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DIAGNOSTIC ACCURACY OF DOPPLER URETERIC JET ASSESSMENT FOR URETERIC OBSTRUCTION USING NON-CONTRAST CT AS THE REFERENCE STANDARD

Dr. Pooja Devi[1], Dr. Rifat Shoaib[2], Dr. Ameet Lalwani[3], Dr. Sana Shaikh[4]*, Dr. Kashaf Anwar Arain[5], Dr. Kainat[6]

[1]Senior Lecturer, Department of Radiology, Sindh Institute of Urology and Transplantation (SIUT), Karachi, Pakistan,
Email: Poojalohana94@gmail.com
[2]Postgraduate Trainee, Department of Radiology, Sindh Institute of Urology and Transplantation (SIUT), Karachi, Pakistan,
Email: rifatkalwar155@gmail.com
[3]Associate Professor, Department of Radiology, Sindh Institute of Urology and Transplantation (SIUT), Karachi, Pakistan,
Email: Dramitsl@gmail.com
[4]Associate Professor, Department of Radiology, Sindh Institute of Urology and Transplantation (SIUT), Karachi, Pakistan,
Email: Docsanashaikh@gmail.com
[5]Assistant Professor, Department of Radiology, Sindh Institute of Urology and Transplantation (SIUT), Karachi, Pakistan,
Email: Kashaf.anwar81@gmail.com
[6]Postgraduate Trainee, Department of Radiology, Sindh Institute of Urology and Transplantation (SIUT), Karachi, Pakistan,
Email: kainatraheem2@gmail.com
***Corresponding Author**: Dr. Sana Shaikh, Email: Docsanashaikh@gmail.com

ABSTRACT

Background: Ureteric obstruction is a common urological condition requiring timely diagnosis to prevent progressive renal dysfunction. Non-contrast computed tomography (NCCT) is highly effective for identifying obstructive ureteric calculi but involves ionizing radiation. Doppler ultrasonographic assessment of ureteric jets provides a radiation-free functional indicator of urine passage across the vesicoureteric junction.

Objective: To determine the diagnostic accuracy of Doppler ureteric jet assessment for detecting ureteric obstruction using NCCT as the reference standard.

Methods: This diagnostic accuracy study included patients with clinical suspicion of ureteric obstruction. Ureteric jets were assessed using Doppler ultrasonography and findings were compared with NCCT. Reduced or absent ureteric jet activity was considered suggestive of obstruction. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and overall diagnostic accuracy were calculated.

Results: Doppler assessment of ureteric jets demonstrated good diagnostic performance for identifying ureteric obstruction compared with NCCT. The technique effectively differentiated obstructed from non-obstructed ureters, supporting its potential role as a functional adjunct to conventional ultrasonography.

Conclusion: Doppler ureteric jet assessment provides a simple, non-invasive, and radiation-free approach for evaluating suspected ureteric obstruction. It may be particularly useful for initial assessment and for patients in whom minimizing radiation exposure is desirable.

KEYWORDS: Ureteric jet; Doppler ultrasonography; ureteric obstruction; non-contrast CT; urolithiasis; diagnostic accuracy.

INTRODUCTION

Ureteric obstruction is a frequently encountered urological condition and represents an important cause of acute flank pain and emergency department presentation. Urolithiasis is among the most common causes of upper urinary tract obstruction, although strictures, congenital abnormalities, tumors, and extrinsic compression may also interfere with normal urinary drainage. Persistent obstruction increases pressure within the collecting system and may progressively compromise renal blood flow, glomerular filtration, and renal function. Early and accurate identification of obstruction is therefore important for appropriate clinical management and prevention of potentially irreversible renal damage.[1,2]

The clinical presentation of ureteric obstruction varies according to its cause, location, severity, and duration. Patients with ureteric calculi frequently present with acute colicky flank pain that may radiate toward the groin and may be accompanied by hematuria, nausea, vomiting, or urinary symptoms. However, symptoms alone cannot reliably establish the presence, level, or severity of obstruction. Imaging consequently has a central role in the evaluation of suspected ureteric obstruction, particularly in determining whether a calculus is present and identifying secondary changes within the urinary tract.[3]

Non-contrast computed tomography (NCCT) has become an important reference imaging modality for evaluating suspected ureteric calculi. It provides rapid and detailed visualization of the urinary tract, can identify most urinary calculi regardless of composition, accurately determines stone location and size, and demonstrates secondary signs of obstruction such as hydronephrosis, hydroureter, and perinephric inflammatory changes.[4,5] NCCT can also reveal alternative causes of acute abdominal or flank pain when urolithiasis is absent. These advantages have contributed to its widespread use in patients with suspected renal colic.

Despite its excellent diagnostic performance, routine reliance on NCCT has limitations. The principal concern is exposure to ionizing radiation, particularly in younger patients and individuals with recurrent stone disease who may undergo repeated imaging examinations during their lifetime.[6] Although low-dose CT protocols can substantially reduce radiation exposure while maintaining acceptable diagnostic performance, access to optimized protocols may vary between institutions.[7] These concerns have encouraged continued evaluation of radiation-free imaging strategies capable of identifying urinary obstruction with sufficient accuracy to guide subsequent management.

Ultrasonography is particularly attractive in this context because it is widely available, relatively inexpensive, non-invasive, and does not involve ionizing radiation. Conventional ultrasonography can demonstrate hydronephrosis and other indirect manifestations of urinary tract obstruction. However, dilatation of the collecting system does not invariably indicate acute mechanical obstruction, and significant obstruction may occasionally be present before prominent hydronephrosis develops.[8] Consequently, structural assessment alone may not fully characterize the functional effect of ureteric obstruction, creating a potential role for Doppler evaluation of urinary flow.

A ureteric jet represents the intermittent passage of urine from the distal ureter through the vesicoureteric junction into the urinary bladder. On color Doppler ultrasonography, these jets can be visualized as transient bursts of flow entering the bladder from the ureteric orifices. Under normal physiological conditions, ureteric jet activity occurs intermittently and may vary with hydration, urine production, bladder volume, and ureteric peristalsis. Obstruction of a ureter may alter this pattern by reducing the frequency or intensity of the jet on the affected side or, in complete obstruction, potentially resulting in absence of a detectable jet.[9,10]

Assessment of ureteric jets therefore provides functional information that differs from the predominantly structural information obtained through grayscale ultrasonography. Comparison of jet activity between the symptomatic and contralateral sides may help identify impaired urinary drainage. Previous investigations have demonstrated reductions in ureteric jet frequency and other Doppler parameters in patients with obstructing ureteric calculi, suggesting that jet assessment may provide additional evidence of obstruction when conventional ultrasonographic findings are equivocal.[11,12] This approach is particularly appealing because Doppler assessment can be incorporated into an existing urinary tract ultrasound examination without exposing the patient to additional radiation.

The potential clinical value of ureteric jet assessment extends beyond diagnosis alone. A reliable Doppler marker of obstruction could assist in selecting patients who require further evaluation with CT while potentially reducing unnecessary CT examinations in selected low-risk individuals. This is especially relevant for patients with recurrent urolithiasis, younger adults, and other populations in whom cumulative radiation exposure is an important consideration. Nevertheless, ureteric jet assessment has inherent limitations. Jet frequency is physiologically variable and can be influenced by hydration status, renal function, bladder filling, observation duration, and technical factors. The presence of a jet also does not necessarily exclude partial obstruction, while temporary absence may occur even in a non-obstructed ureter.[9,13] Standardization of patient preparation, observation time, and diagnostic criteria is therefore important when evaluating its clinical performance.

Furthermore, Doppler ureteric jet assessment should not be regarded as a direct anatomical substitute for NCCT. Whereas Doppler evaluates the functional consequence of impaired ureteric flow, NCCT can directly demonstrate a calculus, determine its location and dimensions, assess secondary obstructive changes, and identify alternative pathology.[4] The more clinically relevant question is therefore whether ureteric jet assessment can discriminate between obstructed and non-obstructed urinary tracts with sufficient diagnostic accuracy to serve as a useful initial or complementary imaging tool.

Although several studies have explored Doppler characteristics of ureteric jets in urinary obstruction, differences in study populations, scanning protocols, definitions of an abnormal jet, and reference standards have resulted in variability in reported diagnostic performance. Local validation against an established reference modality is therefore necessary before incorporating ureteric jet assessment more extensively into routine diagnostic pathways. Evaluating sensitivity, specificity, positive predictive value, negative predictive value, and overall diagnostic accuracy against NCCT provides an objective means of determining its clinical utility.]

Therefore, the present study was conducted to determine the diagnostic accuracy of Doppler ultrasonographic assessment of ureteric jets for detecting ureteric obstruction, using non-contrast computed tomography as the reference standard.

MATERIALS AND METHODS

This cross-sectional validation study was conducted in the **Department of Radiology, Sindh Institute of Urology and Transplantation (SIUT), Karachi, Pakistan**, from **31 December 2021 to 30 June 2022**. A total of **213 patients**, aged **10–50 years**, with clinical suspicion of ureteric obstruction were included. Patients presenting with acute flank pain, having normal kidneys and no evidence of calculi on initial ultrasonography, were considered suspected cases of ureteric obstruction according to the predefined study criteria. Participants were enrolled according to the eligibility criteria of the approved study protocol.

All participants underwent Doppler ultrasonographic assessment of the ureteric jets. The examination was performed using a **Toshiba Xario ultrasound system** equipped with a **3–6 MHz convex transducer** and color, power, and pulsed Doppler capabilities. Before examination, patients were adequately hydrated until the urinary bladder was moderately full. Each participant was examined in the **supine position**, and the urinary bladder was visualized in the transverse plane to permit simultaneous assessment of the right and left ureteric orifices at the level of the trigone. Color Doppler imaging was then applied to visualize urine entering the bladder through the ureteric orifices.

The urinary bladder was observed for a maximum period of **5 minutes** for ureteric jet detection. Flow directed toward the transducer was assigned a red color. Color gain was adjusted immediately below the level at which background noise became visible, and a wide sample gate was positioned to encompass the ureteric jet. The Doppler insonation angle was maintained between **30° and 60°**. For assessment of peak urinary jet velocity, the Doppler cursor was positioned near the corresponding ureteric orifice. The location of the color signal was optimized during the examination to achieve adequate visualization of the jet.

For the primary diagnostic classification, **absence of a detectable ureteric jet during the defined observation period was considered a positive Doppler finding for ureteric obstruction**. Patients in whom a ureteric jet was visualized were categorized as negative for obstruction according to the index-test definition. This operational definition was applied consistently when Doppler findings were subsequently compared with the reference standard.

Following Doppler ultrasonography, all participants underwent **non-contrast computed tomography (NCCT)** for confirmation of ureteric obstruction. NCCT served as the **reference standard**. A definitive diagnosis was established when a ureteric calculus was documented on NCCT, with associated imaging evidence of obstruction including **hydroureter, hydronephrosis, perinephric fluid, and inflammatory changes involving the periureteric or perinephric fat**, where present.

Doppler and NCCT findings were cross-classified as true positive, false positive, true negative, or false negative. A **true-positive** result represented absence of a ureteric jet on Doppler ultrasonography with ureteric obstruction demonstrated on NCCT. A **true-negative** result represented a negative Doppler assessment with absence of obstruction on NCCT. A false-positive result represented a Doppler finding suggestive of obstruction without corresponding obstruction on NCCT, whereas a false-negative result represented NCCT-confirmed obstruction not identified according to the Doppler criteria. These classifications were used to determine the diagnostic performance of ureteric jet assessment.

Data were analyzed using the **Statistical Package for Social Sciences (SPSS)**. Quantitative variables were summarized using mean and standard deviation, while categorical variables were expressed as frequencies and percentages. Diagnostic performance of Doppler ureteric jet assessment was determined by calculating **sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and overall diagnostic accuracy**, with NCCT used as the reference standard. The diagnostic findings were additionally stratified according to **age, gender, diabetes mellitus, and hypertension** to assess whether these factors influenced diagnostic performance.

The study was conducted following approval of the research protocol by the relevant institutional authorities at SIUT. Patient confidentiality was maintained throughout data collection, analysis, and reporting, and study procedures were performed in accordance with institutional ethical requirements.

RESULTS

A total of **213 patients** with suspected ureteric obstruction were included in the study. The mean age of the participants was **31.84 ± 11.32 years**. There were **140 (65.73%) males** and **73 (34.27%) females**, demonstrating a male predominance in the study population.

Doppler ultrasonography yielded a positive test for ureteric obstruction in **120 (56.34%) patients**, whereas **93 (43.66%)** had a negative Doppler result. On non-contrast computed tomography (NCCT), which served as the reference standard, ureteric obstruction was confirmed in **114 (53.52%) patients**, while **99 (46.48%)** had no evidence of obstruction.

Table 1. Demographic characteristics and imaging findings of the study population (n=213)

Variable	Finding
Age, years, mean ± SD	**31.84 ± 11.32**
Male	**140 (65.73%)**
Female	**73 (34.27%)**
Positive Doppler assessment	**120 (56.34%)**
Negative Doppler assessment	**93 (43.66%)**
Ureteric obstruction on NCCT	**114 (53.52%)**
No ureteric obstruction on NCCT	**99 (46.48%)**

Direct comparison of Doppler ultrasonography with NCCT showed that **108 patients were true positive**, with an abnormal ureteric jet assessment and obstruction confirmed on NCCT. Twelve patients were classified as false positive. Among the 93 patients with a negative Doppler assessment, **87 were true negative**, while **6 were false negative**, having ureteric obstruction demonstrated on NCCT despite a negative Doppler result. Thus, Doppler correctly classified **195 of 213 patients**.

Table 2. Diagnostic classification of Doppler ureteric jet assessment against NCCT

Doppler assessment	NCCT obstruction present	NCCT obstruction absent	Total
Positive	**108 (TP)**	**12 (FP)**	**120**
Negative	**6 (FN)**	**87 (TN)**	**93**
Total	**114**	**99**	**213**

TP: true positive; FP: false positive; FN: false negative; TN: true negative; NCCT: non-contrast computed tomography.

The resulting sensitivity of Doppler ureteric jet assessment was **94.7%**, indicating that approximately 95% of patients with NCCT-confirmed ureteric obstruction were correctly identified. Specificity was **87.9%**, demonstrating good discrimination among patients without obstruction. The positive predictive value (PPV) was **90.0%**, while the negative predictive value (NPV) was **93.5%**. Overall diagnostic accuracy was **91.5%**. These values are directly supported by the original 2 × 2 diagnostic table in the dissertation.

Table 3. Diagnostic performance of Doppler ureteric jet assessment for ureteric obstruction

Diagnostic parameter	Value
Sensitivity	**94.7%**
Specificity	**87.9%**
Positive predictive value (PPV)	**90.0%**
Negative predictive value (NPV)	**93.5%**
Diagnostic accuracy	**91.5%**

The particularly high sensitivity and NPV indicate that Doppler ureteric jet assessment had a low false-negative rate in the studied population. Only **6 of 114 patients with NCCT-confirmed obstruction** were missed by Doppler assessment. Conversely, 12 of 99 patients without obstruction on NCCT were categorized as positive on Doppler, accounting for the comparatively lower specificity.

The original dissertation additionally evaluated diagnostic performance after stratification by **age, gender, diabetes mellitus, and hypertension**. These analyses were performed to determine whether demographic characteristics and selected comorbidities materially influenced the diagnostic performance of ureteric jet assessment.

Table 4. Overall agreement between Doppler ureteric jet assessment and NCCT

Classification	n	% of total sample
True positive	108	50.70
True negative	87	40.85
False positive	12	5.63
False negative	6	2.82
Correctly classified (TP + TN)	**195**	**91.55**
Incorrectly classified (FP + FN)	**18**	**8.45**
Total	**213**	**100.00**

Figure 1 — Diagnostic classification matrix

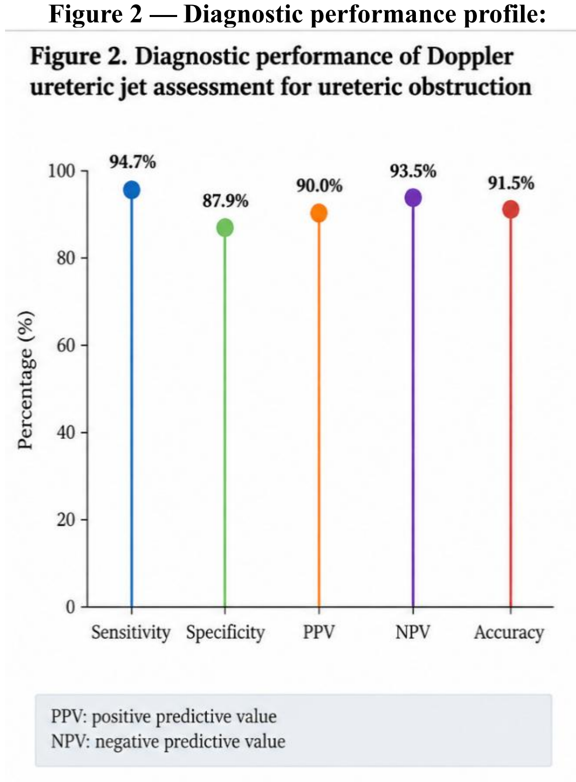
Figure 1. Diagnostic classification of Doppler ureteric jet assessment against non-contrast computed tomography (NCCT)

Doppler ureteric jet assessment (index test)	Ureteric obstruction on NCCT (reference standard)		
	Present (n = 114)	Absent (n = 99)	Total (n = 213)
Positive (no jet)	108 (True Positive)	12 (False Positive)	120
Negative (present jet)	6 (False Negative)	87 (True Negative)	93
Total	114	99	213

Correct classification | Incorrect classification

NCCT: non-contrast computed tomography
Values are presented as number of patients.

Figure 2 — Diagnostic performance profile:



DISCUSSION

The present study demonstrated high diagnostic performance of Doppler ultrasonographic assessment of ureteric jets for detecting ureteric obstruction, using non-contrast computed tomography (NCCT) as the reference standard. Among 213 patients, Doppler assessment showed a **sensitivity of 94.7%, specificity of 87.9%, positive predictive value (PPV) of 90.0%, negative predictive value (NPV) of 93.5%, and overall diagnostic accuracy of 91.5%**. Of the

114 patients with obstruction confirmed on NCCT, 108 were correctly identified, with only six false-negative examinations. These findings suggest that ureteric jet assessment provides useful functional information and may complement conventional ultrasonography in patients presenting with suspected ureteric obstruction.

The high sensitivity observed in the present study is consistent with the physiological consequences of ureteric obstruction. Ureteric jets represent intermittent passage of urine through the vesicoureteric junction into the bladder and can be visualized using color Doppler. Mechanical obstruction alters this flow and may reduce the frequency, duration, or velocity of the jet or result in its complete absence. Burge et al. demonstrated that patients with high-grade ureteric obstruction frequently exhibited absent or markedly abnormal jets on the affected side, while abnormalities were less pronounced in low-grade obstruction.[11] Similarly, Thomas et al. reported abnormal ureterovesical flow patterns in patients with acute obstruction, supporting the functional relationship between impaired ureteric drainage and altered jet activity.[12]

Our sensitivity of **94.7%** compares favorably with previous quantitative Doppler studies. Jandaghi et al. demonstrated significantly lower jet frequency, duration, and peak velocity in obstructed ureters compared with contralateral unobstructed ureters. Using a jet-frequency threshold, they reported approximately **97.8% sensitivity and 87% specificity**.[13] Their sensitivity was slightly higher than that observed in our study, whereas their specificity was almost identical to our value of 87.9%. Importantly, their assessment incorporated quantitative jet characteristics, while the present study employed the simpler criterion of absence of a detectable ureteric jet during the predefined observation period. The comparable performance suggests that a straightforward qualitative assessment may retain substantial diagnostic value and may be easier to incorporate into routine ultrasonography.

Comparable findings have also been reported when ureteric jet assessment is combined with other Doppler parameters. Pepe et al. evaluated patients presenting with renal colic and reported sensitivity and specificity of approximately **98.9% and 90.9%**, respectively, when Doppler parameters including ureteric jets and renal resistive indices were considered.[14] These values are somewhat higher than the sensitivity of 94.7% and specificity of 87.9% observed in the present study. The difference may be attributable to their combined diagnostic approach, whereas our study specifically assessed the diagnostic contribution of ureteric jet evaluation. From a practical perspective, however, a simpler approach requiring only visualization of ureteric jets may be advantageous in busy radiology and emergency settings.

The **NPV of 93.5%** is particularly relevant clinically. Only six patients with NCCT-confirmed obstruction were missed by Doppler assessment, indicating a relatively low false-negative rate. Nevertheless, visualization of a ureteric jet should not be interpreted as absolute exclusion of obstruction. Partial obstruction may allow intermittent urine passage and consequently preserve detectable jet activity. Earlier studies have similarly demonstrated more pronounced jet abnormalities in high-grade than in low-grade obstruction.[11] Therefore, persistent symptoms or strong clinical suspicion despite preserved ureteric jet activity should prompt further evaluation, particularly with NCCT.

In contrast, 12 patients without obstruction on NCCT had positive Doppler findings, accounting for the relatively lower specificity. Physiological variability in ureteric jet activity may explain some of these false-positive examinations. Jet frequency is influenced by hydration, urine production, bladder filling, ureteric peristalsis, and observation duration. Thomas et al. demonstrated that ureteric streams may occasionally be absent even in individuals without obstruction, particularly when urine production is reduced.[12] The standardized preparation used in the present study, including hydration and a moderately full urinary bladder, was therefore important, although transient physiological absence of jet activity could not be completely eliminated.

Ureteric jet assessment also provides information that differs from conventional grayscale ultrasonography. Grayscale imaging primarily identifies structural consequences of obstruction, particularly hydronephrosis and hydroureter. However, collecting-system dilatation is not synonymous with active mechanical obstruction. Dilatation may be minimal during early obstruction, whereas hydronephrosis may persist despite resolution of obstruction or occur in non-obstructive conditions. Pepe et al. reported that pyelocaliceal dilatation was absent in some patients with urolithiasis, illustrating the limitations of relying solely on morphological changes.[14] Doppler assessment of ureteric jets provides a functional measure of urinary passage and can therefore complement structural ultrasonographic findings.

Other Doppler approaches have also been investigated for urinary obstruction, particularly the renal resistive index and the color Doppler twinkling artifact. Studies evaluating resistive index have produced variable results, with some demonstrating useful discrimination and others showing limited ability to differentiate obstructed from non-obstructed kidneys.[15,16] In contrast, color Doppler twinkling associated with urinary calculi has shown promising diagnostic performance. Liu et al. reported sensitivity of approximately **97% and specificity of 90%** for the twinkling artifact in patients with acute renal colic.[17] These values are broadly comparable with those observed in the present study, although the two techniques assess different aspects of stone disease: twinkling facilitates direct stone detection, whereas ureteric jets assess the functional consequence of impaired urinary drainage.

Despite the favorable performance of Doppler assessment, NCCT remains superior for comprehensive anatomical evaluation. NCCT can directly demonstrate most ureteric calculi, accurately determine their size and location, identify secondary signs of obstruction, and detect alternative causes of acute flank pain. Comparative studies have consistently demonstrated the high diagnostic accuracy of unenhanced CT in suspected ureterolithiasis.[18,19] Therefore, the present findings should not be interpreted as suggesting that Doppler ureteric jet assessment can universally replace NCCT. Instead, the technique may function as an **initial or complementary imaging tool**, particularly in patients in whom limiting radiation exposure is desirable.

Avoidance of ionizing radiation is an important advantage of ultrasound-based assessment. Patients with recurrent urolithiasis may undergo repeated imaging examinations, potentially resulting in substantial cumulative radiation exposure. Ultrasound is non-invasive, inexpensive, repeatable, and widely accessible. Nicolau et al. advocated ultrasonography as an initial imaging modality in renal colic, with indirect findings such as altered or absent ureteric jets contributing additional diagnostic information when the calculus itself cannot be visualized.[20] The **91.5% diagnostic accuracy** demonstrated in our study further supports the potential value of this radiation-free approach in appropriately selected patients.

The findings also have relevance beyond adult ureteric stone disease. Doppler ureteric jet characteristics have been investigated in obstructive hydronephrosis in pediatric populations. de Bessa et al. reported that relative jet frequency differentiated obstructive from non-obstructive hydronephrosis with **87% sensitivity and 96.4% specificity**, with approximately 91% overall correct classification.[21] Although the population and etiology differed from those of the present study, the results support the underlying physiological principle that impaired ureteric drainage produces measurable changes in vesicoureteric jet activity.

The present study has several strengths, including a sample of **213 patients**, use of NCCT as the reference standard, and standardized Doppler assessment with patient hydration, appropriate bladder filling, and a defined observation period. Overall, **195 of 213 patients were correctly classified**, demonstrating strong agreement between Doppler findings and NCCT. Nevertheless, the single-center design may limit generalizability. Ureteric jet assessment is also affected by physiological and technical factors and may be less reliable in partial obstruction. The qualitative criterion of jet absence provides simplicity but does not incorporate potentially useful quantitative parameters such as jet frequency, duration, or peak velocity.

Overall, the present findings are consistent with previous evidence and demonstrate that Doppler ureteric jet assessment provides clinically meaningful functional information in suspected ureteric obstruction. Its **94.7% sensitivity, 93.5% NPV, and 91.5% overall diagnostic accuracy** are particularly encouraging for a rapid, non-invasive, and radiation-free technique. However, its lower specificity and the occurrence of both false-positive and false-negative examinations indicate that ureteric jet findings should be interpreted alongside clinical assessment and conventional ultrasonography. **NCCT remains necessary when ultrasound findings are inconclusive, symptoms persist, complications are suspected, or precise anatomical characterization is required.**

CONCLUSION

Doppler ultrasonographic assessment of ureteric jets demonstrated high diagnostic performance for detecting ureteric obstruction, with a **sensitivity of 94.7%, specificity of 87.9%, PPV of 90.0%, NPV of 93.5%, and overall accuracy of 91.5%** when compared with NCCT. The high sensitivity and NPV indicate that ureteric jet assessment can provide useful functional information during the initial evaluation of suspected obstruction. As a rapid, non-invasive, and radiation-free technique, it can complement conventional ultrasonography; however, NCCT remains necessary when findings are inconclusive or detailed anatomical evaluation is required.

RECOMMENDATIONS

Doppler ureteric jet assessment may be incorporated into routine ultrasonographic evaluation of patients with suspected ureteric obstruction. Standardized hydration, bladder filling, observation time, and Doppler technique should be maintained. Further multicenter studies incorporating quantitative jet parameters may help refine diagnostic thresholds and improve reproducibility.

LIMITATIONS

The study was conducted at a single tertiary-care center, which may limit generalizability. Ureteric jet activity is intermittent and can be influenced by hydration, urine output, bladder volume, and observation duration. The primary diagnostic criterion was absence of a detectable jet and did not incorporate quantitative parameters such as jet frequency, duration, or peak velocity. Partial obstruction may also occur despite preservation of jet activity.

CONFLICT OF INTEREST

The authors declare **no conflict of interest**.

FUNDING

The study received **no external funding**.

DATA AVAILABILITY
The data supporting the findings of this study are available from the corresponding author upon reasonable request and subject to institutional and ethical requirements.

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