Original Research Article

Radiological findings and causative organisms in symptomatic pediatric urinary tract infection: A prospective observational study

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Abstract

Background: Symptomatic urinary tract infection (UTI) in children may be associated with congenital or acquired urinary tract abnormalities. Urine culture identifies the causative organism but may yield a negative result despite clinically significant upper-tract disease.
Aim: To describe the causative organisms and radiological findings in children with symptomatic UTI and examine associations between culture status and imaging abnormalities.
Materials and methods: This prospective observational study included 100 children aged 2 months to 12 years who attended a tertiary pediatric hospital between December 2016 and October 2017 with culture-proven UTI or symptoms suggestive of UTI/urosepsis. All underwent renal-bladder ultrasonography. Eighty-seven children with severe upper-tract symptoms underwent dimercaptosuccinic acid (DMSA) scintigraphy and micturating cystourethrography (MCU). Categorical data were analyzed using Pearson chi-square tests.
Results: Urine culture was positive in 51 children. *Escherichia coli* was the leading isolate (23/51, 45.1%), followed by Proteus spp. (12/51, 23.5%) and Klebsiella spp. (7/51, 13.7%). Ultrasonography was abnormal in 66 children; hydroureteronephrosis (48%), renal calculi (16%), pelvi-ureteric junction obstruction (13%), and posterior urethral valves (10%) were prominent findings. VUR was

found in 27/87 (31.0%) intensively imaged children, most commonly grade III. Culture status was not significantly associated with abnormal ultrasonography, DMSA findings, or VUR. In the study cross-tabulation, vesicoureteral reflux was significantly associated with abnormal DMSA findings ($p<0.001$). VUR was significantly associated with abnormal DMSA findings ($p<0.001$).

Conclusion: Structural and renal cortical abnormalities were common, including in culture-negative children. Imaging should be guided by clinical risk, not culture status alone.

Key words

Urinary tract infection; Child; Ultrasonography; DMSA scan; Vesicoureteral reflux; *Escherichia coli*; Urine culture.

Introduction

Urinary tract infection is a common bacterial infection in childhood and may present with fever, vomiting, poor feeding, abdominal pain, or urinary symptoms, particularly in infants and young children. Delayed diagnosis of febrile UTI may result in renal parenchymal involvement, while vesicoureteral reflux, urinary obstruction, bladder–bowel dysfunction, and congenital urinary tract anomalies increase the risk of recurrence and renal injury [1, 5, 7, 13]. *Escherichia coli* remains the principal pediatric uropathogen, although non-*E. coli* organisms are more frequently associated with atypical infection and underlying urinary tract abnormalities [1, 14]. Current guidance recommends microbiological confirmation and selective imaging based on age, recurrence, atypical infection, impaired urinary flow, renal dysfunction, non *E. coli* infection, and abnormal ultrasonography [1, 13, 15]. This study evaluated causative organisms, radiological findings, and culture–imaging associations in children with symptomatic UTI.

Methodology

Study design and setting

A prospective observational hospital-based study was conducted from December 2016 to October 2017 at the Institute of Child Health and Hospital for Children, Madras Medical College, Chennai, India.

Participants

The study enrolled 100 children aged 2 months to 12 years who attended the outpatient department or were admitted to pediatric wards with culture-proven UTI or clinical features suggestive of UTI/urosepsis. Children younger than 36 months presenting with fever without a localizing focus were eligible. Children with fever attributable to a known non-urinary focus were excluded.

Clinical and laboratory evaluation

After written informed consent from a parent or guardian, demographic information, symptoms, anthropometry, vital signs, and physical findings were recorded. Investigations included complete blood count, renal function tests, C-reactive protein, urine routine examination, microscopy, and urine culture. Clean-catch midstream urine was collected after washing the external genitalia in toilet-trained children; transurethral catheterization was used in neonates and infants. Samples were plated within 1 hour or refrigerated at 4°C when a delay was anticipated. Symptomatic upper UTI was defined by fever above 100.4°F and/or abdominal, back, or flank pain, malaise, nausea, vomiting, or diarrhea. Cystitis symptoms included dysuria, frequency, urgency, suprapubic pain, incontinence, or malodorous urine.

Imaging protocol

All children underwent renal and bladder ultrasonography. DMSA scintigraphy was performed in children younger than 3 years with symptomatic or culture-positive UTI and in older children with upper-tract symptoms or abnormal ultrasonography. MCU was undertaken after the acute phase when ultrasonography was abnormal

or when clinically indicated. In practice, 87 children with severe upper-tract symptoms underwent both DMSA and MCU. Imaging categories were not mutually exclusive; a child could have more than one ultrasonographic diagnosis.

Statistical analysis

Data were entered in Microsoft Excel and analyzed using SPSS. Categorical variables are presented as frequencies and percentages. Pearson chi-square tests examined associations between urine culture and ultrasonography, DMSA findings, and VUR, and between DMSA findings and VUR. A two-sided p value below 0.05 was considered statistically significant. Percentages were calculated using the valid denominator for each analysis: 100 children for demographic, microbiological, and ultrasonographic analyses and 87 children for DMSA and MCU analyses. Where percentages in the original statistical output did not correspond exactly to the reported frequencies, percentages were recalculated directly from the available counts.

Ethical considerations

The study received approval from the Institutional Ethics Committee of Madras Medical College/Rajiv Gandhi Government General Hospital, Chennai. Written informed consent was obtained from the parent or legal guardian. The ethics approval number should be inserted before submission.

Results

Participant profile

The study included 100 children, of whom 70 were younger than 5 years and 73 were male (**Table - 1**). Fever was the most frequent presentation (87%), followed by vomiting (59%) and abdominal pain (41%); 36% had no specific urinary symptom (**Table - 2**). The study pathway and denominators used for microbiological and radiological assessment are summarized in **Figure - 1**.

Figure - 1 shows that urine culture and renal-bladder ultrasonography were completed in all 100 children. DMSA scintigraphy and MCU were performed in 87 children selected for severe or upper-tract clinical features; thus, DMSA and VUR percentages use 87 as the denominator.

As shown in **Table - 1**, children younger than 5 years formed 70% of the cohort, including 31 infants. The cohort was predominantly male (73%), reflecting the age distribution and tertiary referral setting.

As detailed in **Table - 2**, systemic manifestations predominated over specific lower-urinary-tract symptoms. This pattern is clinically important because young children may have symptomatic UTI despite the absence of dysuria, frequency, or other classic urinary complaints.

Table - 2 demonstrates that systemic manifestations were more frequent than specific urinary symptoms. Fever affected 87 children, whereas dysuria occurred in 22; the absence of specific urinary symptoms in 36 children illustrates the nonspecific presentation of pediatric UTI. Clinical features were not mutually exclusive.

Microbiological findings

Urine culture was positive in 51 children and negative in 49. Culture positivity was observed in 40/73 boys (54.8%) and 11/27 girls (40.7%). *E. coli* was the most common isolate, accounting for 45.1% of positive cultures, followed by Proteus spp. and Klebsiella spp. (**Table - 3** and **Figure - 2**).

Table - 3 and **Figure - 2** show that *E. coli* was the leading isolate (23/51; 45.1%). Non-*E. coli* organisms collectively accounted for 54.9% of positive cultures, with Proteus spp. (23.5%) and Klebsiella spp. (13.7%) the next most frequent isolates.

Radiological findings

Renal-bladder ultrasonography was abnormal in 66 children and normal in 34.

Hydroureteronephrosis was the most frequently recorded finding; renal calculi, PUJ obstruction, and posterior urethral valves were also common in this tertiary referral cohort (**Table - 4** and **Figure - 3**). Because several children had more than one lesion, the percentages of individual findings exceed the overall proportion with abnormal ultrasonography.

Figure – 1: Study flow and imaging evaluation.

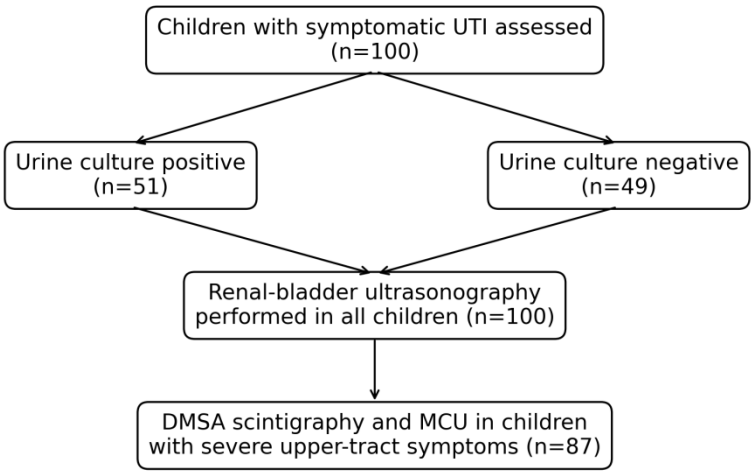


Table – 1: Baseline demographic characteristics of children with symptomatic UTI (N=100).

Characteristic	**n**	**%**
Age <1 year	31	31.0
Age 1-5 years	39	39.0
Age 5-10 years	25	25.0
Age >10 years	5	5.0
Male	73	73.0
Female	27	27.0

Table – 2: Clinical presentation of symptomatic pediatric UTI (N=100).

Clinical feature	**n**	**%**
Fever	87	87.0
Vomiting	59	59.0
Abdominal pain	41	41.0
No urinary symptoms	36	36.0
Decreased urine output	32	32.0
Dysuria	22	22.0
Diarrhea	17	17.0
Abdominal distension	15	15.0
Hematuria	8	8.0

Table - 4 and **Figure - 3** show that ultrasonography was abnormal in 66% of children. Hydroureteronephrosis was the most frequent recorded finding (48%), followed by renal calculi (16%), pelvi-ureteric junction obstruction (13%), and posterior urethral valves (10%). Because more than one lesion could occur in the same child, lesion-specific percentages exceed the overall abnormal-ultrasound proportion when summed.

Table – 3: Distribution of causative organisms among culture-positive children (n=51).

Organism	n	% of positive cultures
Escherichia coli	23	45.1
Proteus spp.	12	23.5
Klebsiella spp.	7	13.7
Acinetobacter spp.	5	9.8
Pseudomonas spp.	2	3.9
Candida albicans	2	3.9

Figure – 2: Distribution of causative organisms among 51 culture-positive children.

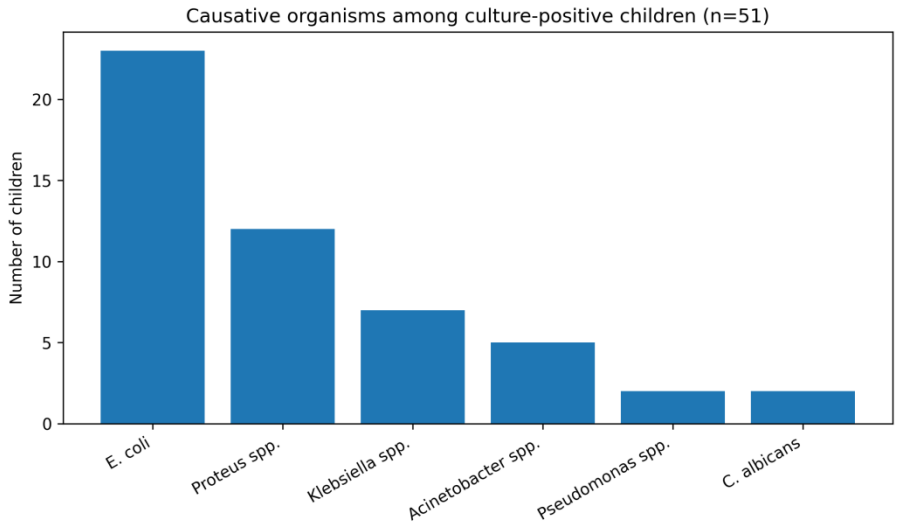


Table – 4: Radiological abnormalities detected by ultrasonography (N=100).

Ultrasonographic finding	n	%
Hydroureteronephrosis	48	48.0
Renal calculi	16	16.0
Pelvi-ureteric junction obstruction	13	13.0
Posterior urethral valve	10	10.0
Pyelonephritis	4	4.0
Cystitis	3	3.0
Left renal agenesis	1	1.0
Duplex collecting system	1	1.0
Normal ultrasonography	34	34.0

Note: Lesion categories overlap; therefore, percentages do not sum to 100%.

Among the 87 children who underwent DMSA scintigraphy and MCU, VUR was identified in 27 children (31.0%). Grade III VUR was the most frequent grade, occurring in 10 of 27 children (37.0%), followed by Grade II in 9 (33.3%), Grade IV in 4 (14.8%), Grade I in 3 (11.1%), and Grade V in 1 (3.7%) (**Table - 5** and **Figure - 4**). The overall DMSA frequency analysis recorded abnormal renal cortical findings in 40 children and normal findings in 47 children. Contemporary guidance supports selective MCU and DMSA assessment in children with recurrent or atypical UTI, abnormal ultrasonography, non-*E. coli* infection, or suspected clinically important reflux [1, 13, 15].

Table - 5 and **Figure - 4** demonstrate that VUR was identified in 27 of 87 children undergoing MCU (31.0%). Grade III was most frequent (37.0%), followed by grade II (33.3%); grades

IV-V together accounted for 18.5% of VUR- positive cases.

Figure – 3: Major ultrasonographic abnormalities. Categories overlap because a child could have more than one finding.

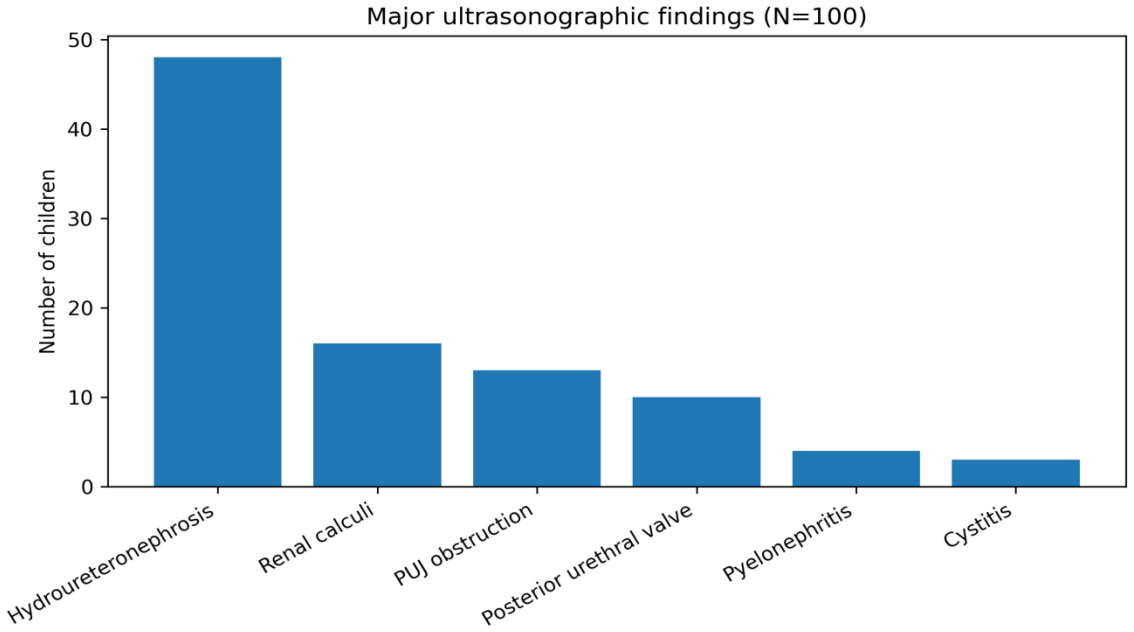


Table – 5: Distribution of vesicoureteral reflux grades among MCU-positive children (n=27).

VUR grade	n	%
Grade I	3	11.1
Grade II	9	33.3
Grade III	10	37.0
Grade IV	4	14.8
Grade V	1	3.7

Figure – 4: Distribution of vesicoureteral reflux grades among 27 MCU-positive children.

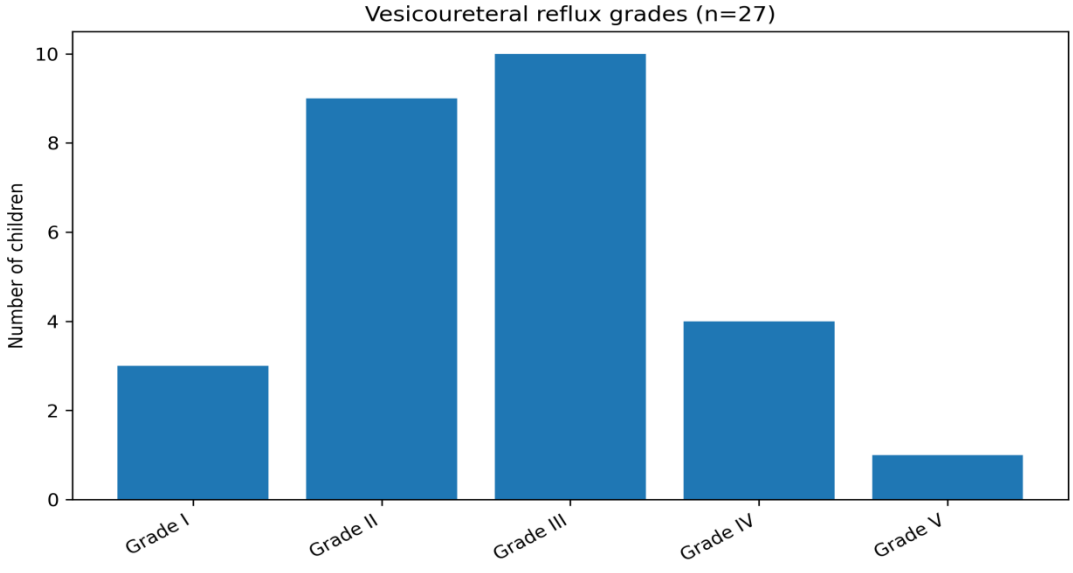


Table – 6: Association of urine culture status with imaging findings.

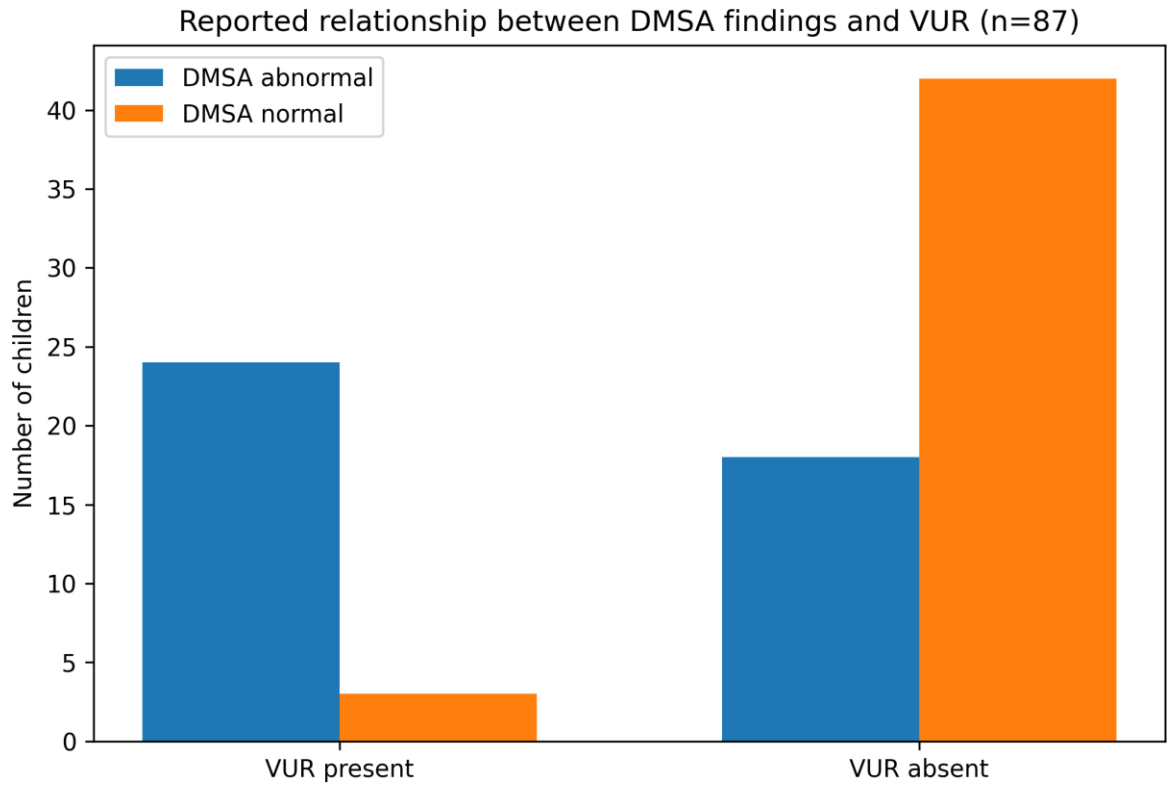
Imaging comparison	Culture positive, n	Culture negative, n	p value
Abnormal ultrasonography	31	35	0.070
Abnormal DMSA	18	22	0.175
VUR present	13	14	0.613

Table – 7: Reported relationship between DMSA findings and vesicoureteral reflux (n=87).

DMSA status	VUR present, n	VUR absent, n	Total
Abnormal	24	18	42
Normal	3	42	45
Total	27	60	87

Note: The overall DMSA frequency table recorded 40 abnormal and 47 normal scans, whereas the DMSA-VUR cross-tabulation contained 42 abnormal and 45 normal observations. Because the cross-tabulated cells generated the reported Pearson chi-square value, these cells have been retained for the association analysis. This two-observation difference should be reconciled against the original SPSS output or individual study records before submission. No values were imputed or altered during manuscript preparation.

Figure – 5: Relationship between DMSA findings and VUR.



Culture-imaging associations

Culture status was not significantly associated with abnormal ultrasonography, DMSA findings, or VUR (**Table - 6**). Notably, 35 culture-negative children had abnormal ultrasonography, 22 culture-negative children had abnormal DMSA findings, and 14 culture-negative children had VUR. These findings indicate that a negative culture did not exclude structural or cortical abnormalities in this symptomatic, high-risk cohort.

Table - 6 shows no statistically significant association between urine-culture status and abnormal ultrasonography (p=0.070), abnormal DMSA findings (p=0.175), or VUR (p=0.613). Nevertheless, substantial abnormalities occurred among culture-negative children: 35 had abnormal ultrasonography, 22 had abnormal DMSA findings, and 14 had VUR.

The study cross-tabulation demonstrated a strong association between VUR and abnormal DMSA findings (Pearson chi-square=22.706; p<0.001). Abnormal DMSA findings were recorded in 24 of 27 children with VUR (88.9%), compared with 18 of 60 children without VUR (30.0%) (**Table - 7** and **Figure - 5**). This pattern is consistent with contemporary evidence showing that renal cortical abnormalities on DMSA are more frequent in children with VUR, particularly clinically important or high-grade reflux [13, 15].

Table - 7 and **Figure - 5** demonstrate the relationship between renal cortical abnormalities on DMSA scintigraphy and VUR detected by MCU. Abnormal DMSA findings were present in 24 of 27 children with VUR (88.9%) and 18 of 60 children without VUR (30.0%). The difference was statistically significant (Pearson chi-square=22.706; p<0.001), indicating substantially greater renal parenchymal involvement among children with VUR in this cohort. DMSA and MCU provide complementary information: DMSA evaluates renal cortical involvement, whereas MCU directly identifies and grades reflux [13, 15].

Discussion

This prospective observational study described the microbiological and radiological profile of symptomatic pediatric UTI in a tertiary referral center. Urine culture was positive in 51%, ultrasonography was abnormal in 66%, and VUR was demonstrated in 31.0% of children who underwent MCU. These proportions should be interpreted as findings from a clinically selected referral cohort rather than population prevalence estimates.

The predominance of *E. coli* in the present study is consistent with contemporary pediatric research, although the proportion of *E. coli* varies across settings. *E. coli* accounted for 45.1% of culture-positive infections, followed by Proteus spp., Klebsiella spp., Acinetobacter spp., Pseudomonas spp., and *Candida albicans*. Recent studies continue to identify *E. coli* as the principal pediatric uropathogen and report a greater frequency of non-*E. coli* organisms in children with atypical infection or urinary tract malformations [1, 14]. The relatively high proportion of Proteus, Klebsiella, and Acinetobacter in this cohort may reflect its tertiary referral setting, previous antibiotic exposure, and the high frequency of structural urinary tract abnormalities.

Ultrasonography identified abnormalities in 66% of the study population, including hydroureteronephrosis, renal calculi, pelvi-ureteric junction obstruction, posterior urethral valves, and VUR-associated changes. This high yield should be interpreted in the context of a tertiary referral cohort enriched for children with severe symptoms and suspected urinary tract disease. Current NICE and Indian Society of Pediatric Nephrology guidance favors selective, risk-based imaging: acute ultrasonography is recommended for atypical UTI, while DMSA and MCU are reserved for defined age groups, recurrent infection, abnormal ultrasonography, non-*E. coli* infection, poor urinary flow, renal impairment, or suspicion of significant reflux or obstruction [1, 13, 15]. The present findings support such risk-based assessment rather than universal DMSA or MCU after every uncomplicated first UTI.

Culture-negative children still had important imaging abnormalities, and culture status was not significantly related to ultrasonography, DMSA, or VUR. Negative culture may follow prior antibiotics, delayed processing, frequent voiding, dilute urine, low bacterial counts, or collection problems. Nammalwar, et al. similarly evaluated DMSA abnormalities in culture-negative acute pyelonephritis [11]. These findings support

basing imaging decisions on the complete clinical phenotype rather than culture status alone.

The statistically significant relationship between VUR and abnormal DMSA findings represents an important observation of this study. Abnormal DMSA findings occurred in 88.9% of children with VUR in the cross-tabulated analysis. This association is clinically plausible because reflux may facilitate ascending infection and renal cortical injury, while DMSA is sensitive to renal parenchymal abnormalities and MCU directly demonstrates reflux [7, 8, 13, 15]. Nevertheless, DMSA and MCU answer different clinical questions and should be selected according to the child's clinical risk profile. The two-observation difference between the overall DMSA frequency table and the DMSA-VUR cross-tabulation should be reconciled from the original statistical output before submission.

Strengths and limitations

Strengths of this study include prospective recruitment, ultrasonography in all participants, microbiological characterization of culture-positive infections, and paired DMSA-MCU assessment in 87 children with severe upper-tract symptoms. The inclusion of culture-negative symptomatic children provides clinically relevant information regarding structural and renal cortical abnormalities that may not be identified through urine culture alone. Limitations include the single-center tertiary referral setting, referral and spectrum bias, overlapping ultrasonographic diagnoses, absence of multivariable analysis, incomplete antimicrobial susceptibility information in the available study records, and lack of long-term follow-up for recurrent UTI, renal scarring, hypertension, and kidney function. In addition, the two-observation difference between the overall DMSA frequency table and the DMSA-VUR cross-tabulation requires verification against the original SPSS output or individual case records before submission.

Conclusion

Symptomatic pediatric UTI may be associated with clinically important structural and renal cortical abnormalities, including in children with negative urine cultures. Ultrasonography is a useful first-line investigation, while DMSA scintigraphy and MCU should be selected according to age, clinical severity, recurrence, atypical infection, and suspicion of obstruction or reflux. The significant association between VUR and abnormal DMSA findings suggests that children with reflux require careful assessment for renal parenchymal involvement. Microbiological and radiological findings should therefore be interpreted together rather than using culture status alone to determine the need for imaging.

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