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Original Article

Diagnostic Accuracy of Renal Artery Resistive Index in Diagnosing Obstructive Uropathy

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ABSTRACT

Background: Obstructive uropathy, a common cause of acute and chronic kidney disease, poses diagnostic challenges, particularly when non-invasive methods are preferred to reduce patient exposure to ionizing radiation from CT scans. The renal artery resistive index (RI) measured by Doppler ultrasound presents a potential non-invasive diagnostic tool, yet its accuracy and utility in clinical practice require further elucidation.

Objective: To assess the diagnostic accuracy of the renal artery resistive index (RI) as measured by Doppler ultrasound in identifying obstructive uropathy, using CT scans as the gold standard for comparison.

Methods: This cross-sectional study included 201 patients presenting with symptoms indicative of obstructive uropathy at a tertiary care hospital. Participants underwent both Doppler ultrasound to measure the renal artery RI and non-contrast CT scans of the kidneys, ureters, and bladder (KUB). The diagnostic performance of the RI was evaluated in terms of sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and overall accuracy, with CT scan findings serving as the benchmark.

Results: The study cohort had a mean age of 43.02±15.62 years, with a male predominance (64.7%). The renal artery RI demonstrated a sensitivity of 81.13%, specificity of 85.81%, PPV of 67.19%, NPV of 92.70%, and an overall accuracy of 84.58% in diagnosing obstructive uropathy. Calculi were more frequently located in the right urinary tract (54.2%) than the left (45.8%), with the majority being smaller than 1 cm (79.1%).

Conclusion: The renal artery resistive index (RI) measured by Doppler ultrasound is a highly accurate diagnostic tool for detecting obstructive uropathy, offering a viable, non-invasive alternative to CT scans. This method could significantly reduce unnecessary radiation exposure in patients, aligning with current healthcare priorities for safety and efficiency.

Keywords: Obstructive Uropathy, Renal Artery Resistive Index, Doppler Ultrasound, CT Scan, Diagnostic Accuracy, Kidney Disease, Non-Invasive Diagnosis, Healthcare Safety.

INTRODUCTION

Obstructive uropathy, defined as any anatomical or functional impediment to urine flow resulting in kidney damage, is identified as a significant, albeit potentially reversible, cause of both acute and chronic kidney disease. This condition afflicts approximately 1.7 per 1000 individuals, accounting for about 10% of all acute and chronic kidney disease cases, inclusive of 5% of individuals on chronic dialysis (1-4). The occurrence of kidney disease due to post-renal factors is notably higher in both younger and older populations. Obstructive uropathy can be classified into several categories: acute versus chronic, unilateral versus bilateral, and partial versus complete obstruction, whether extrinsic or intrinsic. Obstructions may occur at any point within the urinary tract, from the renal calyces to the urethral meatus. Among the myriad factors contributing to this condition, benign prostatic hypertrophy, or hyperplasia, is identified as the most common cause. However, other causes, such as constipation, urethral stenosis, phimosis, paraphimosis, prostatic adenocarcinoma, retroperitoneal adenopathy, colonic endometriosis, ureterocele, urolithiasis, neuropathic bladder dysfunction, parasitic obstructions, bladder endometriosis, and urate nephrolithiasis, are also recognized, albeit less frequently (5-8).

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The clinical manifestation of obstructive uropathy often includes symptoms such as abdominal or groin pain, vomiting, nausea, and excessive sweating or diaphoresis. Kidney, ureter, and urinary tract stones are pinpointed as the most common underlying causes, with pregnancy, prostate cancer, retroperitoneal fibrosis, spinal cord injury, ureteral stricture, and obstruction at the ureteropelvic junction also serving as significant contributors (9-12). The physiological blockade in the urinary system primarily stems from anatomical damages to the renal pelvis and inadequate smooth muscle differentiation.

A variety of imaging modalities are employed for the evaluation of patients presenting with obstructive uropathy, including radiography, CT scan, MRI, ultrasound, intravenous urography, and radionuclide tests. Ultrasonography (USG) is favored for detecting collecting system dilatation in cases of obstruction more effectively than intravenous urography (IVU), despite its limitation in visualizing the central portion of the ureters and revealing the renal tract's functional state (13, 14). CT urography, compared to MR urography, offers more precise diagnostic results, making it the preferred method for diagnosing a range of urological conditions, including urolithiasis, obstructive uropathy, urinary tract infections, renal cancers, and trauma. The introduction of new multidetector CT (MDCT) scanners has enhanced the capacity for rapid imaging with improved temporal-spatial resolution, facilitating the generation of virtual cystoscopy images (15, 16).

Ultrasonography remains the primary diagnostic tool for the initial assessment of patients with acute abdomen symptoms, especially in pediatric cases, highlighting its critical role in diagnosing acute renal coli, a prevalent pathology within the acute abdomen spectrum. Interestingly, studies indicate that up to 30% of patients with acute renal coli exhibit no observable dilation, underscoring that the dilatation observed in the collecting system does not always correlate with obstructions in the downstream urinary tract, and can occasionally be confused with pseudo-aneurysms of the intra-renal arteries (17-19). In this context, Color Doppler Ultrasound (CDUS) becomes an essential diagnostic tool for vascular anomalies, with the measurement of the renal artery resistive index (RI) via Doppler ultrasonography playing a crucial role in delineating changes in renal blood flow.

The therapeutic approach to obstructive uropathy involves promptly halting the obstructive process, with initial interventions often focused on measuring bladder volume to guide further treatment. Particularly in cases attributed to benign prostatic hypertrophy or hyperplasia, the most common causes, the use of a Foley catheter is frequently considered (20). Despite this, the diagnostic accuracy of Doppler ultrasonography, particularly the assessment of the renal artery resistive index, in diagnosing obstructive uropathy, has not been extensively explored in certain regions, such as Pakistan. This study, therefore, aims to assess the diagnostic efficacy of Doppler's ultrasound, specifically the renal artery resistive index, in diagnosing obstructive uropathy, with CT scans serving as the comparative gold standard.

MATERIAL AND METHODS

This cross-sectional study was conducted at the Radiology Department of Liaquat University of Medical & Health Sciences, Jamshoro, subsequent to obtaining synopsis approval from the College of Physicians and Surgeons, Pakistan. Employing a non-probability consecutive sampling method, the investigation spanned approximately seven months, from March 1st, 2022, to October 1st, 2022. The cohort comprised 201 individuals aged between 18 and 80 years, encompassing both genders. Eligibility criteria included patients who underwent non-contrast CT KUB and presented with acute flank pain of any severity, with or without accompanying symptoms of burning micturition for at least an hour. Exclusion criteria were set for patients presenting with similar complaints but diagnosed with renal diseases other than renal obstruction based on medical records, those previously diagnosed with urinary tract infection or stone disease and were seeking follow-up, pregnant women, and children.

Prior to participation, all patients consented in writing to their inclusion in the study. The research meticulously documented demographic details including age, gender, duration of symptoms, and the size and position of calculi. Imaging was executed using a sixteen-slice CT scanner, with a consultant radiologist, boasting over three years of experience in interpreting non-contrast CT scans of the KUB region, analyzing the images on a computer to determine the location and dimensions of the stones. Before the CT scan, participants underwent a color Doppler ultrasound focusing on the bladder, ureters, and kidneys using a curvilinear probe operating at 3.5 MHz. An adept sonologist, with more than three years of experience, performed the ultrasound examination, assessing both the peak systolic and end diastolic velocities of the renal artery, alongside determining the renal artery resistive index (RI).

Data analysis was conducted utilizing SPSS version 25. Quantitative variables, including age, size of the calculi on CT, peak systolic velocity, end diastolic velocity of the renal artery, and renal artery resistive index, were reported as means and standard deviations. Meanwhile, qualitative variables such as gender and the calculi's position on the CT scan were presented as frequencies and percentages. The diagnostic accuracy of the renal artery RI, including sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and overall diagnostic accuracy, were calculated using the findings from the CT scan as the gold standard, and results were tabulated in a 2 x 2 format. Additionally, the influence of potential effect modifiers like age, gender, peak systolic

and end diastolic velocities of the renal artery, calculus size, and stone position on the CT scan on the outcome variables was examined.

The study adhered to the ethical principles outlined in the Declaration of Helsinki, ensuring respect for all participants, safeguarding their right to privacy, and maintaining the confidentiality of their medical information. This approach not only facilitated a comprehensive assessment of the diagnostic accuracy of renal artery resistive index in identifying obstructive uropathy but also underscored the importance of combining advanced imaging techniques for improved diagnostic precision in clinical practice.

RESULTS

In the meticulous exploration of obstructive uropathy diagnostics, our study embarked on evaluating the prowess of renal artery resistive index (RI) against the established gold standard of CT scans. Encompassing a diverse cohort of 201 individuals, our analysis delved into a broad age spectrum, showcasing an almost balanced division with 49.3% of participants under 40 years and 50.7% above, as outlined in Table I.

Table 1: Demographic Details of Patients with Obstructive Uropathy (n = 201)

Variable	Count (Percentage)	Mean ± SD
Age groups		
Less than 40 years	99 (49.3%)	
Greater than 40 years	102 (50.7%)	
Age (years)		43.02 ± 15.62
Gender		
Male	130 (64.7%)	
Female	71 (35.3%)	
Duration of symptoms (days)		
Less than 10	141 (70.1%)	
More than 10	60 (29.9%)	
Duration of Symptoms in days		9.53 ± 8.47
Calculus location		
Left urinary tract	92 (45.8%)	
Right urinary tract	109 (54.2%)	
Calculus size		
Less than 1cm	159 (79.1%)	
Greater than 1cm	42 (20.9%)	
Size of Calculus (cm)		0.83 ± 0.75
Peak systolic velocity (PSV) of renal artery (cm/s)		59.16 ± 21.97
Less than 60	118 (58.7%)	
Greater than 60	83 (41.3%)	
End-diastolic velocity (EDV) of renal artery (cm/s)		19.63 ± 8.04
Less than 20	125 (62.2%)	
Greater than 20	76 (37.8%)	
Obstructive uropathy on resistive index (RI)		
Yes	63 (31.34%)	
No	138 (68.6%)	
Obstructive uropathy on CT scan		
Yes	53 (26.37%)	
No	148 (73.6%)	

This demographic diversity is further nuanced by gender distinctions, where males constituted 64.7% of the study population. The variance in symptom duration, predominantly under 10 days for 70.1% of patients, alongside the calculi's prevalence in the right urinary tract over the left (54.2% vs. 45.8%), frames the complexity of obstructive uropathy's clinical presentation.

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Table 2: The Diagnostic Accuracy of the RI Scan and CT Scan as the Gold Standard with Age, Gender, and Calculus Location

Variable	CT Scan Positive	CT Scan Negative	Total
Age ≤40 years (n=99)			
- RI Scan Positive	27	7	34
- RI Scan Negative	6	59	65
Total	33	66	99
Age >40 years (n=102)			
- RI Scan Positive	16	14	30
- RI Scan Negative	4	68	72
Total	20	82	102
Male Gender (n=130)			
- RI Scan Positive	28	14	42
- RI Scan Negative	7	81	88
Total	35	95	130
Female Gender (n=71)			
- RI Scan Positive	15	7	22
- RI Scan Negative	3	46	49
Total	18	53	71
Calculus Location in Right Urinary System (n=109)			
- RI Scan Positive	21	9	30
- RI Scan Negative	7	72	79
Total	28	81	109
Calculus Location in Left Urinary System (n=92)			
- RI Scan Positive	22	12	34
- RI Scan Negative	3	55	58
Total	25	67	92

A notable facet of our findings, captured meticulously in Table II, reveals the diagnostic accuracy of RI scans across age demographics, illustrating a slightly higher detection rate in younger individuals (≤40 years) with 34 positive RI findings compared to 30 in the older cohort (>40 years). This age-related diagnostic sensitivity is complemented by gender-specific insights, where male participants exhibited a greater number of positive RI scans (42), contrasting with the female subgroup (22). The calculus location further influenced RI scan outcomes, with a marginal discrepancy observed between calculi situated in the left versus the right urinary system, demonstrating the nuanced nature of RI scan efficacy.

Table 3: The Diagnostic Accuracy of the RI Scan and CT Scan as the Gold Standard with PSV, EDV, and Calculus Size

Variable	CT Scan Positive	CT Scan Negative	Total
PSV ≤ 60 cm/s (n=118)			
- RI Scan Positive	21	15	36
- RI Scan Negative	6	76	82
Total	27	91	118
PSV > 60 cm/s (n=83)			
- RI Scan Positive	22	6	28
- RI Scan Negative	4	51	55
Total	26	57	83
EDV ≤ 20 cm/s (n=125)			
- RI Scan Positive	35	21	56
- RI Scan Negative	7	62	69
Total	42	83	125
EDV > 20 cm/s (n=76)			
- RI Scan Positive	8	0	8

Variable	CT Scan Positive	CT Scan Negative	Total
- RI Scan Negative	3	65	68
Total	11	65	76
Calculus Size ≤ 1 cm (n=159)			
- RI Scan Positive	34	20	54
- RI Scan Negative	7	98	105
Total	41	118	159
Calculus Size > 1 cm (n=42)			
- RI Scan Positive	9	1	10
- RI Scan Negative	3	29	32
Total	12	30	42

Diving deeper into the technical realms of diagnostic evaluation, Table III encapsulates the critical role of peak systolic velocity (PSV) and end-diastolic velocity (EDV) alongside calculus size in determining RI scan accuracy. The data elucidates a pronounced diagnostic precision in cases with PSV ≤ 60 cm/s and EDV ≤ 20 cm/s, suggesting lower velocity metrics as potential harbingers of obstructive pathology discernible through RI scanning. Moreover, the analysis underscored the pivotal influence of calculus size on diagnostic outcomes, with smaller calculi (≤1 cm) more frequently associated with positive RI scans, highlighting the intricate interplay between calculus size and RI scan diagnostic utility.

Table 4: The Diagnostic Accuracy of the RI, Taking CT as the Gold Standard

Metric	Value (%)
Sensitivity	81.13
Specificity	85.81
Positive Predictive Value (PPV)	67.19
Negative Predictive Value (NPV)	92.70
Overall Accuracy	84.58

The culmination of our study's findings, presented in Table IV, showcases the diagnostic acumen of the RI scan, boasting an 81.13% sensitivity and 85.81% specificity in the realm of obstructive uropathy detection. The positive and negative predictive values (67.19% and 92.70%, respectively) further accentuate the RI scan's robustness as a diagnostic tool, with an overall accuracy rate of 84.58%. These metrics not only underscore the RI scan's efficacy but also illuminate its role as a viable diagnostic adjunct in the intricate landscape of obstructive uropathy detection, offering a glimpse into its potential utility in enhancing clinical outcomes through precise and timely diagnosis.

DISCUSSION

In our exploration of the diagnostic capabilities of the renal artery resistive index (RI) for identifying obstructive uropathy, this study engaged a cohort of 201 participants, drawing upon CT scans as the definitive standard for comparison. Acute obstructive uropathy, a prevalent cause of acute abdominal distress, presents diagnostic challenges, particularly when urinary tract dilation proximal to the obstruction is minimal. In such contexts, the RI values derived from intra-renal artery Doppler evaluations have been posited as a valuable diagnostic adjunct (21). The impetus for our investigation was to assess the utility of Doppler ultrasound's renal artery RI in diagnosing obstructive uropathy, juxtaposed against the backdrop of CT scan assessments, renowned for their precision yet critiqued for their ionizing radiation risks.

Reflecting on comparative studies, one particular investigation involving 162 patients highlighted the early-stage diagnostic accuracy of Doppler ultrasound for RI in renal blockages. This study revealed a distinct distribution of mean ages between patients with obstructive renal disease and those with non-obstructive kidney conditions (22), aligning with our findings which indicated a mean patient age of 43.02±15.62 years, with a predominance of male participants (64.7%). Our results, mirroring prior research, underscored the diagnostic value of RI, especially at a cutoff value exceeding 0.7, for confirming obstructive uropathy in a significant fraction of cases based on RI and CT scan findings (23, 24).

Further substantiation comes from studies examining the mean resistive index in patients suffering from acute renal colic, predicting hydronephrosis with notable specificity and accuracy (18, 25). Our investigation's sensitivity and specificity metrics for Doppler ultrasound in diagnosing obstructive uropathy—81.13% and 85.81%, respectively—corroborate these prior findings, employing CT scans as the gold standard. Moreover, the analysis not only reaffirmed the diagnostic efficacy of RI but also accentuated its role in

nuanced clinical decision-making, thereby minimizing unnecessary reliance on CT scans and their associated ionizing radiation exposure.

Analogous to another cross-sectional study that pitted intravenous urography (IVU) against intra-renal arterial Doppler ultrasonography among 79 individuals, our study, too, vouched for Doppler ultrasonography's elevated sensitivity, specificity, and diagnostic accuracy (26). Both investigations bear testimony to Doppler sonography's enhanced specificity and precision in diagnosing obstructive uropathy, further validating the utility of RI in clinical settings.

Contrasting findings from a Pakistani study, which established the RI's accuracy in detecting renal calculi verified by IVU, our study diverges slightly, underscoring the nuanced specificity and sensitivity of Doppler ultrasound in diagnosing acute unilateral renal obstruction (27). Such disparities underscore the dynamic interplay between various diagnostic modalities and the intrinsic heterogeneity of patient populations under study.

Our study, notwithstanding its strengths—such as adherence to a robust methodological framework and utilization of CT scans as a gold standard—was not without limitations. The confines of a single-center study, the modest sample size, and the absence of renal vein assessments constitute notable constraints, potentially affecting the generalizability of our findings. Additionally, the exclusive focus on acute obstructive uropathy, to the exclusion of chronic conditions, delineates a scope for further research. Future studies, ideally with broader demographic and clinical spectra, are thus warranted to elucidate the diagnostic accuracy of obstructive uropathy, potentially leveraging IVU as a comparative benchmark.

In conclusion, our investigation attests to the renal resistive index's remarkable diagnostic precision for obstructive uropathy, showcasing impressive sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and overall diagnostic accuracy when juxtaposed with CT scan findings. These insights advocate for the strategic deployment of Doppler ultrasonography in discerning acute renal blockages, heralding a paradigm where clinicians might eschew unnecessary CT scans in favor of a less invasive, yet equally efficacious diagnostic approach.

CONCLUSION

This study substantiates the renal artery resistive index (RI) as a highly accurate diagnostic tool for obstructive uropathy, with commendable sensitivity, specificity, and overall diagnostic accuracy in comparison to CT scans, the gold standard. These findings herald a pivotal shift towards the judicious use of Doppler ultrasonography in the early detection of acute renal obstructions, potentially mitigating the reliance on CT scans and, consequently, reducing patients' exposure to ionizing radiation. The implications for human healthcare are profound, promising enhanced diagnostic efficiency, minimized risks, and improved patient outcomes through the adoption of safer, non-invasive diagnostic methodologies in the management of obstructive uropathy.

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