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Diagnostic Accuracy of Pyuria in Detection of Pediatric Urinary Tract Infections

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ABSTRACT

Introduction: Urinary tract infection (UTI), a common childhood bacterial infection, presents with nonspecific symptoms like fever, vomiting, irritability, and abdominal pain. Early diagnosis is crucial to prevent complications. Pyuria as a marker for UTI varies in diagnostic accuracy based on urine concentration. This study assesses pyuria's diagnostic accuracy in detecting pediatric UTIs, using urine culture as the gold standard across varied urine concentration groups. **Methodology:** This study at Mayo Hospital Lahore from January 23, 2025 to May 23, 2025 enrolled 190 children aged 2–12 suspected of UTI. Urine was sampled using midstream catch or Foley catheter. Urinalysis and culture were done for all samples, categorizing based on gravity and adjusting pyuria thresholds. Diagnostic measures were calculated for sensitivity, specificity, PPV, NPV, and overall accuracy. **Results:** Among 190 children (53.7% male, 46.3% female; mean age 7.29±3.22 years), fever was the most common symptom (62.1%). Urine culture was positive in 56.8% cases, with pyuria also positive in 56.3%. Pyuria had 87.1% sensitivity, 84.1% specificity, 87.8% PPV, 83.1% NPV, and overall accuracy of 85.7% compared to urine culture. Pyuria showed better performance in males and older children (7–12 years). **Conclusion:** Pyuria, adjusted for urine concentration, is highly accurate in detecting pediatric urinary tract infections, making it a useful initial screening tool. Nonetheless, urine culture confirmation remains crucial for accurate diagnosis and proper management.

INTRODUCTION

Urinary tract infections (UTIs) are prevalent bacterial infections that account for approximately 7% of febrile episodes observed in children aged under 24 months.[1-2] The identification and treatment of urinary tract infections (UTIs) pose significant challenges due to the presence of vague clinical manifestations, which may result in delays in appropriate intervention,[3-4] while urine culture is the conventional method for confirming UTI diagnosis, the extended duration of 24 to 48 hours for obtaining results necessitates the use of preliminary screening urinalysis to establish a tentative diagnosis, despite its inconsistent clinical precision.[5-6] The extent of this variability remains inadequately elucidated, notwithstanding the observation that approximately 10% of pediatric patients presenting with both positive urine culture results and symptomatic urinary tract infections exhibit an absence of pyuria as detected by urinalysis.[1,7]

Healthcare providers commonly utilize leukocyte esterase (LE), nitrite levels detected through dipstick urinalysis, and the presence of microscopic pyuria as key diagnostic markers for the preliminary identification of urinary tract infections (UTIs). Elevated quantities of LE or increased levels of pyuria are indicative of a higher likelihood of UTI according to clinical observations.[8-9] Neonates, characterized by the frequent occurrence of hypoosmolar urine, are more susceptible to developing pyuria-negative urinary tract infections (UTIs), a vulnerability that may be further heightened by the presence of such infections.[1,10]

In the research conducted by Nadeem et al., it was observed that the diagnostic efficacy of pyuria in detecting urinary tract infections exhibits variance relative to the concentration of urine samples. The study delineates that at low urine concentrations, pyuria manifests a sensitivity of 83.3% and specificity of 94.8%, whereas at moderate concentrations, the sensitivity elevates to 88.5% with a specificity of 90.7%. Conversely, at higher concentrations of urine, the sensitivity decreases to 73.8% while retaining

a specificity of 87.9%. The investigation ultimately determined that pyuria thresholds of 3 white blood cells per high power field (HPF) for low urine concentrations, 6 white blood cells/HPF for moderate concentrations, and 8 white blood cells/HPF for high concentrations present as optimal indicators for the diagnosis of urinary tract infections.[1]

In the study conducted by Batur and colleagues, the effectiveness of urinalysis parameters in diagnosing urinary tract infections was assessed by comparing them to urine culture, considered the definitive diagnostic method. The findings revealed that the urinalysis parameters demonstrated a sensitivity of 86.0% and a specificity of 68.4%. The positive predictive value (PPV) was calculated at 23.5%, while the negative predictive value (NPV) was notably higher at 97.7%. Additionally, the positive likelihood ratio was determined to be 2.7, whereas the negative likelihood ratio was found to be 0.2.[11]

This study aims to explore the diagnostic accuracy of pyuria in pediatric urinary tract infections, emphasizing its correlation with varying urine concentrations. By utilizing pyuria thresholds at different concentrations (3 WBCs/HPF at low, 6 WBCs/HPF at moderate, and 8 WBCs/HPF at high),[1] the research will offer a detailed evaluation of pyuria's diagnostic utility, informing evidence-based guidelines for interpretation. Ultimately, this will enhance the diagnosis and treatment of pediatric urinary tract infections, minimizing complications.

METHODOLOGY

A cross-sectional study was conducted in the Department of Pediatric Medicine at Mayo Hospital Lahore. The study duration was six months, from September 25, 2024, to March 24, 2025, after the approval of the synopsis. Non-probability consecutive sampling was employed. The sample size of 190 children was calculated using the WHO sample size calculator, considering an expected sensitivity of 86%, specificity of 68.4%,[11] prevalence of 17.6%,[10] a 95% confidence level, and a 12% margin of error.

Children aged 2 to 12 years, of either gender, presenting with symptoms suggestive of urinary tract infection (fever, vomiting, abdominal pain, irritability, and changes in urination habits such as frequency, urgency, or discomfort) were included in the study. Patients were excluded if they had an indwelling catheter, if their urine was collected through bag urine, or if their urine cultures showed mixed/multiple organisms or normal genital flora. After obtaining approval from the hospital's ethical committee and informed consent from parents or legal guardians, 190 children meeting the inclusion criteria were enrolled. Basic demographic data, including name, age, gender, and presenting symptoms, were recorded on a predefined proforma. Urine samples were collected by obtaining 5-10 ml of midstream urine in a sterile, labelled container. In children unable to provide midstream samples, urine was collected through a sterile Foley catheter in-and-out procedure.

The urine samples were immediately sent to the laboratory for urinalysis and culture. Urine concentration was measured using a urinometer and categorized into three groups based on specific gravity: low concentration (<1.011 g/ml), moderate concentration (1.011–1.020 g/ml), and high concentration (>1.020 g/ml). For urine culture, samples were streaked onto agar plates and incubated for 24–48 hours. Cultures were assessed for bacterial growth, and results were categorized as positive or negative according to predefined operational definitions. A positive urine culture was defined as growth of ≥100,000 CFU/ml for midstream specimens and ≥50,000 CFU/ml for catheter-obtained specimens.

For pyuria assessment, urine samples underwent centrifugation, and the white blood cells (WBCs) were counted per high power field (HPF). The pyuria thresholds applied were ≥3 WBCs/HPF for low concentration urine, ≥6 WBCs/HPF for moderate concentration, and ≥8 WBCs/HPF for high concentration. Cases were categorized into true positives, true negatives, false positives, and false negatives according to operational definitions based on urine culture results and corresponding pyuria thresholds. The data underwent entry into the statistical software SPSS version 27.0 for subsequent analysis. Quantitative variables, such as age, urine concentration, and WBCs/HPF, were reported in terms of their mean values and standard deviations. Qualitative variables, such as gender, presenting symptoms, culture results, and pyuria classification, were expressed as frequencies and percentages. Various diagnostic performance metrics, namely sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and overall diagnostic accuracy, were computed utilizing a 2x2 contingency table. Stratification of the data was performed based on age categories and gender, with diagnostic accuracy metrics recalculated for each subgroup post-stratification.

RESULTS

Table 1 shows the frequency distribution of different variables among the 190 children included in the study. Of these, 53.7% were male and 46.3% were female. The majority of children were in the 7–12 years age group (56.3%), while 43.7% were between 2–6 years, with a mean age of 7.29±3.22 years. Regarding presenting symptoms, fever was reported in 62.1% of patients, abdominal pain in 54.2%, vomiting in 57.4%, irritability in 64.7%, and changes in urination habits in 58.4%. When assessing urine concentration, 14.2% of samples were classified as low concentration, 47.4% as moderate, and 38.4% as high, with a mean urine concentration of 1.0182±0.007 g/ml. Urine culture results showed that 56.8% of children had a positive culture while 43.2% had a negative culture. The mean white blood cell count per high power field was 8.20±4.55. Pyuria was found to be positive in 56.3% of the cases and negative in 43.7%.

Table 2 presents the comparison between pyuria results and urine culture findings. Out of 108 culture-positive cases, 94 showed pyuria positivity while 14 were missed by pyuria. Among 82 culture-negative cases, 13 were wrongly identified as pyuria positive. This yielded a sensitivity of 87.1%, specificity of 84.1%, positive predictive value of 87.8%, negative predictive value of 83.1%, and an overall diagnostic accuracy of 85.7%.

Table 3 shows the stratification of findings based on gender. In males, pyuria showed a sensitivity of 86.8%,

specificity of 90.2%, positive predictive value of 92.9%, negative predictive value of 82.2%, and diagnostic accuracy of 88.2%. Among females, sensitivity was 87.2%, specificity was 78.1%, positive predictive value was 82.0%, negative predictive value was 84.2%, and diagnostic accuracy was 82.9%. These results indicate slightly better performance of pyuria in males compared to females.

Table 4 displays the stratification of results according to age groups. In children aged 2–6 years, pyuria demonstrated a sensitivity of 85.3%, specificity of 85.7%, positive predictive value of 85.3%, negative predictive value of 85.7%, and diagnostic accuracy of 85.5%. For children aged 7–12 years, sensitivity was 88.1%, specificity was 82.5%, positive predictive value was 89.3%, negative predictive value was 80.4%, and diagnostic accuracy was 85.9%. The results suggest that pyuria had slightly higher sensitivity and positive predictive value in the older age group.

Table 1

Frequency Distribution of Different Variables (n=190)

Variables		Frequency	Percent
Gender	Male	102	53.7%
	Female	88	46.3%
Age groups	2-6 years	83	43.7%
	7-12 years	107	56.3%
	Mean age	7.29±3.22 years	
Presenting symptoms	Fever	118	62.1%
	Abdominal pain	103	54.2%
	Vomiting	109	57.4%
	Irritability	123	64.7%
	Changes in urination habits	111	58.4%
Urine concentration	Lower than 1.011 g/ml	27	14.2%
	Moderate (1.011-1.020 g/ml)	90	47.4%
	Higher (>1.020 g/ml)	73	38.4%
	Mean urine concentration	1.0182±0.007 g/ml	
Culture result	Positive	108	56.8%
	Negative	82	43.2%
	Mean WBCs/HPF	8.20±4.55	
Pyuria result	Positive	107	56.3%
	Negative	83	43.7%

Table 2

Findings of UTI on Pyuria and Urine Culture

Pyuria result	Urine culture		Total	
	Positive	Negative		
Positive	94	13	107	Sn = 87.1% Sp = 84.1% PPV = 87.8% NPV = 83.1% Accuracy = 85.7%
Negative	14	69	83	
Total	108	82	190	

Table 3

Stratification of Findings of UTI on Pyuria and Urine Culture with Respect to Gender

Gender	Pyuria result	Urine culture		Total	
		Positive	Negative		
Male	Positive	53	4	57	Sn=86.8%, Sp=90.2%, PPV=92.9%, NPV=82.2%, DA=88.2%
	Negative	8	37	45	
	Total	61	41	102	
Female	Positive	41	9	50	Sn=87.2%, Sp=78.1%, PPV=82.0%, NPV=84.2%, DA=82.9%
	Negative	6	32	38	
	Total	47	41	88	

Table 4

Stratification of Findings of UTI on Pyuria and Urine Culture with Respect to Age

Age groups	Pyuria result	Urine culture		Total	
		Positive	Negative		
2-6 years	Positive	35	6	41	Sn=85.3%, Sp=85.7%, PPV=85.3%, NPV=85.7%, DA=85.5%
	Negative	6	36	42	
	Total	41	42	83	
7-12 years	Positive	59	7	66	Sn=88.1%, Sp=82.5%, PPV=89.3%, NPV=80.4%, DA=85.9%
	Negative	8	33	41	
	Total	67	40	107	

DISCUSSION

This study evaluated how adjusting pyuria thresholds based on urine concentration impacts the accuracy of diagnosing urinary tract infections in pediatric patients. The findings revealed that with adjusted thresholds, pyuria showed 87.1% sensitivity, 84.1% specificity, and an overall diagnostic accuracy of 85.7%.

Our study's sensitivity closely aligns with Shaikh et al.'s findings (84%) for leukocyte esterase tests in febrile children <36 months, with higher specificity observed in our study (84.1%). This improvement in specificity (attributed to adjusting pyuria thresholds based on urine concentration) addresses a significant limitation in standardized pyuria assessment.[12]

A review by Sameer et al. found pyuria sensitivity ranging from 59.10% to 92.20% (mean 80.81%). Our 87.1% sensitivity is higher, suggesting concentration adjustments optimize detection. Specificities in the review were 55.70% to 94.00% (mean 76.48%); our 84.1% specificity is robust.[13]

The Canadian Paediatric Society found pyuria to be 73% sensitive and 81% specific for UTI diagnosis. Our study showed higher sensitivity with similar specificity, possibly due to methodological variations in defining and assessing pyuria. The lack of uniformity in pyuria definition, as noted in the literature, contributes to variations in reported diagnostic accuracy.[14]

Our study found slightly better diagnostic performance in males than females. This gender difference, not well-studied previously, may be due to anatomical variations influencing sample collection or diverse pathogen profiles by gender. Additionally, older children showed slightly better sensitivity than younger children, possibly due to developmental aspects affecting sample reliability or immune responses.

A study highlighted that urinalysis techniques significantly influence diagnostic accuracy, with enhanced methods yielding higher sensitivity (84%) and specificity (94%) compared to automated methods. While our study did not compare different urinalysis techniques, our overall results suggest that our methodology produced results comparable to enhanced urinalysis approaches.[15]

It is notable that despite our relatively high sensitivity, 12.9% of culture-proven UTIs did not demonstrate pyuria based on our thresholds. This finding is consistent with literature indicating that pyuria may be absent in true UTIs under certain circumstances. The American Academy of Pediatrics suggests that when pyuria is absent in true UTIs,

it is usually the method or definition of pyuria that is at fault.[16]

However, more recent evidence indicates that other factors, including the type of uropathogen, timing of sample collection relative to symptom onset, and patient-specific factors like neutropenia, may contribute to this phenomenon.[13,16]

The debate around pyuria's role in UTI diagnosis continues, with some arguing that febrile UTIs should always result in pyuria, bringing into question whether many positive cultures without pyuria represent contamination or asymptomatic bacteriuria rather than true infection.[14] Our study contributes to this discussion by demonstrating that even with concentration-adjusted thresholds, a small percentage of culture-proven infections may not exhibit pyuria.

Our methodology of adjusting pyuria thresholds based on urine concentration addresses a critical gap in standardized assessment. Traditional fixed thresholds may lead to misclassification, particularly in highly concentrated or dilute specimens. By implementing concentration-specific cutoffs (≥3 WBCs/HPF for low concentration, ≥6 WBCs/HPF for moderate concentration, and ≥8 WBCs/HPF for high concentration), we attempted to optimize diagnostic accuracy across varying hydration states.

While our approach showed promising results, the findings underscore that pyuria remains an imperfect marker for UTI. A study noted, "for febrile children <36 months of age undergoing bladder catheterization for suspected UTI, pyuria will be absent in ~20% of children who are eventually shown to have pure growth of a pathogen on a culture".[12,17] Our lower rate of missed cases (12.9%) suggests that concentration-adjusted thresholds may reduce but not eliminate this diagnostic challenge.

The implications of these findings are significant for clinical practice. While pyuria demonstrates good diagnostic accuracy and can serve as a valuable screening tool, clinicians should be aware of its limitations. Particularly in high-risk populations or when clinical suspicion is strong despite negative pyuria, proceeding with culture remains essential. This practice aligns with current guidelines that recommend confirming UTI diagnosis with both urinalysis and culture results.[12,14]

CONCLUSION

Pyuria, adjusted for urine concentration, shows high diagnostic accuracy in detecting pediatric urinary tract infections and can serve as an effective preliminary screening tool. However, confirmation with urine culture remains essential to ensure accurate diagnosis and appropriate management.

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