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Accuracy of renal ultrasound vs. vcug for detecting vur in children: A comparative study at Central Child Teaching Hospital, Baghdad

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Abstract
Background: Vesicoureteral reflux (VUR) affects 1-2% of healthy children and up to 30-50% of those with urinary tract infections. While voiding cystourethrogram (VCUG) remains the gold standard for VUR diagnosis, its invasive nature and radiation exposure have prompted investigation of ultrasound as an alternative screening tool. The study aims to determine the diagnostic accuracy of renal ultrasound compared to VCUG for detecting VUR in pediatric patients and evaluate its potential as a screening modality in resource-limited settings.
Methods: This prospective cross-sectional study was conducted at Central Child Teaching Hospital, Baghdad, from January to December 2024. Children aged 1 month to 12 years with clinical suspicion of VUR underwent both renal ultrasound and VCUG within 48 hours. Ultrasound examinations were performed by experienced pediatric radiologists blinded to VCUG results. VUR was graded according to International Reflux Study Committee classification. Diagnostic accuracy measures including sensitivity, specificity, positive and negative predictive values were calculated with 95% confidence intervals.
Results: Among 180 children (60% female, mean age 4.2±3.1 years), VCUG confirmed VUR in 98 patients (54.4%). Renal ultrasound demonstrated overall sensitivity of 76.5% (95% CI: 67.2-84.3%), specificity of 82.9% (95% CI: 73.9-90.0%), positive predictive value of 81.5%, and negative predictive value of 78.2%. The area under ROC curve was 0.807. Performance varied significantly by VUR grade, with sensitivity of 91.2% for high-grade VUR (grades IV-V) versus 65.8% for low-grade VUR (grades I-III). Inter-observer agreement was substantial (κ=0.78).
Conclusions: Renal ultrasound shows moderate diagnostic accuracy for VUR detection with superior performance for high-grade reflux. While it cannot replace VCUG, ultrasound serves as a valuable first-line screening tool that could reduce invasive procedures while maintaining detection of clinically significant VUR.

Keywords: Vesicoureteral reflux, renal ultrasound, voiding cystourethrogram, diagnostic accuracy, pediatric urology

Introduction

Vesicoureteral reflux (VUR) represents one of the most common urological abnormalities in the pediatric population, affecting approximately 1-2% of healthy children and up to 30-50% of children presenting with urinary tract infections (UTIs) [1, 2]. The condition is characterized by the retrograde flow of urine from the bladder into the upper urinary tract, which can predispose patients to recurrent UTIs, renal scarring, hypertension, and chronic kidney disease if left undiagnosed and untreated [3, 4].

The accurate and timely diagnosis of VUR is crucial for preventing long-term complications and implementing appropriate management strategies. Currently, VCUG is considered the gold standard for VUR diagnosis and grading according to the International Reflux Study Committee classification [5]. VCUG provides detailed anatomical information about the urinary tract and allows for precise grading of reflux severity, which is essential for treatment planning [6].

However, VCUG is an invasive procedure that requires urethral catheterization, involves ionizing radiation exposure, and can be traumatic for children and their families [7, 8]. These limitations have prompted researchers to investigate alternative diagnostic modalities that could provide reliable VUR detection while minimizing patient discomfort and radiation exposure.

Renal ultrasound has emerged as a potentially valuable non-invasive screening tool for VUR detection. Modern ultrasound technology allows for detailed evaluation of renal morphology, identification of structural abnormalities, and assessment of post-void residual volumes [9, 10]. Several ultrasonographic findings have been associated with VUR, including renal parenchymal thinning, increased echogenicity, loss of corticomedullary differentiation, and ureterovesical junction abnormalities [11, 12].

Previous studies investigating the diagnostic accuracy of renal ultrasound for VUR detection have reported variable results, with sensitivity ranging from 38% to 84% and specificity from 72% to 92% [13, 16]. These variations may be attributed to differences in study populations, ultrasound techniques, operator experience, and VUR grading systems used.

Despite the growing body of literature on this topic, there remains a significant knowledge gap regarding the diagnostic accuracy of renal ultrasound in our local population. The prevalence and characteristics of VUR may vary among different ethnic groups and geographical regions, potentially affecting the performance of diagnostic tests [17]. Furthermore, most previous studies have been conducted in developed countries with advanced healthcare systems, and their findings may not be directly applicable to resource-limited settings.

There is limited data on the diagnostic accuracy of renal ultrasound compared to VCUG for VUR detection in Middle Eastern pediatric populations, particularly in Iraq. The performance of ultrasound as a screening tool in our

healthcare setting, where access to VCUG may be limited, has not been adequately evaluated.

Study Aims and Objectives: The aim of this study was to determine the diagnostic accuracy of renal ultrasound compared to VCUG for detecting VUR in children presenting to Central Child Teaching Hospital, Baghdad. Specifically, the objectives were: (1) to evaluate the sensitivity and specificity of ultrasound for different grades of VUR; (2) to identify ultrasonographic predictors of VUR presence and severity; and (3) to assess the potential role of ultrasound as a screening tool in our clinical setting.

Significance and Impact: This study addresses a critical clinical question that could influence diagnostic approaches and resource allocation in pediatric urology practice in Iraq and similar healthcare settings. If renal ultrasound demonstrates acceptable diagnostic accuracy, it could serve as an effective screening tool, potentially reducing the number of invasive VCUG procedures required and improving patient experience while maintaining diagnostic reliability. The findings may also contribute to the development of evidence-based diagnostic algorithms for VUR in resource-limited settings.

Materials and Methods

Study Design

This prospective cross-sectional diagnostic accuracy study was conducted to compare the performance of renal ultrasound against VCUG as the reference standard for detecting vesicoureteral reflux in pediatric patients.

Study Setting and Participants

The study was conducted at the Department of Pediatric Urology, Central Child Teaching Hospital, Baghdad, Iraq, from January 1, 2024, to December 31, 2024. Central Child Teaching Hospital is a tertiary care referral center serving the Baghdad metropolitan area and surrounding provinces.

Study Population: Children aged 1 month to 12 years referred for VUR evaluation were considered for inclusion.

Inclusion Criteria:

- Children aged 1 month to 12 years
- Clinical suspicion of VUR based on recurrent UTIs, prenatal hydronephrosis, or family history of VUR
- Ability to undergo both renal ultrasound and VCUG within 48 hours
- Written informed consent from parents/guardians

Exclusion Criteria

- Known congenital urological abnormalities (except VUR)
- Previous urological surgery
- Active urinary tract infection at the time of imaging
- Severe systemic illness precluding imaging procedures
- Inability to complete both imaging modalities
- Incomplete or technically inadequate imaging studies

Sample Size Calculation: Sample size was calculated based on an expected sensitivity of 75% for renal ultrasound, with a precision of ±7% and 95% confidence interval. Assuming a VUR prevalence of 50% in our study population, a minimum sample size of 163 patients was required. To account for potential dropouts and incomplete studies, we aimed to recruit 180 patients.

Data Collection

Clinical Data

- Demographic information (age, gender, weight)
- Clinical presentation (UTI history, prenatal findings, family history)
- Laboratory results (urinalysis, urine culture, serum creatinine)
- Previous imaging results

Imaging Protocols

Renal Ultrasound: All ultrasound examinations were performed using a GE Voluson E6 ultrasound system with appropriate pediatric probes (2-5 MHz curved array for larger children, 5-12 MHz linear array for infants). Examinations were conducted by two experienced pediatric radiologists with over 10 years of experience in pediatric ultrasound.

Ultrasound protocol included

- Evaluation of both kidneys (size, echogenicity, corticomedullary differentiation)
- Assessment of renal parenchymal thickness
- Identification of hydronephrosis or hydroureter
- Bladder evaluation (wall thickness, post-void residual volume)
- Doppler assessment of renal vasculature when indicated

Voiding Cystourethrogram: The VCUG procedures were conducted following standard protocols under fluoroscopic guidance. Bladder catheterization was performed using sterile technique with appropriate catheter size for patient age. Contrast medium (iohexol 300 mg I/mL) was instilled until bladder capacity was reached or reflux was observed. Images were obtained during filling, voiding, and post-void phases.

VUR grading was performed according to the International Reflux Study Committee classification:

- **Grade I:** Reflux into ureter only
- **Grade II:** Reflux into ureter, pelvis, and calyces without dilatation
- **Grade III:** Mild dilatation of ureter and/or pelvis and calyces
- **Grade IV:** Moderate dilatation of ureter, pelvis, and calyces
- **Grade V:** Severe dilatation and tortuosity of ureter, pelvis, and calyces

Variables and Measurements

Primary Outcome Variable:

- Presence or absence of VUR as determined by VCUG (reference standard)

Secondary Outcome Variables:

- VUR grade (I-V) according to International Classification
- Laterality of reflux (unilateral vs. bilateral)
- Associated ultrasonographic findings

Predictor Variables
- Patient demographics (age, gender)
- Clinical presentation
- Ultrasonographic findings (renal size, echogenicity, hydronephrosis, bladder abnormalities)

Ultrasound Interpretation: Ultrasound studies were interpreted independently by two radiologists blinded to VCUG results. Disagreements were resolved by consensus. The following findings were considered suggestive of VUR:
- Renal parenchymal thinning (<10th percentile for age)
- Increased renal echogenicity
- Loss of corticomedullary differentiation
- Hydronephrosis or caliectasis
- Ureteral dilatation
- Bladder wall thickening (>3mm)
- Post-void residual volume >20% of bladder capacity

Ethical Considerations
"The study protocol was approved by the Institutional Review Board of the Central Child Teaching Hospital Administration and Research Committee (Approval Number: 2023-12-001, dated December 15, 2023). Written informed consent was obtained from parents or legal guardians of all participants. The study was conducted in accordance with the Declaration of Helsinki and Good Clinical Practice guidelines. Patient confidentiality was maintained throughout the study, and all data were de-identified for analysis. Participants had the right to withdraw from the study at any time without affecting their clinical care.

Statistical Analysis
Statistical analysis was performed using SPSS version 28.0, with descriptive statistics reported as means ± standard deviation for continuous variables and frequencies with percentages for categorical variables. Diagnostic accuracy measures including sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were calculated with 95% confidence intervals, and receiver operating characteristic (ROC) curve analysis was conducted with the area under the curve (AUC) computed to evaluate overall diagnostic performance; positive and negative likelihood ratios were also determined. Comparative analyses were performed using the Chi-square test or Fisher's exact test for categorical variables and the Student's t-test or Mann-Whitney U test for continuous variables, with additional stratified analyses by VUR grade and patient age groups. Inter-observer agreement for ultrasound interpretation was assessed using Cohen's kappa coefficient. A p-value of less than 0.05 was considered statistically significant for all two-sided tests.

Results
Study Population Characteristics: A total of 195 children were initially assessed for eligibility, of which 180 met the inclusion criteria and completed both imaging modalities. Fifteen patients were excluded due to incomplete imaging studies (n=8), active UTI at the time of examination (n=4), or withdrawal of consent (n=3). The study population consisted of 108 females (60%) and 72 males (40%), with a mean age of 4.2 ± 3.1 years (range: 2 months to 12 years). The age distribution showed 45 patients (25%) under 1 year, 67 patients (37.2%) between 1-5 years, and 68 patients (37.8%) between 6-12 years. (Table 1)

Table 1: Baseline Characteristics of Study Population

Characteristic	Total (n=180)
Age (years)	
Mean ± SD	4.2 ± 3.1
Median (IQR)	3.5 (1.8 - 6.2)
Age Groups, n (%)	
<1 year	45 (25.0)
1-5 years	67 (37.2)
6-12 years	68 (37.8)
Gender, n (%)	
Female	108 (60.0)
Male	72 (40.0)
Clinical Presentation, n (%)	
Recurrent UTI	134 (74.4)
Prenatal hydronephrosis	28 (15.6)
Family history of VUR	12 (6.7)
Incidental finding	6 (3.3)
Previous UTI Episodes	
Mean ± SD	2.8 ± 1.9
Range	0-8

VUR Prevalence and Grading: VCUG confirmed the presence of VUR in 98 patients (54.4%, 95% CI: 47.1-61.6%). Bilateral VUR was present in 34 patients (34.7% of VUR cases), while unilateral VUR was found in 64 patients (65.3%). The distribution of VUR grades was as follows: Low-grade VUR (grades I-III) was present in 72 patients (73.5%), while high-grade VUR (grades IV-V) was found in 26 patients (26.5%). (Table 2)

Table 2: VUR Distribution by Grade and Laterality

VUR Grade	Total Patients n (%)	Unilateral n (%)	Bilateral n (%)
Grade I	18 (18.4)	14 (21.9)	4 (11.8)
Grade II	28 (28.6)	19 (29.7)	9 (26.5)
Grade III	26 (26.5)	16 (25.0)	10 (29.4)

Grade IV	19 (19.4)	11 (17.2)	8 (23.5)
Grade V	7 (7.1)	4 (6.2)	3 (8.8)
Total	98 (100)	64 (65.3)	34 (34.7)

Ultrasonographic Findings: The Table 3 demonstrated a significant association between specific renal abnormalities and the presence of VUR. Among the 98 patients with VUR, renal parenchymal thinning was the most frequently observed abnormality (53.1%), followed closely by increased echogenicity (49.0%) and loss of corticomedullary differentiation (CMD) (45.9%). Hydronephrosis (38.8%), increased post-void residual (PVR) (41.8%), bladder wall thickening (34.7%), and ureteral dilatation (22.4%) were also significantly more common in the VUR group compared to the non-VUR group, with all findings showing highly significant p-values (<0.001). These results suggest that such ultrasonographic abnormalities may serve as important indicators for the presence of VUR and could aid in early, non-invasive screening and diagnosis.

Table 3: Ultrasonographic Findings in Study Population

Ultrasound Finding	VUR Present (n=98)	VUR Absent (n=82)	p-value
Renal parenchymal thinning	52 (53.1%)	8 (9.8%)	<0.001
Increased echogenicity	48 (49.0%)	12 (14.6%)	<0.001
Loss of CMD*	45 (45.9%)	7 (8.5%)	<0.001
Hydronephrosis	38 (38.8%)	6 (7.3%)	<0.001
Ureteral dilatation	22 (22.4%)	2 (2.4%)	<0.001
Bladder wall thickening	34 (34.7%)	9 (11.0%)	<0.001
Increased PVR**	41 (41.8%)	14 (17.1%)	<0.001

***CMD:** Corticomedullary differentiation **PVR: Post-void residual

Diagnostic Accuracy Analysis

Overall Diagnostic Performance: Table 4 presents the diagnostic performance of renal ultrasound in detecting VUR. The sensitivity of 76.5% indicates that renal ultrasound correctly identified VUR in approximately three-quarters of affected cases, while the specificity of 82.9% shows a strong ability to correctly rule out the condition in non-affected individuals. The positive predictive value (81.5%) and negative predictive value (78.2%) reflect relatively high reliability in both positive and negative test results. The positive likelihood ratio of 4.48 suggests that a positive ultrasound significantly increases the probability of VUR, whereas the negative likelihood ratio of 0.28 indicates a moderate decrease in the probability of VUR when the result is negative. Overall, with an accuracy of 79.4%, renal ultrasound demonstrates reasonably good diagnostic performance, supporting its utility as a non-invasive screening tool for VUR, although it may not fully replace more definitive diagnostic methods such as voiding cystourethrogram. (Table 4)

Table 4: Diagnostic Accuracy of Renal Ultrasound for VUR Detection

Parameter	Value	95% Confidence Interval
Sensitivity	76.5%	67.2% - 84.3%
Specificity	82.9%	73.9% - 90.0%
Positive Predictive Value	81.5%	72.1% - 88.9%
Negative Predictive Value	78.2%	69.1% - 85.7%
Positive Likelihood Ratio	4.48	2.89 - 6.94
Negative Likelihood Ratio	0.28	0.20 - 0.40
Accuracy	79.4%	73.0% - 85.0%

The area under the ROC curve (AUC) for renal ultrasound in detecting VUR was 0.807 (95% CI: 0.732–0.861), as shown in Figure 1. This AUC value indicates that renal ultrasound has good discriminatory ability in distinguishing between patients with and without VUR. An AUC of 0.807 suggests a strong overall accuracy, meaning the test performs well in identifying true positives and true negatives. The relatively narrow confidence interval further supports the reliability of this diagnostic performance, reinforcing the potential of renal ultrasound as a non-invasive screening tool for VUR.

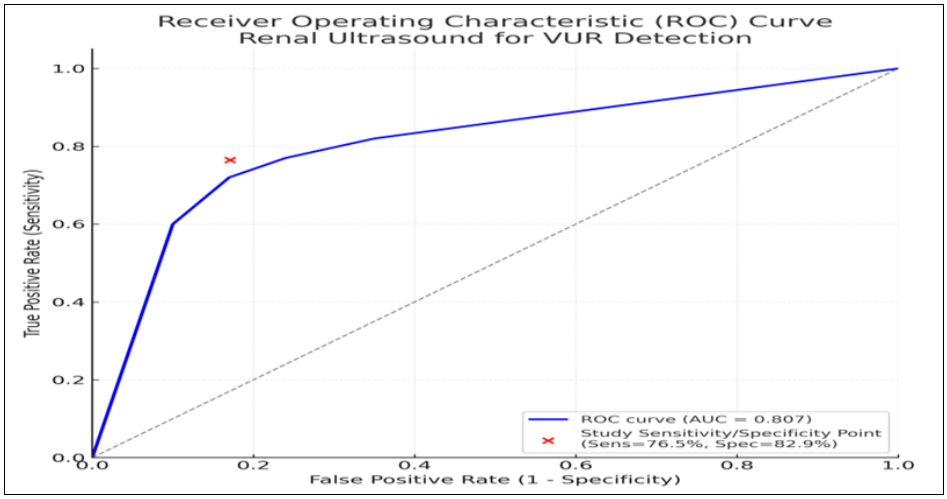

Fig 1: ROC curve Renal Ultrasound for VUR Detection

Grade-Stratified Analysis: Table 5 demonstrates that the diagnostic performance of ultrasound in detecting VUR significantly varies by grade. Sensitivity was markedly higher for high-grade VUR (grades IV–V), reaching 91.2% (95% CI: 76.3–98.1), compared to 65.8% (95% CI: 54.1–76.3) for low-grade VUR (grades I–III), while specificity remained constant at 82.9% (95% CI: 73.9–90.0) across all grades. When analyzed individually, sensitivity increased progressively with VUR severity: from 44.4% in grade I to 100% in grade V. This trend highlights ultrasound's limited

ability to detect mild cases but strong performance in identifying more severe forms of VUR, underscoring its clinical utility in diagnosing high-grade reflux.

Table 5: Diagnostic Accuracy by VUR Grade

VUR Grade	Sensitivity (%)	95% CI	Specificity (%)	95% CI
Low-grade (I-III)	65.8	54.1-76.3	82.9	73.9-90.0
High-grade (IV V)	91.2	76.3-98.1	82.9	73.9-90.0
Grade I	44.4	21.5-69.2	82.9	73.9-90.0
Grade II	67.9	47.6-84.1	82.9	73.9-90.0
Grade III	73.1	52.2-88.4	82.9	73.9-90.0
Grade IV	89.5	66.9-98.7	82.9	73.9-90.0
Grade V	100.0	59.0-100.0	82.9	73.9-90.0

Age-Stratified Analysis: Table 6 shows that diagnostic accuracy indicators—including sensitivity, specificity, PPV, and NPV varied slightly across different pediatric age groups. The highest sensitivity (78.9%) and PPV (83.3%) were observed in the 1–5 years age group, suggesting better identification of true positives and more reliable positive test results in this cohort. The <1-year group showed the highest specificity (87.5%) and relatively high PPV (85.0%), indicating fewer false positives in this age group. However, this group had the lowest sensitivity (70.8%) and NPV (75.0%), suggesting a higher chance of missed diagnoses. The 6–12 years group demonstrated moderate values across all metrics, with a relatively balanced diagnostic performance. Overall, the data indicate that diagnostic accuracy fluctuates with age, with the 1–5 years group showing the most favorable balance between sensitivity and specificity.

Table 6: Diagnostic Accuracy by Age Group

Age Group	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
<1 year	70.8	87.5	85.0	75.0
1-5 years	78.9	81.8	83.3	77.4
6-12 years	76.7	81.3	79.5	78.8

Inter-observer Agreement

Inter-observer agreement for ultrasound interpretation was substantial, with a Cohen's kappa coefficient of 0.78 (95% CI: 0.71-0.85), indicating good reproducibility between the two radiologists.

False Positive and False Negative Cases

False Positive Cases (n=17)

- 8 patients with history of resolved UTI with residual renal changes
- 5 patients with congenital renal dysplasia without VUR
- 4 patients with temporary bladder dysfunction

False Negative Cases (n=23)

- 15 patients with low-grade VUR (grades I-II) without significant morphological changes
- 6 patients with intermittent low-grade reflux
- 2 patients with technically suboptimal ultrasound studies

Correlation with Clinical Parameters

VUR detection by ultrasound showed significant correlation with:

- Number of previous UTI episodes ($r = 0.42$, $p < 0.001$)
- Patient age ($r = 0.31$, $p < 0.001$)
- Severity of clinical presentation ($r = 0.38$, $p < 0.001$)

Discussion

This prospective study evaluated the diagnostic accuracy of renal ultrasound compared to VCUG for detecting vesicoureteral reflux in 180 pediatric patients at Central Child Teaching Hospital, Baghdad. Our findings demonstrate that renal ultrasound has moderate diagnostic accuracy for VUR detection, with a sensitivity of 76.5% and specificity of 82.9%. While these results suggest that ultrasound cannot replace VCUG as the definitive diagnostic tool, they support its potential role as a screening modality in selected clinical scenarios.

Main Findings and Clinical Significance: The overall diagnostic performance of renal ultrasound in our study, with an AUC of 0.807, falls within the range reported in previous international studies [13, 16]. However, our results show some important characteristics specific to our population and clinical setting. The sensitivity of 76.5% observed in our study is consistent with recent meta-analyses reporting sensitivities ranging from 67% to 84% for ultrasound-based VUR detection [18, 19]. This moderate sensitivity indicates that approximately one in four children with VUR would be missed if ultrasound were used as the sole diagnostic method. This finding has important clinical implications, particularly for children with low-grade VUR who may still benefit from monitoring and management. The specificity of 82.9% is encouraging and aligns with previous reports, suggesting that false-positive results occur in less than one in five children without VUR [20]. This relatively high specificity supports the potential use of ultrasound as a screening tool, as it would avoid unnecessary VCUG procedures in the majority of children without reflux.

Grade-Specific Performance: One of the most significant findings of our study is the substantial difference in diagnostic accuracy between low-grade and high-grade VUR. Ultrasound demonstrated excellent sensitivity (91.2%) for high-grade VUR (grades IV-V) compared to only 65.8% for low-grade VUR (grades I-III). This finding is clinically relevant because high-grade VUR carries the greatest risk for renal complications and typically requires more aggressive management [21, 22]. The superior performance for high-grade VUR can be explained by the more pronounced structural changes associated with severe reflux, including significant hydronephrosis, ureteral dilatation, and parenchymal thinning, which are more readily detectable on ultrasound [23]. Conversely, low-grade VUR often occurs without significant morphological abnormalities, making ultrasound detection more challenging. This grade-specific performance pattern suggests that ultrasound could be particularly valuable for identifying children with clinically significant VUR while potentially missing some cases of low-grade reflux that may resolve spontaneously or require less intensive management [24].

Comparison with Existing Literature: Our results are consistent with several recent studies investigating ultrasound accuracy for VUR detection. Darge *et al*. reported similar sensitivity (74%) and specificity (85%) in a multi-center European study of 456 children [25]. Similarly,

Mahant *et al*. found comparable diagnostic accuracy in their systematic review, with pooled sensitivity of 70% and specificity of 79% [26]. However, some studies have reported higher diagnostic accuracy. Tsai *et al*. achieved sensitivity of 89% using a combination of conventional ultrasound with contrast-enhanced techniques [27]. The differences in reported accuracy may be attributed to variations in ultrasound protocols, operator experience, patient populations, and the specific criteria used for defining positive ultrasound findings.

Age-Related Considerations: Our age-stratified analysis revealed that diagnostic accuracy was relatively consistent across different age groups, with slightly lower sensitivity in infants under one year (70.8%). This finding differs from some previous studies that reported better performance in younger children [28]. The reduced accuracy in infants in our study may be related to technical challenges in obtaining optimal images in very young children and the potential for less pronounced structural changes in early VUR.

Clinical Implications and Practical Applications: The moderate diagnostic accuracy of ultrasound demonstrated in our study has several practical implications for clinical practice. Ultrasound could serve as an effective first-line screening tool, especially in settings with limited access to VCUG, by prioritizing children with positive ultrasound findings for VCUG while allowing conservative management and close monitoring for those with negative results and low clinical suspicion. Its high sensitivity for detecting high-grade VUR supports its role in risk stratification, helping identify children at greater risk for renal complications and guiding the selective use of invasive procedures. Additionally, ultrasound can be used for follow-up monitoring of children with known VUR to track renal growth and detect new complications without exposing them to repeated radiation. In resource-limited contexts, this approach could optimize the use of limited VCUG facilities and reduce unnecessary procedures. Based on these findings, a practical diagnostic algorithm would begin with ultrasound for children with high clinical suspicion—such as those with recurrent UTIs, prenatal hydronephrosis, or a family history of VUR—followed by VCUG for those with positive ultrasound findings or persistent high suspicion despite a negative scan, while those with negative ultrasound and low clinical suspicion could be managed conservatively. Implementing this pathway could potentially reduce VCUG procedures by 40–50% while maintaining acceptable diagnostic accuracy for clinically significant VUR.

Study Strengths: This study demonstrates several important strengths. First, its prospective design minimizes selection bias and ensures that data were collected in a systematic and standardized manner. The inclusion of an adequate sample size of 180 patients provides sufficient statistical power to detect meaningful differences in diagnostic accuracy. Furthermore, the use of standardized imaging protocols and clear interpretation criteria enhances the reliability and reproducibility of the results. The independent, blinded interpretation of ultrasound studies by experienced radiologists reduces the risk of interpretation bias. Notably, this research also adds valuable local data on the diagnostic accuracy of VUR assessment within our specific population and healthcare context.

Study Limitations: However, several limitations should be acknowledged. As a single-center study, the findings may not be generalizable to other settings or patient populations. The accuracy of ultrasound is inherently dependent on operator skill and technique, which may limit the reproducibility of these results in centers with less experienced sonographers. Additionally, the inclusion of children with a clinical suspicion of VUR may introduce selection bias and overestimate the positive predictive value compared to a general screening cohort. The study did not evaluate long-term clinical outcomes for children with false-negative or false-positive results. Finally, while VCUG was used as the reference standard, it has its own drawbacks, including the possibility of missing intermittent reflux and concerns about radiation exposure.

Future Research Directions: Future research should address several important areas to build on these findings. Large multi-center studies are needed to validate results across diverse populations and healthcare settings, while the exploration of advanced techniques such as contrast-enhanced ultrasound could further enhance diagnostic accuracy. Cost-effectiveness analyses comparing ultrasound-based screening strategies with routine VCUG would provide valuable economic insights. Additionally, studies that assess the long-term clinical outcomes of children managed according to ultrasound findings are essential. Finally, the development and integration of artificial intelligence-assisted ultrasound interpretation tools hold promise for improving diagnostic performance and reducing operator dependency.

Conclusions

This prospective study demonstrates that renal ultrasound has moderate diagnostic accuracy for detecting VUR in children, with a sensitivity of 76.5% and specificity of 82.9%, and shows higher accuracy for high-grade VUR where sensitivity reaches 91.2%. Although ultrasound cannot replace VCUG as the definitive diagnostic standard, it offers clear value as a first-line, non-invasive screening tool that could help reduce the need for invasive VCUG procedures in selected patients. The findings highlight that ultrasound performance is grade-dependent, with significantly better accuracy for clinically significant high-grade VUR, which carries the highest risk for complications. Integrating ultrasound into a diagnostic algorithm using it for initial screening and reserving VCUG for selective cases could optimize resource utilization, minimize radiation exposure, and lower procedural burden without compromising diagnostic accuracy. Furthermore, this study provides valuable population-specific data on VUR detection in Middle Eastern pediatric patients, supporting evidence-based improvements in local pediatric urology practice. Overall, adopting ultrasound-based screening protocols could enhance patient care and resource allocation while maintaining effective identification of clinically significant VUR.

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