



DOI: 10.5281/zenodo.22846735 · UDC: 616.61/.62-022.7-053.2

URINARY TRACT INFECTIONS IN CHILDREN: EPIDEMIOLOGY, CLINICAL FEATURES, AND DIAGNOSIS

Albina-Mihaela Iliev^{1,2}, Veronica Burlac^{1,2}, Maria Anton¹

¹ National Agency for Public Health, Chişinău, Republic of Moldova

² State University of Medicine and Pharmacy “Nicolae Testemiţanu”, Chişinău, Republic of Moldova

ABSTRACT

Objectives. To synthesize current evidence on the epidemiology, age-specific clinical manifestations, microbiological etiology, risk factors, and conventional and emerging diagnostic strategies for urinary tract infections (UTIs) in children, with particular attention to antimicrobial resistance (AMR) and renal risk.

Methods. A narrative review was conducted using a structured search of PubMed, Scopus, and Web of Science for publications issued between 1 January 2020 and 3 August 2026. Pediatric guidelines and consensus documents, systematic reviews and meta-analyses, randomized controlled trials, diagnostic accuracy studies, and population-based, cohort, and other observational studies were considered.

Results. UTIs affect approximately 8% of girls and 2% of boys during the first decade of life, and recurrence occurs in about 30% of affected children. Boys predominate during early infancy, whereas girls are more frequently affected after the first year of life. *Escherichia coli* causes approximately 80% of pediatric UTIs, although increasing multidrug resistance and extended-spectrum beta-lactamase production complicate empirical treatment. Clinical manifestations are predominantly nonspecific in infants and become more localized with age. Recurrent infection, congenital urinary tract anomalies, vesicoureteral reflux, and bladder-bowel dysfunction increase the likelihood of renal involvement. Urinalysis and urine culture remain the diagnostic foundation, with specimen quality being essential for reliable interpretation. Biomarkers and molecular assays may accelerate pathogen and resistance detection, but their routine pediatric use remains limited by cost, validation requirements, and uncertain clinical specificity.

Conclusions. An age-adapted diagnostic approach is essential in children with suspected urinary tract infection. Early recognition, reliable urine sampling, culture-based confirmation, awareness of local resistance patterns, and selective use of imaging help identify children at risk of recurrence or renal involvement. Emerging molecular tools are promising adjuncts but should complement rather than routinely replace conventional microbiological methods.

Keywords: urinary tract infection, children, epidemiology, clinical features, diagnosis, antimicrobial resistance

Introduction

Urinary tract infections (UTIs) are among the most common bacterial infections in childhood and remain a frequent cause of febrile illness, emergency assessment, antimicrobial exposure, and pediatric hospitalization. Their clinical spectrum ranges from lower urinary tract infection, usually cystitis, to febrile upper urinary tract infection or acute pyelonephritis, which may be associated with bacteremia and renal parenchymal involvement. Contemporary reviews emphasize that the diagnostic challenge is greatest in neonates, infants, and young children because urinary symptoms are often absent and systemic manifestations are nonspecific [1–3].

The epidemiology of pediatric UTI changes substantially with age and sex. Boys, particularly uncircumcised boys,

are more vulnerable during early infancy, whereas girls predominate after the first year of life. Recurrence is common, and the probability of repeated infection is influenced by congenital anomalies of the kidney and urinary tract (CAKUT), vesicoureteral reflux (VUR), bladder-bowel dysfunction, voiding habits, prior antimicrobial exposure, and host-related factors [1, 4, 5, 6, 7]. These associations are clinically important because a UTI may be the first sign of an underlying urinary tract abnormality and because recurrent febrile episodes are more strongly associated with renal scarring than a single uncomplicated infection [1, 4, 5, 8, 9].

At the same time, antimicrobial resistance (AMR) is reshaping the microbiological profile of pediatric UTI. *Escherichia coli* remains the predominant pathogen, but increasing resistance to commonly used oral agents and the expansion of extended-spectrum beta-lactamase-producing

Enterobacterales complicate empirical treatment [2, 3, 5]. Diagnostic stewardship is therefore increasingly linked to antimicrobial stewardship: treatment should be based on a credible clinical syndrome, an appropriately collected urine specimen, and microbiological confirmation whenever possible.

Conventional diagnosis still relies on urinalysis and urine culture. However, limitations of standard culture, including turnaround time, contamination, low-count bacteriuria, fastidious organisms, and mixed infections, have stimulated development of automated urinalysis, biomarkers, multiplex polymerase chain reaction (PCR), mass spectrometry, microfluidic systems, and next-generation sequencing [2, 3, 5, 10]. Pediatric evidence for several emerging platforms remains limited, and greater analytical sensitivity does not necessarily translate into improved clinical specificity. The aim of this review was therefore to synthesize recent evidence on pediatric UTI with an emphasis on epidemiology, age-related clinical features, risk factors, microbiology, and contemporary diagnosis, while highlighting areas in which new diagnostic technologies may change clinical practice.

Materials and Methods

This article was developed as a narrative review. Three contemporary publications were used as foundational sources: a 2024 pediatric review addressing epidemiology, kidney involvement, diagnosis, treatment, and guideline variation; a 2025 systematic review of conventional and emerging diagnostic technologies; and a 2026 critical narrative review focused on diagnostic innovation, AMR, and implementation [1–3].

The literature search was conducted in PubMed, Scopus, and Web of Science for publications issued between 1 January 2020 and 3 August 2026, with the final search performed on 3 August 2026. The search strategy combined terms related to urinary tract infections, the pediatric population, epidemiological and clinical characteristics, risk factors, diagnostic methods, and AMR.

The following database-specific search expressions were used:

PubMed: (("urinary tract infection"[Title/Abstract] OR "urinary tract infections"[Title/Abstract] OR "UTI"[Title/Abstract]) AND ("child"[Title/Abstract] OR "children"[Title/Abstract] OR "pediatric"[Title/Abstract]) AND ("epidemiology"[Title/Abstract] OR "clinical features"[Title/Abstract] OR "risk factors"[Title/Abstract] OR "urine collection"[Title/Abstract] OR "urine culture"[Title/Abstract] OR "biomarkers"[Title/Abstract] OR "polymerase chain reaction"[Title/Abstract] OR "PCR"[Title/Abstract] OR "molecular diagnostics"[Title/Abstract] OR "vesicoureteral reflux"[Title/Abstract] OR "renal scarring"[Title/Abstract] OR "antimicrobial resistance"[Title/Abstract])) AND 2020/01/01:2026/08/03[dp]

Scopus: TITLE-ABS-KEY(("urinary tract infection" OR "urinary tract infections" OR "UTI") AND ("child"

OR "children" OR "pediatric") AND ("epidemiology" OR "clinical features" OR "risk factors" OR "urine collection" OR "urine culture" OR "biomarkers" OR "polymerase chain reaction" OR "PCR" OR "molecular diagnostics" OR "vesicoureteral reflux" OR "renal scarring" OR "antimicrobial resistance")) AND PUBYEAR AFT 2019 AND PUBYEAR BEF 2027

Web of Science: TS= (("urinary tract infection" OR "urinary tract infections" OR "UTI") AND ("child" OR "children" OR "pediatric") AND ("epidemiology" OR "clinical features" OR "risk factors" OR "urine collection" OR "urine culture" OR "biomarkers" OR "polymerase chain reaction" OR "PCR" OR "molecular diagnostics" OR "vesicoureteral reflux" OR "renal scarring" OR "antimicrobial resistance")) AND PY=(2020-2026).

At the database-search stage, the publication period was the only filter applied. No language, document type, geographical, or open-access filters were applied directly in the databases. Full-text availability was assessed during the subsequent eligibility screening.

Eligible publications included pediatric guidelines and consensus documents, systematic reviews and meta-analyses, randomized controlled trials, diagnostic accuracy studies, and population-based, cohort, or other observational studies. Studies were included if they involved participants younger than 18 years or reported separately extractable pediatric data and addressed at least one of the following domains: epidemiological burden and recurrence; age- and sex-related patterns; microbiological etiology and AMR; age-dependent clinical manifestations; structural, functional, or renal risk factors; and conventional or emerging diagnostic strategies. Adult-only diagnostic studies were considered only when they provided directly transferable information regarding diagnostic performance, technological implementation, or AMR relevant to pediatric practice. Duplicate publications, case reports, small case series, conference abstracts without an available full text, editorials or letters without original data, non-human studies, and publications unrelated to the review objectives were excluded.

After duplicate removal, the titles and abstracts of the identified publications were screened for relevance. Potentially eligible publications were subsequently assessed in full text according to the predefined eligibility criteria. Uncertainties regarding eligibility were resolved through discussion among the authors. Priority was given to recent publications with clearly described methods, robust study designs, and direct relevance to the predefined domains. Following the screening and eligibility assessment, 31 publications were included in the final narrative synthesis. The selected evidence was synthesized descriptively and organized into the six thematic domains.

Consistent with its narrative design, this review did not include protocol registration, meta-analysis, or standardized risk-of-bias assessment. A methodological limitation was the exclusion of publications whose full text was not available through open-access sources. This criterion was applied solely

to permit complete article assessment and was not considered an indicator of methodological quality; nevertheless, some relevant evidence may have been omitted. Heterogeneity in study populations and methods also limited direct comparisons.

Results

Epidemiological burden, age, sex, and recurrence

The available evidence consistently identifies UTI as a major bacterial infection in children, but prevalence estimates depend on the clinical setting and denominator used. Maringhini et al. reported that almost 8% of girls and 2% of boys experience a UTI during the first decade of life, while approximately 30% of affected children develop a second episode [1]. Reviews and guidelines published since 2020 report similar patterns and emphasize that UTI should be considered in febrile infants and in older children with compatible urinary or systemic symptoms [4–9].

Age modifies both risk and sex distribution. In a Korean cohort of 359 children with a first febrile UTI, 78.0% were younger than 12 months. The male-to-female ratio was 5.3:1 at 0–2 months, 2.1:1 at 3–5 months, and 1.6:1 at 6–11 months; female predominance emerged after 12 months [13]. This age-related reversal is consistent with contemporary pediatric reviews [6–9]. Uncircumcised male infants are at increased risk during the first year of life, whereas the shorter female urethra, periurethral colonization, and later behavioral factors contribute to the higher incidence among girls after infancy [11, 13].

Risk-factor evidence extends beyond anatomy. A 2022 meta-analysis found that circumcision was associated with a markedly lower occurrence of UTI, and breastfeeding was also protective. Conversely, overweight or obesity increased the risk of UTI, while poor fluid intake and infrequent voiding were associated with recurrent infections [11]. These findings reinforce the importance of modifiable voiding and hydration behaviors in children with recurrent UTI, particularly when bladder-bowel dysfunction is present (Table 1).

Microbiological etiology and antimicrobial resistance

Most pediatric UTIs develop through ascending spread of intestinal and perineal flora. Escherichia coli remains the dominant uropathogen, commonly accounting for approximately 80% or more of pediatric infections [1, 6–9, 12, 13]. In the 2021 febrile UTI cohort reported by Suh et al., Escherichia coli caused 83.8% of first febrile episodes, followed by Enterococcus species and Klebsiella pneumoniae [13]. Other clinically relevant organisms include Proteus mirabilis, Klebsiella species, Enterobacter species, Pseudomonas aeruginosa, Enterococcus species, and selected Gram-positive bacteria [1–3, 6, 7].

The etiological profile becomes more heterogeneous in recurrent infection, children with urinary tract abnormalities, prior hospitalization, previous antibiotic exposure, or healthcare-associated infection [3, 23, 24]. Non-Escherichia coli infection is therefore both a microbiological finding and a potential clinical marker of complicated disease. Several guidelines use atypical pathogens, together with recurrent febrile infection and abnormal ultrasonography, to identify children who may require more intensive evaluation [4, 5, 16,

Table 1. Epidemiological and risk-factor profile of urinary tract infection in children

Domain	Current evidence	Clinical relevance
Cumulative burden	Approximately 8% of girls and 2% of boys experience a UTI during the first decade of life [1].	The probability of infection varies substantially by age and sex.
Recurrence	About 30% of children have a subsequent infection after an initial UTI [1].	Previous UTI should increase vigilance for recurrent symptoms and underlying risk factors.
Early infancy	Male predominance is most evident in the first months of life; uncircumcised boys have higher risk [1, 11, 13].	Sex-specific risk in infancy differs from later childhood.
After infancy	Female predominance becomes progressively more marked [6–10, 12, 13].	Localized urinary symptoms become more common and epidemiological pre-test probability rises in girls.
Modifiable factors	Poor fluid intake, infrequent voiding, excess weight, and bladder-bowel dysfunction are associated with occurrence or recurrence [10, 11, 15].	Hydration, regular voiding, and constipation management should be incorporated into recurrent UTI assessment.
Structural factors	CAKUT and VUR are associated with febrile and recurrent UTI and influence imaging decisions [1, 4, 5, 15–17].	Risk-stratified imaging is preferable to indiscriminate invasive testing.

Abbreviations: CAKUT, congenital anomalies of the kidney and urinary tract; UTI, urinary tract infection; VUR, vesicoureteral reflux.

17].

AMR is an increasingly important determinant of empirical treatment. Longitudinal pediatric studies have documented rising resistance to multiple commonly prescribed agents. Suh et al. observed significant increases in multidrug-resistant and extended-spectrum beta-lactamase-producing enteric Gram-negative organisms over a decade, while Choi et al. reported progressive resistance across several antibiotic classes in hospitalized children with febrile UTI [13, 24]. A dedicated pediatric review concluded that multidrug-resistant UTI may occur both in children with classic risk factors, such as prior antimicrobial exposure or urological malformations, and in otherwise healthy community patients [23]. These findings support routine use of local antibiograms and careful reassessment of empirical therapy once culture results are available.

Clinical features according to age

The clinical presentation of pediatric UTI is strongly age dependent. In newborns and young infants, symptoms are often nonspecific and may resemble other systemic infections. Fever, lethargy, irritability, reduced feeding, vomiting, poor weight gain, and general clinical deterioration may occur, and bacteremia is an important consideration in neonates and young infants [1, 6-9]. A very ill neonate may occasionally lack fever, so absence of elevated temperature should not be used to exclude infection in this age group [1].

During later infancy and the toddler years, fever without a clear source remains one of the most important presentations. Vomiting, anorexia, abdominal discomfort, dehydration, and irritability may accompany the febrile illness. Localizing urinary complaints are frequently absent because the child cannot reliably describe dysuria, urgency, or flank pain. Consequently, the diagnostic threshold for urine testing should be lower in young children with unexplained fever, especially in those with previous UTI or known urinary tract

abnormalities [5-10].

In preschool-aged children, the presentation begins to localize. Fever and abdominal pain remain common, but dysuria, frequency, urgency, new urinary incontinence, or changes in voiding behavior become more informative. Bladder-bowel dysfunction and constipation should be actively sought because these are associated with recurrent infection and can coexist with abnormal bladder emptying [10, 11, 15-17].

School-aged children and adolescents more often present with the classic lower urinary tract syndrome: dysuria, urgency, frequency, suprapubic discomfort, hematuria, or new-onset daytime wetting or secondary enuresis. Fever, flank or lumbar pain, vomiting, systemic malaise, and costovertebral angle tenderness increase concern for upper urinary tract involvement [1, 6-9]. Although the distinction between cystitis and pyelonephritis is clinically useful, localization remains imperfect; fever above 38 °C is a particularly important indicator of febrile UTI or possible pyelonephritis [1] (Table 2).

Structural and functional risk factors, renal involvement, and long-term outcomes

A pediatric UTI can be the sentinel event that reveals an underlying urinary tract abnormality. CAKUT can promote infection through urinary stasis, impaired emptying, obstruction, or reflux of contaminated urine [1, 4-9]. VUR is one of the most frequently discussed abnormalities and has been reported in a substantial proportion of children evaluated after UTI. However, contemporary evidence increasingly treats VUR as one component of a broader risk profile rather than as an isolated predictor of renal damage [1, 4, 5, 9, 16, 17].

Bladder-bowel dysfunction is particularly relevant in preschool and school-aged children. A history of constipation, infrequent voiding, urgency, withholding behaviors, daytime

Table 2. Age-related clinical presentation of urinary tract infection in children

Age group	Typical manifestations	Diagnostic implications
Neonates and young infants	Fever or temperature instability, lethargy, irritability, poor feeding, vomiting, poor weight gain; bacteremia may occur [1, 6-9].	Urinary symptoms may be absent. Consider UTI in systemic illness or fever without a source.
Infants and toddlers	Fever, vomiting, anorexia, abdominal discomfort, dehydration, irritability [5-9].	Low threshold for urine testing when fever has no clear focus.
Preschool children	Fever, abdominal pain, emerging dysuria, frequency, urgency, incontinence or voiding changes [6-10, 15].	Assess constipation and bladder-bowel dysfunction, especially in recurrent UTI.
School-aged children	Dysuria, urgency, frequency, suprapubic pain, hematuria, secondary enuresis; flank pain may occur [1, 6-9].	Localized urinary symptoms have greater diagnostic value than in younger children.
Any age with suspected upper UTI	Fever, flank or lumbar pain, vomiting, malaise, costovertebral angle tenderness, systemic illness [1, 6-9].	Consider pyelonephritis, renal involvement, and need for closer clinical assessment.

Abbreviation: UTI, urinary tract infection.

wetting, or incomplete emptying should prompt targeted assessment. Sjostrom et al. demonstrated an association between bladder-bowel dysfunction and children previously evaluated for febrile UTI, supporting the integration of bladder and bowel history into recurrent UTI care [15].

Renal scarring after febrile UTI remains an important concern, but its pathogenesis is multifactorial. Maringhini et al. noted that scars in children with VUR may be congenital or acquired and described recurrent febrile infections, higher-grade reflux, delayed therapy, virulence factors, and bladder-bowel dysfunction as relevant contributors [1]. More recent population-level evidence suggests that the long-term risk for most children is lower than historically assumed. In a Welsh cohort of 159,201 children, 7% had a microbiologically confirmed UTI before five years of age, while renal scarring was diagnosed in only 0.16% by seven years; the authors emphasized the need for longer follow-up to clarify associations with later hypertension or chronic kidney disease in otherwise low-risk children [22].

Conventional laboratory diagnosis and urine collection

Clinical findings alone cannot reliably confirm pediatric UTI, particularly in infants and young children. Urinalysis is useful for rapid assessment, but urine culture remains the reference method for microbiological confirmation and susceptibility testing [1, 4-9, 14-17]. Leukocyte esterase supports the presence of pyuria, while nitrite is relatively specific for nitrate-reducing organisms but has limited sensitivity in children who void frequently. Interpretation should therefore combine symptoms, urinalysis, culture, collection method, and the pre-test probability of infection.

The validity of culture depends heavily on specimen quality. In toilet-trained children, a properly performed midstream clean-catch sample is generally preferred. In non-toilet-trained children, clean-catch techniques can be attempted, but urethral catheterization or suprapubic aspiration may be required when a reliable culture is essential, especially in ill infants. Bag specimens are easy to obtain but have high contamination rates and should not be used as definitive culture specimens [1, 5, 7, 9, 18]. Diviney and Jaswon highlighted the trade-off between invasiveness, feasibility, and contamination and emphasized that the collection method should be selected according to age, clinical severity, and the purpose of testing [18].

A positive culture must be interpreted in relation to collection technique and inflammatory evidence. Guideline thresholds for significant colony counts differ, reflecting variation in specimen type and diagnostic philosophy [1, 4, 5, 16, 17]. This lack of complete harmonization is clinically relevant: excessively high thresholds may miss low-count infection, whereas indiscriminate interpretation of low bacterial counts can promote overdiagnosis and unnecessary antimicrobial exposure.

Biomarkers may help improve discrimination in febrile children. Urinary neutrophil gelatinase-associated lipocalin (NGAL), CCL3, and interleukin-8 have shown promising

ability to differentiate febrile children with and without UTI [19]. An individual patient data meta-analysis also found urinary NGAL to be a promising diagnostic biomarker in young febrile children, although assay standardization and implementation remain unresolved [20]. Biomarkers should therefore be viewed as adjunctive tools rather than replacements for appropriate urine sampling and culture.

Emerging molecular diagnostics and resistance profiling

The 2025 and 2026 diagnostic reviews describe rapid expansion of culture-independent approaches, including multiplex PCR, loop-mediated isothermal amplification, mass spectrometry, microfluidic phenotypic susceptibility systems, and next-generation sequencing [2, 3]. These methods may shorten turnaround time, detect fastidious organisms, identify mixed infections, and, in some platforms, provide resistance markers within hours rather than days. Such capabilities are attractive in complicated, recurrent, or previously treated UTI and in antimicrobial stewardship programs.

However, increased analytical sensitivity creates new interpretive challenges. Molecular assays may detect organisms at low abundance, nonviable DNA after recent therapy, colonizing organisms, or multiple taxa whose causal significance is uncertain. The 2025 systematic review therefore concluded that emerging tools are promising complements to conventional methods but that widespread adoption depends on validation, standardization, cost-effectiveness, and integration into clinical workflows [2]. The 2026 critical review similarly emphasized that technological performance alone is insufficient unless implementation improves prescribing and patient outcomes [3].

Evidence directly involving children is beginning to emerge. In a 2024 prospective pediatric emergency department study including 48 patients aged 3–21 years, multiplex PCR was reported as noninferior and more sensitive than standard urine culture for organism detection [30]. The small sample size and substantial commercial conflicts of interest require cautious interpretation, and larger independent pediatric studies are needed. More broadly, a 2022 systematic review and meta-analysis found that molecular diagnostic techniques may have diagnostic performance comparable with culture, but heterogeneity and specificity limitations remained [29]. Studies comparing multiplex PCR with standard culture also show that enhanced detection does not automatically establish clinical causality [31] (Table 3).

Imaging and diagnostic risk stratification

Imaging strategies have become more selective as understanding of congenital abnormalities and renal scarring has evolved. Current pediatric guidelines generally use age, recurrent or atypical infection, non-*Escherichia coli* pathogens, abnormal renal and bladder ultrasonography, and clinical severity to determine the need for further studies [4, 5, 8, 9, 15, 16]. Renal and bladder ultrasonography is noninvasive and remains the principal first-line imaging modality, whereas voiding cystourethrography and dimercaptosuccinic acid scintigraphy are increasingly reserved for selected higher-risk

Table 3. Contemporary diagnostic methods for suspected urinary tract infection in children

Method	Main role or strength	Principal limitation
Urine dipstick and microscopy	Rapid screening for pyuria and bacteriuria; supports immediate clinical decisions [1, 5, 7, 16-18].	Sensitivity varies; nitrite may be negative with frequent voiding or non-nitrate-reducing organisms.
Standard urine culture	Reference method for pathogen identification and phenotypic susceptibility testing [1-3, 5, 7].	Usually requires longer turnaround time; vulnerable to contamination and may miss some low-count or fastidious organisms.
Urinary biomarkers	Potential rapid host-response evidence; NGAL, CCL3, and interleukin-8 are promising [19, 20].	Assay thresholds and routine pediatric implementation are not yet standardized.
Multiplex PCR	Rapid detection of multiple pathogens and selected resistance genes; high analytical sensitivity [2, 3, 29-31].	Can detect colonization or low-level DNA of uncertain significance; cost and stewardship implications require validation.
Next-generation sequencing	Broad microbial detection and characterization of complex microbial communities [2, 3].	Turnaround time, cost, bioinformatics, contamination control, and interpretation currently limit routine pediatric use.
Rapid phenotypic susceptibility platforms	Potential earlier targeted antimicrobial selection [2, 3].	Need clinical validation, workflow integration, and demonstration of outcome and cost benefits.

Abbreviations: NGAL, neutrophil gelatinase-associated lipocalin; PCR, polymerase chain reaction.

children rather than being routinely applied after every first infection.

A 2024 study evaluating children after a first UTI suggested that a more selective ultrasonography strategy based on atypical pathogens or recurrence could substantially reduce imaging while missing few severe abnormalities, but guideline recommendations remain heterogeneous [21]. The most recent European guideline update continues to emphasize practical risk stratification and minimizing invasive investigations while preserving the ability to detect clinically significant anatomical abnormalities [4].

Treatment and stewardship implications

Although this review focuses on epidemiology, clinical features, and diagnosis, recent treatment evidence is relevant because diagnostic accuracy directly affects antimicrobial exposure. Contemporary guidance supports prompt treatment of clinically credible febrile UTI, followed by adjustment according to culture and susceptibility results [4, 5, 7-9]. Randomized trials have renewed interest in shorter antibiotic courses. The SCOUT trial found a low absolute failure rate after a five-day course in children who had already improved clinically, although standard therapy produced fewer early failures [25]. The STOP trial reported that five days of oral amoxicillin-clavulanate could be effective for selected well-appearing children aged 3 months to 5 years with uncomplicated febrile UTI [26]. These findings support individualized duration rather than indiscriminate prolongation of therapy.

Antibiotic prophylaxis is now used more selectively. In infants with grade III-V VUR and no previous UTI, the PREDICT trial found that continuous prophylaxis reduced first UTI occurrence but increased non-*Escherichia coli*

infections and antimicrobial resistance [27]. Thus, prophylaxis should be reserved for clearly defined higher-risk groups after balancing recurrence risk, anatomy, adverse effects, and AMR. Evidence for adjuvant corticosteroids to reduce renal scarring is promising but not sufficiently established for routine practice; systematic review data suggest a possible reduction in scars, but larger confirmatory studies and clearer safety data are needed [28].

Discussion

This review demonstrates that pediatric UTI should not be approached as a single uniform disease. Epidemiological probability, symptom specificity, pathogen distribution, diagnostic reliability, and risk of complications all change across childhood. The most clinically useful organizing principle is age: the younger the child, the less specific the clinical presentation and the more important it becomes to integrate fever pattern, general condition, risk factors, and a properly collected urine specimen. In older children, urinary symptoms become more informative, but microbiological confirmation remains important because symptoms overlap with vulvovaginitis, dysfunctional voiding, urethral irritation, and other noninfectious conditions [1, 4-9].

The available epidemiological evidence supports a characteristic transition from male predominance in early infancy to female predominance after the first year of life [10, 12, 13]. This pattern has practical implications for pre-test probability, but sex alone should never determine whether urine testing is performed. A febrile infant with no clear source, especially an uncircumcised boy or a child with known urinary tract abnormalities, warrants serious consideration of

UTI. Conversely, in older girls, dysuria and frequency raise suspicion, but these symptoms require appropriate sampling rather than automatic antibiotic treatment.

Recurrence deserves particular attention because it connects epidemiology with functional and anatomical risk factors. Approximately one-third of affected children may have another episode, and recurrent infection should prompt review of constipation, voiding frequency, withholding, fluid intake, daytime wetting, previous culture results, and any known CAKUT or VUR [1, 10, 11, 15]. This perspective broadens the evaluation beyond imaging alone and recognizes bladder-bowel dysfunction as a modifiable contributor to repeated infections.

The dominant role of *Escherichia coli* remains one of the most stable features of pediatric UTI epidemiology. [1, 6-10, 12, 13]. What is changing is susceptibility. The increasing prevalence of multidrug-resistant and extended-spectrum beta-lactamase-producing strains reduces the reliability of empiric regimens based on historical patterns [13, 23, 24]. Local antimicrobial susceptibility data should therefore be integrated into pediatric treatment pathways, and urine cultures should be obtained before antibiotics whenever clinically feasible. A negative or contaminated culture after unnecessary empirical therapy creates diagnostic uncertainty and may expose the child to avoidable antibiotics.

Reliable urine collection remains one of the most important and underappreciated diagnostic steps. The benefit of even the most sophisticated molecular method is limited if the specimen is contaminated or collected from a population with very low pre-test probability. Clean-catch sampling is preferable when feasible; catheterization or suprapubic aspiration retains a role in young or seriously ill children when definitive culture is required [5, 7, 9, 16-18]. Bag specimens are convenient for screening but should not be used to establish a culture diagnosis because contamination can lead directly to false-positive diagnoses and antibiotic exposure.

The emerging diagnostic landscape is promising but requires disciplined interpretation. Molecular assays can substantially shorten time to pathogen detection and can identify organisms or resistance genes missed by routine culture [2, 3, 29-31]. In theory, rapid resistance profiling could reduce broad-spectrum empirical therapy and improve stewardship. In practice, molecular positivity does not always distinguish infection from colonization, low-level carriage, or residual DNA after treatment. This challenge is especially important in pediatrics, where unnecessary antibiotic exposure has long-term consequences for resistance, microbiome disruption, and future diagnostic complexity. The most appropriate near-term role for molecular diagnostics may therefore be targeted use in complicated, recurrent, culture-negative, or pretreated cases rather than universal replacement of culture.

The long-term consequences of childhood UTI also require balanced interpretation. Renal scarring can occur after acute pyelonephritis, particularly in children with recurrent febrile infections, high-grade reflux, or underlying renal abnormalities [1, 4, 5]. However, recent population-

based data suggest that severe long-term outcomes are uncommon in the majority of otherwise low-risk children [22]. This supports selective follow-up and imaging strategies that focus resources on children with recurrent infection, atypical pathogens, abnormal ultrasound findings, impaired renal function, or complex clinical courses.

Current evidence also illustrates the need to connect diagnostic stewardship with therapeutic stewardship. Shorter antibiotic regimens may be sufficient in selected children who respond promptly, while prophylaxis should be targeted to those with clearly elevated recurrence risk rather than used routinely [25-27]. These developments make diagnostic precision more important, not less: clinicians need reliable evidence that infection is present, adequate assessment of disease severity, and culture or susceptibility information that supports narrowing or discontinuing therapy.

Strengths and limitations

A strength of this review is the integration of three highly contemporary core reviews published in 2024, 2025, and 2026 with recent pediatric guidelines, meta-analyses, randomized trials, cohort studies, and diagnostic research. This approach permits simultaneous consideration of traditional pediatric concepts and rapidly evolving molecular technologies. The synthesis also emphasizes age-specific clinical reasoning, which is central to everyday pediatric practice.

The main limitation is that this is a narrative rather than a formal systematic review. The search was targeted, no standardized risk-of-bias instrument was applied across all included studies, and quantitative pooling was not performed. Diagnostic thresholds, urine collection practices, definitions of febrile UTI, and imaging strategies vary across countries and studies, limiting direct comparison. In addition, several emerging molecular technologies have been evaluated predominantly in adult populations, and the pediatric evidence base remains relatively small. Commercial involvement in some molecular diagnostic studies also warrants cautious interpretation. These limitations should be considered when translating novel test performance into routine pediatric practice.

Conclusions

Urinary tract infection is a common, clinically heterogeneous, and frequently recurrent bacterial infection in children. Epidemiological patterns are strongly age dependent: boys have relatively higher risk in early infancy, whereas girls predominate after infancy. *Escherichia coli* remains the principal uropathogen, but increasing antimicrobial resistance requires continuous review of empirical treatment strategies and local susceptibility data.

Clinical manifestations also evolve with age. Fever, lethargy, poor feeding, vomiting, and irritability predominate in infants, while dysuria, urgency, frequency, abdominal or flank pain, hematuria, and urinary incontinence become more

informative in older children. Recurrent infection, CAKUT, VUR, bladder-bowel dysfunction, atypical pathogens, and abnormal imaging findings identify children who may require more intensive evaluation.

Urinalysis and properly collected urine culture remain the foundation of diagnosis. Emerging biomarkers and molecular methods can provide faster or broader detection and may support antimicrobial stewardship, particularly in

complicated or recurrent cases, but they currently complement rather than replace conventional microbiology. A practical pediatric strategy should combine age-adjusted clinical suspicion, high-quality specimen collection, microbiological confirmation, awareness of AMR, and selective imaging to improve diagnostic accuracy while minimizing unnecessary antibiotics and invasive investigations.

Bibliography

1. Maringhini S, Alaygut D, Corrado C. Urinary Tract Infection in Children: An Up-To-Date Study. *Biomedicines*. 2024;12(11):2582. doi:10.3390/biomedicines12112582
2. Baimakhanova B, Sadanov A, Berezin V, Baimakhanova G, Trenozhnikova L, Orasymbet S, et al. Emerging technologies for the diagnosis of urinary tract infections: advances in molecular detection and resistance profiling. *Diagnostics (Basel)*. 2025;15(19):2469. doi:10.3390/diagnostics15192469
3. Mohan V, Mitsakakis K. Diagnostic tests for urinary tract infections and antimicrobial resistance: a reality check between diagnostic innovation and implementation: a critical narrative review. *Front Cell Infect Microbiol*. 2026;16:1784139. doi:10.3389/fcimb.2026.1784139
4. Burduniuc O, Ceban E, Bălan G, et al. Asigurarea calității în diagnosticul microbiologic al infecțiilor tractului urinar: ghid. Agenția Națională pentru Sănătate Publică; 2021. Accessed August 2, 2026. <https://repository.usmf.md/handle/20.500.12710/27779>
5. Gnech M, Bujons A, Radmayr C, et al. Update and summary of the EAU/ESPU paediatric guidelines on urinary tract infection in children. *J Pediatr Urol*. 2026;22(2):105481. doi:10.1016/j.jpuro.2025.06.016
6. Hari P, Meena J, Kumar M, et al. Evidence-based clinical practice guideline for management of urinary tract infection and primary vesicoureteric reflux. *Pediatr Nephrol*. 2024;39(5):1639-1668. doi:10.1007/s00467-023-06173-9
7. Tullus K, Shaikh N. Urinary tract infections in children. *Lancet*. 2020;395(10237):1659-1668. doi:10.1016/S0140-6736(20)30676-0
8. Simoes e Silva AC, Oliveira EA, Mak RH. Urinary tract infection in pediatrics: an overview. *J Pediatr (Rio J)*. 2020;96 Suppl 1(Suppl 1):65-79. doi:10.1016/j.jped.2019.10.006
9. Mattoo TK, Shaikh N, Nelson CP. Contemporary management of urinary tract infection in children. *Pediatrics*. 2021;147(2):e2020012138. doi:10.1542/peds.2020-012138
10. Brandstrom P, Hansson S. Urinary tract infection in children. *Pediatr Clin North Am*. 2022;69(6):1099-1114. doi:10.1016/j.pcl.2022.07.003
11. Renko M, Salo J, Ekstrand M, et al. Meta-analysis of the risk factors for urinary tract infection in children. *Pediatr Infect Dis J*. 2022;41(10):787-792. doi:10.1097/INF.0000000000003628
12. Daniel M, Szymanik-Grzelak H, Sierdzinski J, Podsiadly E, Kowalewska-Mlot M, Panczyk-Tomaszewska M. Epidemiology and Risk Factors of UTIs in Children: a single-center Observation. *J Pers Med*. 2023;13(1):138. doi:10.3390/jpm13010138
13. Suh W, Kim BN, Kang HM, Yang EA, Rhim JW, Lee KY. Febrile urinary tract infection in children: changes in epidemiology, etiology, and antibiotic resistance patterns over a decade. *Clin Exp Pediatr*. 2021;64(6):293-300. doi:10.3345/cep.2020.00773
14. Werbel K, Jankowska D, Wasilewska A, Taranta-Janusz K. Clinical and epidemiological analysis of children's urinary tract infections in accordance with antibiotic resistance patterns of pathogens. *J Clin Med*. 2021;10(22):5260. doi:10.3390/jcm10225260
15. Sjöström S, Sillén U, Bachelard M, et al. Bladder/bowel dysfunction in pre-school children following febrile urinary tract infection in infancy. *Pediatr Nephrol*. 2021;36(6):1489-1497. doi:10.1007/s00467-020-04853-4
16. Buettcher M, Trueck J, Niederer-Loher A, et al. Swiss consensus recommendations on urinary tract infections in children. *Eur J Pediatr*. 2021;180(3):663-674. doi:10.1007/s00431-020-03714-4
17. Brandstrom P, Linden M. How Swedish guidelines on urinary tract infections in children compare to Canadian, American and European guidelines. *Acta Paediatr*. 2021;110(6):1759-1771. doi:10.1111/apa.15727
18. Diviney J, Jaswon MS. Urine collection methods and dipstick testing in non-toilet-trained children. *Pediatr Nephrol*. 2021;36(7):1697-1708. doi:10.1007/s00467-020-04742-w
19. Shaikh N, Liu H, Kurs-Lasky M, Forster CS. Biomarkers for febrile urinary tract infection in children. *Pediatr Nephrol*. 2022;37(1):171-177. doi:10.1007/s00467-021-05173-x
20. Forster CS, Lubell TR, Dayan PS, Shaikh N. Accuracy of NGAL as a biomarker for urinary tract infection in young febrile children: an individual patient data meta-analysis. *J Pediatr*. 2023;258:113394. doi:10.1016/j.jpeds.2023.113394

21. Aydin O, Karademir S, Bulbul M. Evaluating the requirement of ultrasonography for children with their first urinary tract infection. *J Pediatr Urol.* 2024;20(3):504-512. doi:10.1016/j.jpuro.2023.10.026
22. Hughes K, Cannings-John R, Jones H, Lugg-Widger F, Lau TMM, Paranjothy S, et al. Long-term consequences of urinary tract infection in childhood: an electronic population-based cohort study in Welsh primary and secondary care. *Br J Gen Pract.* 2024;74(743):e371-e378. doi:10.3399/BJGP.2023.0174
23. Mahony M, McMullan B, Brown J, Kennedy SE. Multidrug-resistant organisms in urinary tract infections in children. *Pediatr Nephrol.* 2020;35(9):1563-1573. doi:10.1007/s00467-019-04316-5
24. Choi U, Kim E, Lyu DH, Kim KS, Park BH, Chung H, et al. The change of antibiotic susceptibility in febrile urinary tract infection in childhood and adolescence during the last decade. *Investig Clin Urol.* 2022;63(1):99-106. doi:10.4111/icu.20210350
25. Zaoutis T, Shaikh N, Fisher BT, Coffin SE, Bhatnagar S, Downes KJ, et al. Short-course therapy for urinary tract infections in children: the SCOUT randomized clinical trial. *JAMA Pediatr.* 2023;177(8):782-789. doi:10.1001/jamapediatrics.2023.1979
26. Montini G, Tessitore A, Console K, Ronfani L, Barbi E, Pennesi M; STOP Trial Group. Short oral antibiotic therapy for pediatric febrile urinary tract infections: a randomized trial. *Pediatrics.* 2024;153(1):e2023062598. doi:10.1542/peds.2023-062598
27. Morello W, Baskin E, Jankauskiene A, Yalcinkaya F, Zurowska A, Puccio G, et al. Antibiotic prophylaxis in infants with grade III, IV, or V vesicoureteral reflux. *N Engl J Med.* 2023;389(11):987-997. doi:10.1056/NEJMoa2300161
28. Gkiourtzis N, Glava A, Moutafi M, Vasileiadou T, Delaporta T, Michou P, et al. The efficacy and safety of corticosteroids in pediatric kidney scar prevention after urinary tract infection: a systematic review and meta-analysis of randomized clinical trials. *Pediatr Nephrol.* 2023;38(12):3937-3945. doi:10.1007/s00467-023-05922-0
29. Robledo XG, Arcila KVO, Riascos SHM, García-Perdomo HA. Accuracy of molecular diagnostic techniques in patients with a confirmed urine culture: A systematic review and meta-analysis. *Can Urol Assoc J.* 2022;16(9):E484-E489. doi:10.5489/cuaj.7677
30. Bhavsar SM, Polavarapu N, Haley E, Luke N, Mathur M, Chen X, et al. Noninferiority of multiplex polymerase chain reaction compared to standard urine culture for urinary tract infection diagnosis in pediatric patients at Hackensack Meridian Health Children's Hospital emergency department. *Pediatr Health Med Ther.* 2024;15:351-364. doi:10.2147/PHMT.S491929
31. Haley E, Luke N, Mathur M, Festa RA, Wang J, Jiang Y, et al. Comparison shows that multiplex polymerase chain reaction identifies infection-associated urinary biomarker-positive urinary tract infections that are missed by standard urine culture. *Eur Urol Open Sci.* 2023;58:73-81. doi:10.1016/j.euro.2023.10.008

Received – 01.08.2026, accepted for publication – 19.09.2026

Corresponding author: Maria Anton, maria.anton@ansp.gov.md

Conflict of Interest: The authors declare no conflict of interest.

Funding statement: The authors received no specific funding for this work.

Ethics statement: Not applicable. This manuscript is a literature review and does not involve primary data collection from human participants or animals.

Author contributions statement: Iliev Albina-Mihaela – conceptualization, methodology, literature search, data curation, writing - original draft; Burlac Veronica – validation, literature synthesis, writing - review and editing; Anton Maria – conceptualization, supervision, writing - review and editing.

All authors have read and approved the final manuscript.

Citation: Iliev AM, Burlac V, Anton M. Urinary tract infections in children: epidemiology, clinical features, and diagnosis. *Arta Medica.* 2026;100(3):e2026353. doi: 10.5281/zenodo.22846735