Original Article

Prevalence and Morphological Spectrum of Congenital Anomalies of the Kidney and Urinary Tract in Children Presenting with Urinary Tract Infections in Central India

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Abstract

Background: Congenital anomalies of the kidney and urinary tract (CAKUT) are the most common cause of pediatric chronic kidney disease and often first manifest as urinary tract infections (UTIs). Data regarding the exact prevalence and morphological spectrum of these anomalies in Central India are limited. The objective is to determine the prevalence and morphological pattern of CAKUT in children diagnosed with UTIs at a tertiary care center in Central India. **Material and Methods:** A hospital-based cross-sectional observational study was conducted over a year in the Departments of Paediatrics and Paediatric Surgery at a tertiary teaching hospital in Indore. Eighty children presenting with clinical and laboratory evidence of UTI were enrolled using consecutive sampling. Diagnostic evaluation included ultrasonography of the kidneys, ureters, and bladder (USG KUB), with micturating cystourethrogram (MCU) reserved for recurrent UTIs or abnormal sonographic findings. **Results:** CAKUT was identified in 23.8% of the cohort, with a striking predominance in neonates (100%) and infants (60.0%). Males were more frequently affected (60.0%). First-episode UTIs were noted in 88.8%, but recurrent UTIs were strongly associated with CAKUT (88.9%). Structural anomalies were present in 46% of children, with hydroureteronephrosis and high-grade VUR being the most common. All children with CAKUT needed long-term multidisciplinary follow-up. **Conclusion:** Almost one-quarter (24%) of pediatric patients with UTIs had CAKUT, especially younger children and those with recurrent UTIs, and early targeted imaging is important to prevent further renal damage.

Keywords: Congenital anomalies of the kidney and urinary tract; CAKUT; Urinary tract infection; Vesicoureteral reflux; Central India.

Received: 19 April 2026 **Revised: 01 May 2026** **Accepted: 22 May 2026** **Published: 06 July 2026**

Introduction

Congenital anomalies of the kidney and urinary tract (CAKUT) comprise a heterogeneous group of structural malformations that arise from perturbations in embryonic renal development and are the most common congenital defects in pediatric populations, accounting for the majority of global childhood chronic kidney disease (CKD) and end-stage renal disease (ESRD).[1,2] The clinical presentation of CAKUT varies significantly, with some being clinically silent and others becoming evident when complicated by secondary pathologies, such as urinary tract infections (UTIs).[3]

UTIs are among the most common bacterial infections during early childhood and often are the presenting sign of an underlying structural urinary tract malformation.[4] The pathophysiological link between CAKUT and UTI is bidirectional: structural obstruction and refluxing anomalies lead to urinary stasis and bacterial colonization, whereas the resultant recurrent infections lead to progressive renal scarring, hypertension, and nephron loss.[5] Although the need for immediate imaging after pediatric UTIs to identify CAKUT is well recognized, the region-specific epidemiological data from Central India is lacking, and the disease burden has not been established. This study aimed to assess the prevalence, clinical presentation, and morphological pattern of CAKUT in children with UTIs at a tertiary care center in Central India.

Materials and Methods

Study Design and Setting: A hospital-based cross-sectional observational study was conducted over a one-year period within the Department of Paediatrics and the Department of Paediatric Surgery at M.Y. Hospital, attached to M.G.M. Medical College, Indore, Madhya Pradesh.

Study Population and Sampling: Children up to 18 years of age who presented to the outpatient department or were admitted to the pediatric wards with clinical and/or laboratory

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DOI:
10.21276/amit.2026.v13.i2.805

How to cite this article: Sharanya J, Biswas M, Chaudhary M, Shukla RM. Prevalence and Morphological Spectrum of Congenital Anomalies of the Kidney and Urinary Tract in Children Presenting with Urinary Tract Infections in Central India. Acta Med Int. 2026:13(2):960-964.

evidence of UTI were included in the study. Consecutive sampling was used and sample size was calculated to be 80 using Cochran's formula based on a prior estimated CAKUT prevalence of 8.77% in pediatric nephrology cohorts (5% attrition rate).[6]

Diagnostic Criteria and Evaluation: Diagnosis of UTI was based on compatible clinical features, abnormal urinalysis (significant pyuria), and culture-confirmed significant bacteriuria obtained prior to the administration of antibiotics.[5]

Standard ultrasonography of the kidneys, ureters, and urinary bladder (USG KUB) was done in all participants and a micturating cystourethrogram (MCU) was done in children presenting with abnormal sonographic findings suggestive of structural uropathy or a documented history of recurrent UTIs.

Operational Definitions

- Urinary Tract Infection (UTI): Defined by compatible symptoms, pyuria, and growth of a single uropathogen in significant colony counts ($\geq 10^5$ CFU/mL for midstream clean-catch; $\geq 10^4$ CFU/mL for catheterized specimens).[3,5]
- Pyuria: The presence of >5 white blood cells per high-power field in centrifuged urine sediment.[5]
- CAKUT: Congenital structural anomalies of the kidneys and/or urinary tract confirmed on radiological imaging (USG KUB/MCU).[1]
- Recurrent UTI: More than one symptomatic UTI episode documented at separate time points and treated appropriately.

Data Collection and Statistical Analysis: Demographic parameters, clinical history, laboratory metrics, and radiological outcomes were recorded using a predesigned semi-structured proforma. Data were analyzed using SPSS version 25.0. Descriptive statistics were utilized, and associations between categorical variables were assessed using the Chi-square test, with a p-value <0.05 considered statistically significant.

Results

[Table 1] delineates the foundational socio-demographic and anthropometric profiles of the 80 enrolled children evaluated for urinary tract infections. The cohort was predominantly composed of patients in early childhood (41.3%) and middle childhood (30.0%), with neonates and adolescents each representing a marginal 5.0%. A clear male preponderance was documented, yielding a male-to-female ratio of 1.5:1. The majority of the study population belonged to the upper-lower (38.8%) and lower-middle (35.0%) socioeconomic strata, which aligns with the typical patient demographic of a public tertiary care center, while a robust 83.8% of the participants maintained a normal weight-for-age nutritional status.

Table 1: Baseline Socio-Demographic Characteristics of the Study Population (n = 80)

Variable	Category	Frequency (n)	Percentage (%)
Age Group	Neonate (0–28 days)	4	5.0
	Infant (29 days–12 months)	15	18.8
	Early Childhood (>1–5 years)	33	41.3
	Middle Childhood (>5–12 years)	24	30.0
	Adolescent (>12 years)	4	5.0
Gender	Male	48	60.0
	Female	32	40.0
Socioeconomic Status	Upper Lower	31	38.8
	Lower Middle	28	35.0
Nutritional Status	Normal Weight	67	83.8
	Underweight	13	16.3

Table 2: Clinical Presentation, UTI Episodes, and Microbiological Profile (n = 80)

Variable	Category	Frequency (n)	Percentage (%)
Symptoms at Presentation*	Dysuria	68	85.0
	Fever	60	75.0
	Abdominal Pain	37	46.3
	Vomiting	15	18.8
UTI Episode Type	First Episode	71	88.8
	Recurrent UTI	9	11.3
Urine Culture Yield	Sterile	58	72.5
	Escherichia coli	11	13.8
	Klebsiella pneumoniae	7	8.8
	Enterococcus spp.	4	5.0

*Multiple responses were possible for symptoms.

[Table 2] illustrates the primary clinical manifestations and the specific microbiological etiology of the documented infections. Dysuria (85.0%) and fever (75.0%) emerged as the most prominent clinical indicators, whereas systemic signs like vomiting were comparatively rare (18.8%). An overwhelming majority of the cohort (88.8%) were evaluated during their first recognized infectious episode. Although a high proportion of urine cultures returned sterile (72.5%), likely reflecting empirical antibiotic administration prior to tertiary referral, Escherichia coli (13.8%) remained the dominant offending pathogen among the culture-positive samples, distantly followed by Klebsiella pneumoniae and Enterococcus species.

Table 3: Radiological Findings: USG KUB and MCU

Imaging Modality	Finding Category	Frequency (n)	Percentage (%)
USG KUB (n=80)	Normal	35	43.8
	Cystitis (including mild urothelial thickening)	24	30.0
	Other anomalies (HN, HUN, VUR, PCK, ureterocele, calculus)	21	26.3
MCU (n=26)	Normal	17	65.4
	Abnormal (VUR, PUV, Ureterocele, etc.)	9	34.6

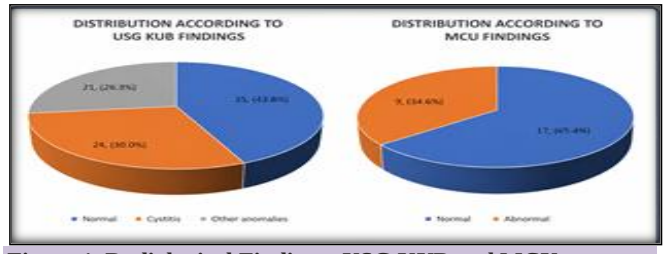

Figure 1. Radiological Findings: USG KUB and MCU

[Table 3 and Figure 1] present the radiological yield. Of the total cohort, USG KUB revealed structural anomalies in 26.3%, most commonly hydronephrosis and multicystic dysplastic kidneys. MCU, performed selectively in 26 patients, showed major anomalies such as high-grade VUR and posterior urethral valves in 34.6% of those imaged, justifying further advanced imaging for recurrent cases.

Table 4: Morphological Spectrum of Structural Anomalies (USG KUB and MCU Findings)

Specific Anomaly Identified	Frequency (n)	Overall Percentage (%)
Mild Hydroureteronephrosis	2	2.5
Moderate Hydroureteronephrosis [Vesicoureteric Junction (VUJ) obstruction; Grade IV VUR; Left ureterocele with Grade IV VUR; Grade V VUR; Posterior Urethral Valves (PUV)]	5	6.3
Gross Hydroureteronephrosis [Grade V VUR]	3	3.8
Moderate to Gross Hydroureteronephrosis [Grade II VUR (Right) and Grade V VUR (Left)]	1	1.3
Mild Hydronephrosis	2	2.5
Moderate Hydronephrosis	1	1.3
Multicystic Dysplastic Kidney (MCDK)	2	2.5
Renal Agenesis	1	1.3
Supranumerary Kidney / Polycystic Kidney	2	2.5

[Table 4] delineate the diverse morphological spectrum of the 19 confirmed CAKUT cases identified through baseline ultrasonography and targeted micturating cystourethrograms. Hydroureteronephrosis of varying severity was the predominant structural defect. Specifically, moderate hydroureteronephrosis was observed in unilateral and bilateral configurations [caused by vesicoureteric junction (VUJ) obstruction; Grade IV vesicoureteral reflux (VUR); left ureterocele with Grade IV VUR; Grade V VUR; and posterior urethral valves (PUV)]. Gross hydroureteronephrosis was frequently bilateral [driven exclusively by high-grade Grade V VUR]. Isolated mild to moderate hydronephrosis was also noted alongside parenchymal malformations such as multicystic dysplastic kidneys, showcasing a significant burden of obstructive and refluxing uropathies.

Table 5: Management Modalities and Clinical Outcomes (n = 80)

Variable	Category	Frequency (n)	Percentage (%)
Management Modality	Medical Therapy	70	87.5
	Surgical Intervention	10	12.5
Clinical Outcome	Successfully Discharged	60	75.0
	Required Follow-up	20	25.0

[Table 5] summarizes the primary therapeutic interventions and the subsequent short-term clinical trajectories of the study participants. The vast majority of the infectious episodes were successfully managed using conservative medical therapy (87.5%), which primarily consisted of targeted or empirical antibiotic administration. Conversely, surgical intervention was necessitated in 12.5% of the cohort, representing the subset of patients with severe, obstructive, or high-grade refluxing anatomical lesions. Consequently, while three-quarters (75.0%) of the total population were successfully treated and discharged from the hospital, exactly one-quarter (25.0%) required continued, rigorous outpatient monitoring to manage their underlying structural vulnerabilities.

Table 6: Association of CAKUT and Outcomes with Demographics and Clinical Parameters

Parameter	Subcategory	CAKUT Present n (%)	CAKUT Absent n (%)	p-value
Age Group	Neonate (0–28 days)	4 (100.0%)	0 (0.0%)	<0.001
	Infant (29 days–12m)	9 (60.0%)	6 (40.0%)	
	Early Childhood	2 (6.1%)	31 (93.9%)	
UTI Episode	First Episode	11 (15.5%)	60 (84.5%)	<0.001

	Recurrent UTI	8 (88.9%)	1 (11.1%)	
Outcome	Required Follow-up	19 (100.0%)	1 (1.6%)	<0.001
	Discharged	0 (0.0%)	60 (98.4%)	

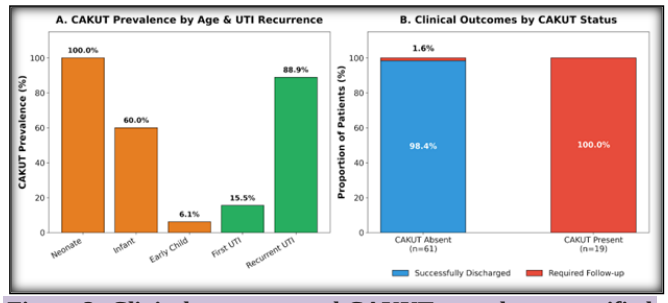

Figure 2: Clinical outcomes and CAKUT prevalence stratified by age and UTI recurrence.

[Table 6 and Figure 2] highlight the critical statistical associations between the presence of structural anomalies, clinical manifestations, and patient trajectories. The prevalence of CAKUT was inversely proportional to patient age; it was universally present in 100% of symptomatic neonates and 60.0% of infants, dropping sharply in older cohorts ($p<0.001$). Furthermore, structural anomalies were diagnosed in a staggering 88.9% of children presenting with recurrent UTIs, establishing a powerful diagnostic link ($p<0.001$). Consequently, the clinical outcomes diverged massively: 100% of patients with confirmed CAKUT mandated continuous, multidisciplinary follow-up or surgical intervention, whereas 98.4% of patients with anatomically normal urinary tracts were successfully treated and discharged ($p<0.001$).

Discussion

In this cross-sectional study, nearly one-quarter (23.8%) of children assessed at a Central Indian tertiary care center for UTIs had underlying CAKUT, which is significantly higher than the 8.77% overall contribution of CAKUT to total pediatric nephrologic disorders reported by Younoussa et al.[6] This difference is fundamentally because the current study limited its cohort to children presenting with UTIs, a highly specific critical clinical marker for congenital urinary pathology.

The demographic distribution demonstrated an extremely high frequency of structural anomalies among the youngest age groups, with 100% of the neonates and 60% of the infants with a UTI diagnosed with CAKUT, a prevalence that declined sharply in older children. This is consistent with the observations of Bondada et al., which show that severe obstructive anomalies tend to occur very early in the first year of life.[7] Similarly, Bhat et al. found that 85% of their cohort of hospitalized pediatric CAKUT patients were aged 0 to 5 years, indicating the necessity of rapid, aggressive imaging protocols for any infant with a febrile UTI.[8]

There was a marked male preponderance (60.0%), reflecting general epidemiological trends; male sex was identified as an independent risk factor for CAKUT from their meta-analysis by Wisnu et al.[9] In addition, Li et al. found higher detection rates in male newborns, primarily as a result of male-specific pathologies such as posterior urethral valves, which accounted for the majority of the gender disparity in infant structural uropathies.[10]

This bidirectional, negative association between recurrent infections and structural anomalies was clearly evident; 88.7% of children with recurrent UTIs were confirmed to have CAKUT, which corroborates Ramayani et al., who also identified an enormous susceptibility to recurrent infections in children with structural urinary tract abnormalities.[11] In addition, Sharmina et al. recently identified recurrent UTIs as the most common, prevalent morbidity (42.3%) in their CAKUT cohort, causing progressive renal scarring.[12]

The most common lesion type was hydroureteronephrosis, often complicated by high-grade VUR, which is consistent with morphologic distribution found by Zhang et al., who described hydronephrosis as the most common lesion during ultrasound screening.[13] The need for prolonged multidisciplinary follow-up in 100% of our CAKUT patients, as opposed to none of those with no anomalies, confirms that CAKUT is not a transient pediatric problem but a chronic disease that requires a lifelong renal preservation strategy.

Conclusion

CAKUT was identified in nearly one-fourth of children presenting with UTIs in this Central Indian cohort. The burden is heavily concentrated in neonates and infants, and intricately linked to recurrent infections. Early, systematic imaging is paramount for timely detection, enabling surgical or medical interventions that mitigate the long-term trajectory of chronic kidney disease.

Recommendations: Routine implementation of USG KUB for all young children presenting with UTI is advised; MCU should be strictly reserved for patients with recurrent infections or abnormal sonographic findings to prevent insidious renal scarring.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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