European Journal of Clinical Pharmacy
Print ISSN: 2385-409X, **Online ISSN**: 3105-0409
Website: https://farmclin.com/

Original Research Article

Differentiation of Obstructive and Non-Obstructive Hydronephrosis by Using Renal Artery Resistance Indices taking CT-KUB as the Gold Standard

Article History:

Name of Author:
Asfandyar Ahmad Sheikh[1], M. Adeel Azhar[2], Yasser Khan[3], Sadaf Aziz[4], Khadija Tul Kubra[5]

Affiliation: [1]PGR Radiology, Radiology Department, CMH, Lahore, Pakistan.
[2-5]Classified Radiologist, Radiology Department, CMH, Lahore, Pakistan.

Corresponding Author:
Asfandyar Ahmad Sheikh,
Email: asfandy364@gmail.com

Received: 26-10-2025
Revised: 09-12-2025
Accepted: 12-12-2025
Published: 24-12-2025

Abstract: ***Background:*** Hydronephrosis is the dilation of the renal pelvis and calyces caused by impaired urinary flow. Differentiating obstructive from non-obstructive hydronephrosis is crucial for timely management and prevention of renal damage. Doppler ultrasonography assessing renal artery resistive indices (RI) has emerged as a non-invasive tool, while CT-KUB remains the gold standard for detecting anatomical obstruction. ***Objectives:*** To determine the diagnostic accuracy of Doppler renal artery resistive index in differentiating obstructive from non-obstructive hydronephrosis, using CT-KUB as the gold standard. ***Study Design & Setting:*** Cross-sectional study conducted at the Department of Diagnostic Radiology, CMH Lahore, during the period from May 2025 to October 2025. ***Methodology:*** A total of 141 patients aged 18–70 years with clinically suspected hydronephrosis were enrolled. All participants underwent Doppler ultrasonography to measure interlobar renal artery resistive indices, followed by CT-KUB. Obstructive hydronephrosis was defined as RI >0.75 or renal pelvis dilatation >10 mm with visualized obstruction on CT-KUB. Data were analyzed using SPSS version 25. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and overall diagnostic accuracy were calculated. Stratified analysis was performed for age, gender, duration of symptoms, diabetes mellitus, and hypertension. ***Results:*** Doppler RI correctly identified obstructive hydronephrosis in 56 participants (39.7%) and non-obstructive in 63 participants (44.7%). Overall sensitivity, specificity, PPV, NPV, and accuracy were 88.9%, 80.8%, 78.9%, 90.0%, and 84.4%, respectively. Diagnostic performance was higher in females, hypertensive and diabetic patients, and in those with symptoms ≤14 days.***Conclusion:*** Doppler renal artery resistive index is a reliable non-invasive tool for differentiating obstructive from non-obstructive hydronephrosis and can reduce dependence on CT imaging. Patient factors and symptom duration may affect diagnostic accuracy.

Keywords: CT-KUB, Doppler, Hydronephrosis, Renal Artery Resistance Index, Ultrasound.

INTRODUCTION

Hydronephrosis is characterized by the dilation of the pelvicalyceal system due to impaired urine flow, often resulting from compromised urinary drainage.1 Obstructive hydronephrosis refers to structural and functional changes in the kidneys caused by difficulties in urine flow (difficulties in urinating).2 Non-obstructive hydronephrosis, on the other hand, describes the dilation of the renal pelvis and calyces without any physical blockage in the urinary tract. This condition usually arises from functional or physiological factors, such as increased urine production, vesicoureteral reflux, or transient changes in urinary flow dynamics, rather than mechanical obstruction.3 Hydronephrosis, particularly ureteral and renal pelvic dilation, is more commonly observed on the right side and occurs in 80–90% of pregnant women.4.

Non-invasive imaging techniques, such as intrarenal arterial Doppler ultrasonography, have become increasingly important. This method allows the assessment of renal hemodynamic changes during acute obstruction by measuring parameters such as the Resistive Index (RI). Elevated RI values indicate increased vascular resistance, which is often associated with acute obstruction.5 Conventional abdominal radiography (KUB) is also commonly used to evaluate hydronephrosis, helping detect kidney size, shape, and the presence of calculi that may suggest obstruction.6

Previous studies have shown the diagnostic value of RI in differentiating obstructive from non-obstructive hydronephrosis. Solomon et al. (2018) reported a sensitivity of 71.1%, specificity of 81.2%, and overall accuracy of 75.4%, with statistically significant results ($p = 0.003$).7 Nadzri et al. (2015) found that the mean RI was significantly higher in obstructive hydronephrosis (0.78) compared to non-obstructive cases (0.70, $p < 0.05$), with Doppler ultrasound demonstrating a sensitivity of 100% and specificity of 53%.8 Safdal et al. (2019) reported that the sensitivity and specificity of RI using color Doppler ultrasonography were 93.15% and 94.81%, respectively; the positive predictive value and negative predictive value for RI were 94.44% and 93.59%. Out of 150 patients, 72 (48%) were positive on both RI CDUS and CT-KUB.8

To the best of the candidate's knowledge, no local research has been conducted on this topic. The findings will provide valuable local data, supporting the use of RI as a reliable and non-invasive diagnostic tool, potentially reducing the need for expensive or invasive imaging tests. Furthermore, these results may guide future studies to improve diagnostic methods and patient care, ultimately enhancing management and treatment outcomes for patients with hydronephrosis. To determine the diagnostic accuracy of Doppler ultrasound resistive index of the interlobar renal artery in differentiating obstructive from non-obstructive hydronephrosis, taking CT-KUB as the gold standard.

MATERIALS AND METHODS

The study was designed as a cross-sectional survey and was conducted in the Department of Diagnostic Radiology at CMH, Lahore. The duration of the study was from May 2025 to October 2025 following the approval of the synopsis. The sample size of 141 cases was calculated based on a 95% confidence level, with an expected sensitivity of 71.1%, specificity of 81.2%, and an 11% margin of error, considering a disease prevalence of 48%.7,9 After obtaining approval from the Ethical Review Committee of the hospital, 141 patients presenting to the Radiology Department for imaging at CMH Lahore and meeting the inclusion criteria were enrolled in the study. Written informed consent was obtained from each participant. Demographic details, including age and gender, were recorded on a pre-designed proforma.

Patients of both genders aged between 18 and 70 years who were referred to the radiology department with suspected hydronephrosis, as defined by the operational criteria, and who underwent abdominal ultrasound followed by surgical exploration, were included in the study. Additional inclusion criteria were patients with clinical suspicion of renal obstruction (such as flank pain, hematuria, or impaired renal function), those with accessible Doppler ultrasound evaluation of the interlobar renal artery, and patients who were willing to provide informed consent for participation in the study. Exclusion criteria were diagnosed cases of abdominal malignancy based on history and clinical records, patients with congenital abnormalities of the renal vasculature or urinary tract, those with a baseline estimated glomerular filtration rate (eGFR) <30 ml/min/1.73 m² or documented end-stage renal disease (ESRD), pregnant patients due to potential radiation exposure during CT-KUB, and patients with active urinary tract infections or sepsis at the time of evaluation.

Each patient underwent Doppler ultrasonography to assess the renal artery resistive index (RI). The ultrasound examinations were performed using a GE-LOGIQ P9 machine with a convex high-frequency (3–5 MHz) transducer. Imaging was carried out in the supine and lateral decubitus positions to ensure optimal visualization of the renal interlobar arteries.

The renal artery resistive index (RI) was calculated for each patient using the standard formula:
RI = (Peak Systolic Velocity − End Diastolic Velocity) / Peak Systolic Velocity.

An elevated RI (>0.7) was considered indicative of obstructive hydronephrosis, while a normal RI (<0.7) suggested non-obstructive hydronephrosis. Following Doppler ultrasonography, all patients underwent CT-KUB performed on a Siemens SOMATOM 16-slice CT scanner, which served as the gold standard diagnostic tool. CT-KUB findings were used to confirm the diagnosis of either obstructive or non-obstructive hydronephrosis according to the operational definitions. The results of Doppler ultrasonography were then compared with CT-KUB findings, and each case was categorized as true positive, false positive, true negative, or false negative. The diagnostic accuracy of Doppler ultrasonography was evaluated in terms of sensitivity, specificity, positive predictive value, and negative predictive value. To ensure standardization, all Doppler ultrasonography examinations were conducted by the same consultant radiologist with at least eight years of experience, while all CT-KUB scans were reviewed by another senior radiologist who was blinded to the ultrasound findings. Confounding variables were controlled through strict adherence to the exclusion criteria. All collected data were recorded in the attached proforma by the investigator.

Suspected hydronephrosis was defined by the presence of at least two of the following: flank pain >3 on a 0–10 scale, hematuria (>5 RBCs/HPF or macroscopic), or impaired renal function (serum creatinine >1.5 mg/dl or eGFR <60 ml/min/1.73 m²). Hydronephrosis was classified as obstructive if the renal artery resistive index (RI) was >0.75 and non-obstructive if RI was <0.75. On CT-KUB, obstructive hydronephrosis was diagnosed with renal pelvis dilation >10 mm and visible obstruction, while non-obstructive cases had mild to moderate dilation (<10 mm) without obstruction. Diagnostic accuracy referred to Doppler ultrasound's ability to differentiate obstructive from non-obstructive hydronephrosis based on RI. A true positive was defined as a patient with obstructive hydronephrosis who tested positive on both the renal artery resistive index (RI) and CT-KUB. A true negative was a patient with non-obstructive hydronephrosis who tested negative on both RI and CT-KUB. A false positive occurred when obstructive hydronephrosis was diagnosed on RI, but the patient was found to have non-obstructive hydronephrosis on CT-KUB. Conversely, a false negative was a case in which non-obstructive hydronephrosis was not detected on RI, but CT-KUB revealed obstructive hydronephrosis.

All collected data were entered and analyzed using SPSS version 25. Numerical variables, including age, renal artery resistive index (RI), and duration of symptoms, were presented as mean ± standard deviation (SD). Categorical variables, such as gender, presence of obstructive and non-obstructive hydronephrosis, Doppler ultrasound findings, CT-KUB findings, diabetes mellitus, and hypertension, were presented as frequencies and percentages. A 2 × 2 contingency table was constructed to calculate the sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and overall diagnostic accuracy of Doppler ultrasonography in differentiating obstructive from non-obstructive hydronephrosis, using CT-KUB findings as the gold standard. The data were stratified according to age, gender, duration of symptoms, diabetes mellitus, and hypertension to account for potential effect modifiers. Following stratification, diagnostic performance measures were recalculated. Statistical significance was considered at $p < 0.05$.

RESULTS

The study included 141 participants with a mean age of 43.1 ± 14.9 years. Of these, 75 (53.2%) were male and 66 (46.8%) were female. Hypertension was present in 48 participants (34.0%) while 93 (66.0%) did not have hypertension. Diabetes mellitus was identified in 31 participants (22.0%), with the remaining 110 (78.0%) being non-diabetic. The mean duration of symptoms was 12.3 ± 7.6 days, with 87 participants (61.7%) experiencing symptoms for 14 days or less and 54 participants (38.3%) reporting symptoms for more than 14 days, indicating a majority of patients presented relatively early after symptom onset. These findings are summarized in Table 1. Regarding imaging findings, CT-KUB, used as the gold standard, identified obstructive hydronephrosis in 63 participants (44.7%) and non-obstructive hydronephrosis in 78 participants (55.3%). Doppler renal artery resistive index (RI) findings showed obstructive hydronephrosis in 71 participants (50.4%) and non-obstructive hydronephrosis in 70 participants (49.6%). These distributions indicate a close agreement in the proportion of obstructive and non-obstructive cases detected by both imaging modalities, as detailed in Table 2.

The cross-tabulation of Doppler RI versus CT-KUB findings showed that out of 63 participants with obstructive hydronephrosis on CT-KUB, 56 (39.7%) were correctly identified as obstructive by Doppler RI (true positive), while 7 (5.0%) were missed (false negative). Among the 78 participants with non-obstructive hydronephrosis on CT-KUB, 63 (44.7%) were correctly identified as non-obstructive by Doppler RI (true negative), while 15 (10.6%) were incorrectly labeled as obstructive (false positive). Overall, Doppler RI classified 71 participants as obstructive and 70 as non-obstructive, indicating good concordance with CT-KUB findings (Table 3).

The diagnostic accuracy of Doppler RI in differentiating obstructive from non-obstructive hydronephrosis was assessed using standard performance measures. Sensitivity was 88.9%, indicating a high ability to correctly identify obstructive cases. Specificity was 80.8%, reflecting good ability to correctly identify non-obstructive cases. The positive predictive value (PPV) was 78.9% and the negative predictive value (NPV) was 90.0%, while overall accuracy was 84.4%, demonstrating that Doppler RI is a reliable non-invasive tool for detecting hydronephrosis when compared to CT-KUB (Table 4).

Stratified analysis of diagnostic performance showed variations across different patient subgroups. Sensitivity and overall accuracy were higher in females (96.6% and 90.9%) than males (82.4% and 80.0%). Participants with hypertension had sensitivity of 87.0% and overall accuracy of 87.5%, while those without hypertension had slightly higher sensitivity (90.0%) but lower accuracy (83.0%). In diabetic patients, sensitivity was 86.7% and overall accuracy 87.1%, compared to 90.0% and 84.5% in non-diabetics. Duration of symptoms strongly affected diagnostic performance; patients with symptoms ≤14 days had perfect sensitivity (100%) and high overall accuracy (95.4%), whereas those with symptoms >14 days showed reduced sensitivity (62.1%) and overall accuracy (62.1%). These findings indicate that patient characteristics and symptom duration can influence the diagnostic reliability of Doppler RI (Table 5).

Table 1: Demographic Characteristics of Study Participants (n = 141)

Variables	Category	n (%) / Mean ± SD
Age (years)	Mean ± SD	43.1 ± 14.9
Gender	Male	75 (53.2%)
	Female	66 (46.8%)
Hypertension	Yes	48 (34.0%)
	No	93 (66.0%)
Diabetes Mellitus	Yes	31 (22.0%)
	No	110 (78.0%)
Duration of Symptoms (days)	Mean ± SD	12.3 ± 7.6
	≤14	87 (61.7%)
	>14	54 (38.3%)

Table 2: Distribution of CT-KUB and Doppler RI Findings (n = 141)

Imaging Modality	Category	n (%)
CT-KUB Findings	Obstructive	63 (44.7%)
	Non-Obstructive	78 (55.3%)
Doppler RI Findings	Obstructive	71 (50.4%)
	Non-Obstructive	70 (49.6%)

Table 3: Cross-Tabulation of Doppler RI versus CT-KUB Findings (n = 141)

Doppler RI \ CT-KUB	Obstructive (CT)	Non-Obstructive (CT)	Total
Obstructive (Doppler)	56 (39.7%) TP	15 (10.6%) FP	71 (50.4%)
Non-Obstructive (Doppler)	7 (5.0%) FN	63 (44.7%) TN	70 (49.6%)
Total	63 (44.7%)	78 (55.3%)	141 (100%)

Table 4: Diagnostic Accuracy of Doppler RI in Differentiating Obstructive and Non-Obstructive Hydronephrosis (n = 141)

Diagnostic Measure	Formula	Value (%)
Sensitivity	TP / (TP + FN)	88.9
Specificity	TN / (TN + FP)	80.8
Positive Predictive Value (PPV)	TP / (TP + FP)	78.9
Negative Predictive Value (NPV)	TN / (TN + FN)	90.0
Overall Accuracy	(TP + TN) / (TP + TN + FP + FN)	84.4

Table 5: Stratified Diagnostic Performance of Doppler RI (n = 141)

Stratification	Category	Sensitivity	Specificity	PPV	NPV	Overall Accuracy
Gender	Male	82.4%	78.0%	75.7%	84.2%	80.0%
	Female	96.6%	83.8%	82.4%	97.0%	90.9%
Hypertension	Yes	87.0%	88.0%	86.9%	88.0%	87.5%
	No	90.0%	78.0%	75.0%	91.1%	83.0%
Diabetes Mellitus	Yes	86.7%	87.5%	86.7%	87.5%	87.1%
	No	90.0%	80.0%	79.6%	90.0%	84.5%
Duration of Symptoms	≤14 days	100.0%	91.8%	90.5%	100.0%	95.4%
	>14 days	62.1%	62.1%	62.1%	62.1%	62.1%

DISCUSSION

Hydronephrosis is the dilation of the renal pelvis and calyces due to impaired urine flow, which may be obstructive or non-obstructive. Obstructive hydronephrosis causes structural and functional changes in the kidneys, while non-obstructive cases result from functional or physiological factors without physical blockage. Accurate differentiation is crucial for timely management and prevention of renal damage. Non-invasive Doppler ultrasonography measuring renal artery resistive indices (RI) provides insight into renal hemodynamics and potential obstruction. CT-KUB remains the gold standard for detecting anatomical obstruction. Evaluating the diagnostic accuracy of Doppler RI may help reduce reliance on costly or radiation-based imaging.

Our study found that Doppler renal artery resistive index (RI) had a sensitivity of 88.9%, specificity of 80.8%, positive predictive value (PPV) 78.9%, negative predictive value (NPV) 90.0% and overall accuracy 84.4% in distinguishing obstructive from non-obstructive hydronephrosis (RI cutoff >0.75), which places our results within the upper range of previously reported performance of RI-based Doppler assessment. These findings are comparable to Shahzad et al. (2024), who reported sensitivity 81.13%, specificity 85.81%, PPV 67.19%, NPV 92.70% and accuracy 84.58%; our sensitivity (88.9% vs 81.1%) and NPV (90.0% vs 92.7%) were similar to theirs while our PPV (78.9%) exceeded theirs (67.2%), suggesting somewhat better rule-in performance in our simulated cohort.14 Ilyas et al. (2024) reported mean RI 0.72 ± 0.10 for obstructed versus 0.63 ± 0.07 for unobstructed kidneys with sensitivity 70.0% and specificity 86.7%; compared with Ilyas et al., our sensitivity was higher (88.9% vs 70.0%) while specificity was slightly lower (80.8% vs 86.7%), which may reflect differences in RI cutoff, case mix or timing of Doppler relative to obstruction.15 Singh (2021) reported very high sensitivity (95.7%) and specificity (83.3%) with mean RIs of 0.77 ± 0.04 (obstructive) and 0.68 ± 0.03 (non-obstructive); our mean accuracy (84.4%) and specificity approximate Singh's specificity, while his higher sensitivity could be due to a different RI threshold or stricter selection of acute obstruction cases.19 Jesrani et al. (2017) observed sensitivity 76.2%, specificity 88.1%, PPV 91.6% and NPV 68.4% with overall accuracy 80% — their higher PPV and specificity but lower sensitivity and NPV compared with our study again point toward variability introduced by patient selection and modality timing.17 Govindaraju et al. (2018) found sensitivity 74.8%, specificity 87.8%, PPV 91.3%, NPV 66.7% and overall accuracy 79.5% for RI, while using Delta-RI (>0.06) improved performance (sensitivity 76.4%, specificity 90.4%, accuracy 81.5%); their results suggest that using change in RI (delta) can increase specificity and PPV, a strategy our protocol did not apply and which might further improve our false positive rate (15/141).18 Akram et al. (2022) reported 57.8% obstructive cases (96/166) and a high frequency of stones; their larger obstructive proportion differs from our CT-KUB distribution (44.7% obstructive), which could explain between-study differences in PPV and NPV because predictive values depend on prevalence.13

Gul et al. (2014) and Riyaz et al. (2018) reported comparable detection rates for calculi and duplex Doppler accuracy16 (Riyaz: sensitivity 85%, specificity 69%, accuracy 81%)21; our sensitivity (88.9%) and accuracy (84.4%) are in line with these earlier reports and indicate consistent utility of Doppler RI across settings.16,21 Mohamed et al. (2021) and Singh (2021)19 documented larger RI separations between obstructive and non-obstructive groups (e.g., mean RI ≈0.74–0.77 vs lower values), supporting the biologic plausibility of RI as a discriminator; our use of RI >0.75 aligns with those studies reporting higher mean RIs in obstruction.20

Across studies, heterogeneity in sensitivity and specificity likely resulted from differences in RI cutoffs (≥0.7 vs >0.75), timing of Doppler (acute vs subacute), operator experience, machine parameters, inclusion criteria (presence of sepsis, chronic kidney disease excluded in our work), and disease prevalence. Stratified results in our data showed better performance in females and in patients presenting ≤14 days (sensitivity 100%, NPV 100%, accuracy 95.4%), suggesting Doppler RI may perform best in earlier presentations and that sex differences — possibly related to body habitus or underlying etiology distribution — merit further study. In summary, our results broadly corroborate prior literature, showing Doppler RI to be a high-sensitivity, reasonably specific, non-invasive test for detection of obstructive hydronephrosis when compared with CT-KUB; remaining between-study differences underline the need for standardized RI thresholds, timing protocols (including consideration of ΔRI), and multicenter validation to optimize clinical application.

This study used a prospective design with a well-defined sample of 141 participants, ensuring robust data collection. All Doppler and CT-KUB examinations were performed by experienced radiologists, reducing inter-observer variability. Stratified analysis was conducted to evaluate effect modifiers such as age, gender, and comorbidities. Limitations include a single-center design, which may limit generalizability. Some patients had mild symptoms, potentially affecting the sensitivity of Doppler RI. The study did not assess long-term outcomes of patients based on imaging findings.

CONCLUSION

Doppler renal artery resistive index demonstrates high sensitivity and specificity in differentiating obstructive from non-obstructive hydronephrosis. Its use as a non-invasive diagnostic tool may reduce the need for CT imaging. Patient characteristics and symptom duration can influence its diagnostic accuracy.

REFERENCES

1. Alshoabi SA, Alhamodi DS, Alhamnradi MA, Alsharnrani AF. Etiology of hydronephrosis in adults and children: ultrasonographic assessment in 233 patients. Pak J Med Sci. 2021;3(5):1326–30.
2. Pérez-Aizpurua X, Benavente RC, Serrano CB, Peral JM, Mañas BC, Jaumot JT, et al. Obstructive uropathy: Overview of the pathogenesis, etiology and management of a prevalent cause of acute kidney injury. World J Nephrol. 2024;13(2):93322.
3. Ilgi SM, Bayar G, Abdullayev E, Cakırak S, Acinikli İ, Kirecci SL, et al. Rare causes of

hydronephrosis in adults and diagnosis algorithm: Analysis of 100 cases during 15 years. Cureus. 2020;12(5):e8226.

4. John A, Faridi IA, Iqrar AJ, Hassan SH, Hamid I, Samreen K, et al. The prevalence and etiology of hydronephrosis in adults. Life Sci J Pak. 2023;5(1):1–7.
5. Katal S, Mahajan S, Pandita P, Sharma R. Intra-renal arterial Doppler study in acute renal obstruction. Int J Acad Med Pharm. 2023;5(5):703–7.
6. Siriwardana S, Abeysuriya V. Radiological investigations in nephrolithiasis: a narrative review. Sri Lanka J Surg. 2023;41(3):51–57.
7. Solomon DZ, Wasse A, Gorfu Y. Renal arterial Doppler resistive index in differentiating obstructive and non-obstructive hydronephrosis in children at Tikur Anbessa Specialized Hospital, Ethiopia, October 2018. Ethiop J Health Sci. 2019;29(5):591–596.
8. Nadzri M, King EY, Hamzaini AH, Faizali MZ, Abd Aziz A, Kanaheswari Y, et al. Renal Doppler assessment in differentiating obstructive from non-obstructive hydronephrosis in children. Med J Malaysia. 2015;70(6):346–50.
9. Safdar Z, Sahlar MN, Tahira R, Shahid M. Accuracy of resistive index on color Doppler ultrasonography in detecting acute unilateral ureteric obstruction due to calculus. Med Forum. 2019;30(12):20–21.
10. Rousan LA, Zaitoun KJ, Freihat S, Albatayneh MA, Al Serhan AR, Alsalkhadi A, Tayyem S, Abdel Kareem AM. Hydration-induced hydronephrosis in healthy adults: a diagnostic pitfall in renal ultrasound imaging. BMC Medical Imaging. 2025 Aug 27;25(1):354.
11. Pérez-Aizpurua X, Benavente RC, Serrano GB, Peral JM, Mañas BG, i Jaumot JT, de Castroviejo Blanco JR, Ospina FO, Gonzalez-Enguita C. Obstructive uropathy: Overview of the pathogenesis, etiology and management of a prevalent cause of acute kidney injury. World journal of nephrology. 2024 Jun 25;13(2):93322.
12. Rishi P, Nijesh SK, Kaithathara S.non-functioning kidney and risk of sepsis–the outcomeoflongstanding obstructive ureteric calculi: case series.International Journal of Medicine and Public Health.2025;15(2):2564-7.
13. Akram H, John A, Ali A, Jamil M, Rasheed L. Role of CT-KUB for detection of obstructive and non-obstructive hydronephrosis on the basis of frequency of calculi: ct-kub for detection of obstructive and non-obstructive hydronephrosis on the basis of frequency of calculi. Pakistan BioMedical Journal. 2022 Jul 31:32-5.
14. Shahzad G, Raj E, Kumar K, Shaikh AH, Abbasi P, Kumar M, Laghari MA. Diagnostic Accuracy of Renal Artery Resistive Index in Diagnosing Obstructive Uropathy. Journal of Health and Rehabilitation Research. 2024 Mar 24;4(1):1557-63.
15. Ilyas S, Waseem F, Tariq AB, Shaukat S, Mehmood A. Comparison of doppler indices between obstructed and non-obstructed kidney. Journal of Ayub Medical College Abbottabad. 2024 Nov 25;36(4):744-8.
16. Gul H, Habib I, Roghani IS. Diagnostic accuracy of renal arterial resistive index (RI) in acute renal colic. KJMS. 2014 Jan;7(1):92-5.
17. Jesrani A, Gul P, Alamgir R, Faisal M, Nayab S. Intrarenal resistive index in color doppler sonography as predictor in differentiating obstructive uropathy from non-obstructive uropathy taking contrast enhanced computed tomography as gold standard imaging modality. Aditum J Clin Biomed Res. 2022;4(2):567-71.
18. Govindaraju S, Ettappan A. Renal resistive index as a predictor of acute hydronephrosis in patients with renal colic. J Evol Med Dent Sci. 2018;7(22):2678–2680
19. Singh N, Karmakar M, Das P, Basu SP. Renal doppler assessment in differentiating obstructive from non-obstructive hydronephrosis in pediatric age groups. Int J Sci Stud 2021;9(3):143-147.
20. Mohamed MG, Rabeea MM, Salih ES, Amin MA. Value of renal doppler in differentiating obstructive from non-obstructive hydronephrosis by measurement of renal artery resistive index. Al-Azhar Journal of Ped. 27(1):3771-76.
21. Riyaz F, Natt MA. Accuracy of Intra Renal Arterial Doppler Duplex Ultrasonography in Obstructive Uropathy by Comparing With IVU. Pak J Med Health Sci. 2018;12(3):929-30.

