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Original Article

Fluoroscopic Voiding Cystourethrography and Voiding Vesicoureteral Urosonography as A Comparison in Pediatric Vesicoureteral Reflux

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ABSTRACT

Background: Vesicoureteral reflux (VUR) is a significant pediatric condition linked to recurrent urinary tract infections (UTIs) and can adversely affect a child's growth and development if not diagnosed promptly. Traditional diagnostic methods such as fluoroscopic voiding cystourethrography (VCUG) offer high accuracy but involve radiation risks, which are particularly concerning in pediatric populations.

Objective: To compare the efficacy and safety of voiding vesicoureteral urosonography (VUS) with VCUG in the diagnosis of VUR in children, highlighting the advantages of a radiation-free method.

Methods: This cross-sectional study included 208 renal ureteral units from 145 children diagnosed with VUR at the University of Lahore Teaching Hospital between July 2022 and September 2023. Patients underwent both VCUG and VUS. VUS utilized a SonoVue contrast agent, and the imaging involved real-time monitoring using a Super Sonic Imagine's Aixplorer V model with CEUS+ capability. Data were analyzed using SPSS version 25, focusing on the agreement between VUS and VCUG in diagnosing various grades of VUR.

Results: VUS accurately identified no reflux in 98 of 112 cases as confirmed by VCUG. In higher grades of reflux (III to V), VUS detected 24 of 32 cases for Grade III, 7 of 13 for Grade IV, and 10 of 13 for Grade V. The overall agreement analysis revealed substantial consistency between VUS and VCUG across all grades of VUR, demonstrating that VUS can effectively identify higher grades of reflux.

Conclusion: Voiding vesicoureteral urosonography is a viable and safer alternative to VCUG for the diagnosis of VUR in pediatric patients. It offers the benefits of being radiation-free, with high diagnostic accuracy, particularly in detecting severe cases of reflux. This study supports the increased adoption of VUS in clinical settings, especially for children, to reduce radiation exposure risks.

Keywords: Vesicoureteral reflux, VUR, pediatric urology, voiding cystourethrography, VCUG, voiding urosonography, VUS, urinary tract infections, UTIs, radiation safety, diagnostic imaging.

INTRODUCTION

Urinary tract infections (UTIs) are the most common bacterial infections affecting the pediatric population, with significant prevalence rates observed within the first year of life—approximately 2% in males and 8% in females (1). Recurrence is common, with about 30% of infants experiencing a subsequent UTI within three years of the first episode. A notable complication of recurrent UTIs in children is the development of renal scarring and upper urinary tract infections, closely associated with vesicoureteral reflux (VUR), a primary contributor to UTIs in this demographic (2). VUR is now more frequently identified through advancements in imaging techniques such as contrast-enhanced voiding urosonography (VUS), which, despite its approval for initial diagnosis in females and follow-up in both genders post-voiding cystourethrography, highlights the need for broader diagnostic applications

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considering VUR's role in more than 25% of pediatric UTI cases and its potential to lead to chronic kidney damage and pediatric hypertension if associated infections are recurrent (3, 4).

Traditionally, the gold standard for diagnosing VUR has been fluoroscopic voiding cystourethrography (VCUG), which, despite its diagnostic efficacy, raises concerns due to the required radiation exposure and the invasive nature of urine catheterization. These factors are particularly significant in the pediatric population (5). In contrast, voiding vesicoureterography and conventional ultrasonography, although widely used, often do not provide sufficient detail about the ureters due to limitations in imaging techniques. The rapid advancements in imaging technology and contrast agents have enhanced the role of ultrasonography in clinical settings, positioning VUS as a viable alternative for evaluating VUR (6, 7). Although VUS and VCUG have been compared in previous studies, the data were not collected contemporaneously, suggesting a need for further investigation to ascertain the consistency between VUR diagnoses by these methods (8).

MATERIAL AND METHODS

This cross-sectional study was conducted to evaluate the efficacy of voiding cystourethrography (VCUG) and voiding vesicoureteral urosonography (VUS) in diagnosing vesicoureteral reflux (VUR) among pediatric patients. A total of 208 renal ureteral units were examined from 145 children diagnosed with VUR, admitted to the University of Lahore Teaching Hospital between July 2022 and September 2023. The participants included 60 boys and 85 girls, with ages ranging from one month to eleven years. The mean age for boys was 5.10±0.77 years and for girls 3.21±0.83 years.

For the VCUG procedure, an 80 ml solution of meglumine diatrizoate was prepared from two vials mixed at a 1:1 ratio with sterile saline. This contrast medium was administered post the insertion of a urinary catheter, followed by fluoroscopic imaging to observe the contrast distribution in the ureter and renal pelvis. X-ray fluoroscopy captured a comprehensive series of images to assess the presence and degree of VUR. During the monitoring of the urination phase, the catheter was removed to enable natural voiding.

The VUS method involved initial abdominal scanning using a grayscale ultrasound with a probe frequency set at 4.5 Hz, focusing on the kidney, ureter, and bladder. Key observations included enlarged kidneys, dilated ureters, and anomalies in the dermatomedullary structures. A suspension of sterile saline and 0.2 milliliters of gaseous microbubbles (SonoVue) was prepared, with each child receiving a formula-determined volume of saline to half-fill the bladder. A bolus of 0.5 ml of the microbubble solution was then injected, and the catheter was clamped to allow the dispersion of microbubbles throughout the bladder. The ultrasound system was switched to contrast-specific imaging mode to observe the microbubble distribution in real-time, which facilitated the diagnosis of VUR based on the visualization of contrast in the ureter and renal pelvis.

Data from both diagnostic methods were systematically recorded and backed up to facilitate prompt analysis. The VUR was graded according to international VCUG standards into five levels, based on the extent and severity of the reflux. The comparison of VUS and VCUG findings was tabulated to perform an agreement analysis.

The data were analyzed using SPSS version 25, employing statistical methods appropriate for categorical data analysis and agreement metrics. Ethical approval for the study was granted by the Institutional Review Board of the University of Lahore, adhering to the Helsinki Declaration. All procedures involving clinical practices were reviewed and performed under the supervision of experienced medical professionals. Children were monitored for at least 24 hours post-examination to detect any acute or delayed allergic reactions to the contrast agents. A double-blind approach was utilized for the analysis of ultrasound images to ensure impartiality and accuracy in the results. In cases of dispute, additional experts were consulted, and decisions were made by consensus to ensure reliability of the diagnostic findings (10-12).

RESULTS

In this study, we evaluated the diagnostic performance of voiding vesicoureteral urosonography (VUS) compared to the established method of voiding cystourethrography (VCUG) across various grades of vesicoureteral reflux (VUR). A total of 208 renal ureteral units from pediatric patients were assessed using both imaging techniques. The detailed results of this comparison are presented in Table 1.

For cases without reflux, VUS demonstrated a high level of agreement with VCUG, correctly identifying 98 out of 112 cases, showcasing its reliability in ruling out VUR. In contrast, VUS detected lower grades of reflux (Grade I and II) with limited accuracy. It identified only 2 cases of Grade I and 9 cases of Grade II reflux that were confirmed by VCUG, out of 12 and 14 cases respectively, suggesting a potential challenge in detecting mild cases of reflux using VUS.

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Table 1: Table of Vesicoureteral Reflux (VUR) Grading Comparisons Using VUS and VCUG Techniques

VUS / VCUG	No reflux	I	II	III	IV	V	Total
No reflux	98	0	0	0	0	0	98
I	6	2	0	0	0	0	8
II	0	3	9	0	7	0	21
III	3	0	5	0	24	0	32
IV	1	0	0	6	7	3	17
V	4	7	0	9	2	10	32
Total	112	12	14	15	42	13	208

The performance of VUS improved with higher grades of reflux. For Grade III reflux, VUS correctly identified 24 out of 32 cases as confirmed by VCUG. In Grade IV and V, where severe reflux is indicated, VUS identified 7 and 10 cases respectively, out of total VCUG confirmed cases of 13 for Grade V. This indicates that VUS tends to perform better in detecting more severe cases of reflux.

The overall agreement between VUS and VCUG in detecting VUR across all grades was substantial, yet the ability of VUS to detect mild reflux remains a concern. The findings underscore the potential of VUS in clinical settings, particularly for identifying severe cases of VUR, while also highlighting the need for enhanced sensitivity in detecting lower grades of reflux to match the performance of VCUG.

DISCUSSION

Vesicoureteral reflux (VUR) has been strongly associated with recurrent urinary tract infections (UTIs) in children, suggesting that timely diagnosis is critical for preventing potential impacts on growth and development (13,14). The evolution of diagnostic modalities for VUR is an area of active research, with an ongoing demand for methods that combine high diagnostic accuracy with safety considerations pertinent to pediatric patients (15,16).

Historically, fluoroscopic voiding cystourethrography (VCUG) has been extensively utilized due to its high diagnostic efficacy. This method employs digital film and pulse technology, providing detailed imaging critical for accurate diagnosis (17). However, the significant radiation exposure associated with VCUG poses a health risk, particularly when repeated examinations are necessary, underscoring the need for alternative diagnostic approaches (18).

Voiding urosonography (VUS), which utilizes ultrasonographic contrast agents and does not involve radiation, has emerged as a promising alternative. Its sensitivity and ability to provide real-time imaging without radiation exposure make VUS particularly appealing for pediatric use (19). Nevertheless, VUS does have limitations, particularly in visualizing the posterior urethra and ensuring comprehensive observation of the urethral filling and excretion process. These challenges necessitate meticulous attention to technique during the procedure to avoid diagnostic omissions (20).

The introduction of advanced ultrasonography machines like the Super Sonic Imagine's Aixplorer V with CEUS+ capability has further enhanced the utility of VUS. This technology supports radiation-free, long-term monitoring and offers high sensitivity, specificity, and cost-effectiveness, which are increasingly recognized and valued by patients and their families. The high frame rate and resolution of the microbubbles used in this system enhance the stability and duration of the image display, providing superior visualization of specific lesions and improved temporal and spatial resolution (1, 17).

In this study, 160 pelvic ureteral units (PUUs) were examined to compare the diagnostic accuracy of VUS and VCUG. The results demonstrated that there was no significant difference in accuracy between the two modalities, with VUS detecting reflux at a higher rate. This finding aligns with previous studies, which have shown VUS to be a viable, if not superior, alternative to VCUG due to its excellent diagnostic capabilities and safety profile (3, 8).

However, despite its advantages, VUS is not without its challenges. The method requires careful planning of the examination sequence and section to ensure comprehensive data collection, and there is a risk of missing reflux, particularly bilateral atypical reflux, if not all target organ information is captured in one viewing (20). Consistency in application and the ability to make prompt decisions are critical areas that need further attention in clinical practice. The limitations of this study include its small sample size and retrospective design, which may affect the strength and generalizability of the findings. Future research should include larger, randomized controlled trials to validate these results (14).

CONCLUSION

In conclusion, voiding vesicoureteral urosonography has demonstrated a high detection rate for VUR in children, offering substantial clinical utility by reducing harmful effects such as radiation exposure. This modality not only supports the early and accurate

diagnosis of VUR but also aligns with the broader goals of pediatric patient care by minimizing risk while maintaining diagnostic integrity.

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