the first year of life. This pattern supports existing evidence suggesting an increased susceptibility in male infants, likely related to anatomical and physiological factors.<sup>16</sup> After the first year of life, the prevalence shifted towards females, which may be explained by anatomical differences and greater vulnerability to ascending infections.<sup>15-17</sup>

A particularly relevant finding was the age- and sex-related variation in pathogen distribution between 12 months and 5 years of age. In this period, *Proteus mirabilis* became comparatively more prevalent than *E. coli* in males, accounting for a substantial proportion of isolates. In contrast, among females in the same age range, *E. coli* remained the predominant pathogen, with *P. mirabilis* contributing to a smaller proportion of infections. In adolescence, *Staphylococcus saprophyticus* showed a marked increase in prevalence (35%), nearly equaling *E. coli* in frequency. These findings underscore the importance of age- and sex-specific considerations when selecting empirical antibiotic therapy, as the distribution of causative pathogens varies across pediatric age groups.<sup>18</sup>

Antimicrobial resistance remains a major concern in pediatric UTIs. In our cohort, *E. coli* demonstrated high sensitivity to cefuroxime-axetil (97.7%) but showed a considerable resistance rate to amoxicillin-clavulanic acid (28.1%). These results align with global trends reporting increasing resistance of *E. coli* to commonly used antibiotics, particularly beta-lactams.<sup>18,19</sup> Additionally, *Staphylococcus saprophyticus* isolates in adolescents exhibited high sensitivity to amoxicillin-clavulanic acid (approximately 95%) but intrinsic resistance to fosfomicin, highlighting the need for careful antibiotic selection in this population.<sup>19</sup>

The consistently high sensitivity of cefuroxime-axetil (90%) across most isolated microorganisms supports its use as a first-line empirical treatment for pediatric UTIs up to 12 years of age. Conversely, given the increased prevalence of *Staphylococcus saprophyticus* in adolescents and its favorable susceptibility profile to amoxicillin-clavulanic acid, this agent may represent a more appropriate empirical option in older patients. These findings reinforce the importance of continuous surveillance of local resistance patterns to guide empirical antibiotic choices and reduce the risk of treatment failure and further resistance development.<sup>20</sup>

Finally, our study highlights that the majority of pediatric UTI cases were managed in the emergency department (95%), with fewer cases addressed in outpatient clinics (3.5%) or inpatient settings (1.5%). This distribution raises important considerations regarding access to and adequacy of primary care services for pediatric UTI management. Strengthening outpatient diagnostic pathways and early treatment strategies may help reduce emergency department utilization while ensuring timely and effective care.<sup>16</sup>

## Limitations

Although this study provides important insights into the epidemiological profile and antibiotic resistance patterns of pediatric urinary tract infections, certain limitations warrant consideration. The retrospective nature of the study may introduce selection bias, and data collection from electronic records may lead to missing information. Additionally, we did not evaluate the clinical outcomes of different antibiotic regimens, which could provide further evidence on the effectiveness of specific treatments.

Future research should focus on longitudinal analyses to assess trends in antibiotic resistance over time and the impact of recurrent UTIs on resistance patterns. Investigating factors such as previous antibiotic exposure, underlying conditions, and treatment adherence could help refine empirical antibiotic prescribing and strengthen strategies for preventing antimicrobial resistance.<sup>21</sup>

## CONCLUSION

This study reinforces the predominance of *E. coli* as the main causative agent of pediatric UTIs, with a notable increase in *Staphylococcus saprophyticus* prevalence in adolescence. The observed resistance patterns highlight the importance of tailoring empirical antibiotic therapy based on local epidemiological data. Cefuroxime-axetil remains the preferred choice for children up to 12 years, while amoxicillin-clavulanic acid may be more suitable for adolescents. Continuous surveillance and adherence to antimicrobial stewardship programs are essential to optimize treatment and mitigate antibiotic resistance in pediatric UTIs.<sup>13</sup> Furthermore, given the intrinsic resistance of *Staphylococcus saprophyticus* to fosfomicin, future studies are warranted to assess the appropriateness of its use in empirical treatment, particularly in adolescents where this pathogen is more prevalent.

## LEARNING POINTS

*Escherichia coli* remains the leading cause of pediatric UTIs, but *Staphylococcus saprophyticus* shows increasing prevalence in adolescents.

Local resistance patterns should guide empirical therapy: cefuroxime-axetil is most effective in children up to 12 years, while amoxicillin-clavulanic acid is suitable for adolescents.

Rising resistance to fosfomicin highlights the need for cautious antibiotic use.

Continuous surveillance and adherence to antimicrobial stewardship programs are essential to optimize treatment,

reduce broad-spectrum antibiotic use, and mitigate resistance in pediatric urinary tract infections.

### Ethical Disclosures

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**Confidentiality of Data:** The authors declare that they have followed the protocols of their work center on the publication of patient data.

**Protection of Human and Animal Subjects:** The authors declare that the procedures followed were in accordance with the regulations of the relevant clinical research ethics committee and those of the Code of Ethics of the World Medical Association (Declaration of Helsinki as revised in 2024).

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### Contributorship Statement

**IC and CS:** Performed data collection, data analysis and interpretation, and wrote the manuscript.

**AA:** Assisted in data elaboration.

**AA, BF, JR, MM and LP:** Revised the manuscript.

All authors approved the final version to be published.

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