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RENAL VENOUS DOPPLER SONOGRAPHY IN OBSTRUCTIVE UROPATHY

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ABSTRACT

Background: Obstructive uropathy impairs urine flow and may lead to progressive renal damage if not detected early. Doppler ultrasonography, particularly venous parameters, enables functional assessment before anatomical changes appear. This study aimed to evaluate the diagnostic utility of renal venous Doppler sonography in the early detection of acute obstructive uropathy. **Materials and Methods:** This cross-sectional analytical study included 140 participants (70 cases and 70 controls) recruited by convenient sampling at the Department of Radiodiagnosis, Government Stanley Medical College and Hospital, Chennai, between February 2024 and February 2025. Adults with ultrasound- or CT-confirmed acute ureteric obstruction and healthy controls were included. Intrarenal arterial (resistive index) and venous Doppler parameters (venous impedance index, waveform pattern, and peak venous flow) were measured using standardized techniques. Group comparisons and receiver operating characteristic (ROC) curve analysis were performed. **Results:** Peak venous flow was higher in obstructed kidneys than in unobstructed kidneys (26.10 ± 10.98 vs 20.30 ± 12.68 cm/s; p = 0.001), and venous impedance index was significantly lower (0.250 ± 0.059 vs 0.412 ± 0.073; p = 0.001). ROC analysis showed high diagnostic performance for venous impedance index (cut-off ≤ 0.35; AUC 0.93; sensitivity 92%; specificity 91%) and for peak venous flow (cut-off ≥ 16 cm/s; AUC 0.88; sensitivity 86%; specificity 88%). In early obstruction without pelvicalyceal system dilatation, peak venous flow was 36.95 ± 6.75 cm/s, venous impedance index was 0.305 ± 0.027, and arterial resistive index was 0.628 ± 0.042. Venous impedance index showed a significant negative correlation with the degree of obstruction (r = –0.26, p = 0.03). **Conclusion:** Renal venous Doppler, particularly venous impedance index and peak venous flow, provides a sensitive, non-invasive means of detecting early acute obstructive uropathy, showing higher diagnostic performance than arterial indices.

INTRODUCTION

Obstructive uropathy is a pathological condition characterised by impaired urine flow due to mechanical or functional obstruction at any level of the urinary tract.[1]

This disruption leads to a cascade of physiological changes, including increased intrapelvic pressure, decreased renal blood flow, and potential compromise of renal function. If left untreated, obstruction may progress to irreversible nephron loss and chronic kidney disease. Early diagnosis and intervention are crucial in preventing long-term complications and preserving renal function.[2-4]

Conventional grey-scale ultrasonography is the most commonly employed first-line imaging modality in suspected cases of obstructive uropathy.[5] Its advantages include non-invasiveness, affordability, wide availability, and the absence of radiation exposure. However, grey-scale ultrasound primarily detects anatomical changes such as hydronephrosis, which may not be present in the early phase of obstruction. This limitation reduces its sensitivity in detecting acute or partial obstruction where functional impairment precedes morphological changes.[6-8]

Doppler ultrasonography, by enabling the assessment of renal blood flow, gives valuable understandings into the functional status of the kidney.[9,10]

Among the arterial parameters, the resistive index (RI) and peak systolic velocity (PSV) have been studied widely for their potential to identify obstructive patterns. While some studies have shown moderate sensitivity of these indices, their reliability is reduced by variability due to age, systemic vascular resistance, hydration status, and coexisting renal parenchymal disease.[11,12]

More recently, venous Doppler parameters have been proposed as alternative and potentially superior indicators of obstructive uropathy. Parameters such as the venous impedance index (VII) and peak venous flow have been demonstrated to change significantly in acute obstruction, reflecting increased intrarenal venous congestion and compliance alterations. These changes may appear earlier than arterial flow disturbances or hydronephrosis, making venous Doppler particularly attractive for early diagnosis.[13-15]

Despite promising results from international studies, the role of venous Doppler sonography remains underutilised in routine clinical practice, particularly in resource-constrained settings. Limited data exist in the Indian population regarding its diagnostic value, and few studies have attempted to directly compare the diagnostic performance of arterial and venous Doppler parameters in acute obstruction. This highlights the need for more region-specific evidence to inform clinical practice.

Aim

This study aimed to evaluate the diagnostic utility of renal venous Doppler sonography in the early detection of acute obstructive uropathy.

MATERIALS AND METHODS

This cross-sectional analytical study was conducted on 140 participants at the Department of Radiodiagnosis, Government Stanley Medical College and Hospital, Chennai, from February 2024 to February 2025. The study was approved by the Institutional Ethics Committee of Government Stanley Medical College. Informed consent was obtained from all patients before enrolling in the study. Participants were recruited using convenient sampling from eligible patients referred to the radiology department.

Inclusion criteria

Patient group: Patients aged >18 years, both sexes, with symptoms of renal colic of less than 4 weeks duration, with positive radiological evidence of obstruction (calculus or stricture) identified on ultrasound, intravenous urography, or CT imaging were included.

Control group: Healthy volunteers and patients without congenital renal anomalies, focal renal lesions (benign or malignant), acute or chronic renal infections, without systemic diseases known to affect renal parenchyma (e.g., diabetes mellitus, hypertension, or connective tissue disorders) were also included.

Exclusion criteria

Patients unwilling to undergo Doppler ultrasonography, incapable of providing informed consent due to cognitive impairment or mental illness, congenital renal anomalies, focal lesions (tumours), or infections (acute/chronic), with systemic diseases such as diabetes mellitus, hypertension, or autoimmune/connective tissue disorders known to alter renal parenchymal architecture were excluded.

Sample size: Sample size was calculated based on the VII values reported by Vadana et al,[16] using 80% power, 95% confidence interval and OpenEpi software, yielding 70 participants per group after adjusting for 10% non-response.

Methods

A total of 140 participants were included, comprising 70 patients with confirmed acute obstruction and 70 age-matched healthy controls without renal pathology. All patients underwent preliminary imaging with either grayscale ultrasonography or non-contrast CT KUB to confirm obstructive pathology. Only patients with evidence of acute ureteric obstruction (ureteric calculus or stricture) were included. Patients with sonographic pelvicalyceal system dilatation were excluded to restrict the analysis to early obstructive changes prior to hydronephrosis.

Eligible participants underwent comprehensive renal Doppler ultrasonography using a MINDRAY DC-80 system with curvilinear transducers and spectral Doppler capability. Examinations were performed in the supine or slight oblique position. Intrarenal arterial flow was assessed at the interlobar or segmental arteries in both kidneys, with spectral waveforms obtained from the upper, mid, and lower poles.

The RI was calculated as (PSV – End Diastolic Velocity) / PSV, and the mean of three measurements was used for analysis.

Venous Doppler evaluation was performed on the interlobar renal veins of both kidneys. The VII was calculated as (maximum venous velocity − minimum venous velocity)/maximum venous velocity. Venous waveform patterns were classified as continuous, biphasic, or monophasic. All grayscale and Doppler parameters were documented using a structured proforma. Demographic details, clinical data, and relevant laboratory and imaging findings (CT/IVU) were also recorded. Data were recorded using a pre-tested structured proforma capturing demographic, clinical, CT and Doppler variables.

The primary outcome measures were VII, arterial RI, and ΔRI. Secondary variables included age, sex, symptom duration, and CT-based obstruction characteristics.

Statistical analysis

Data were entered in Microsoft Excel 365 and analysed using SPSS version 26. Descriptive statistics were expressed as mean, standard deviation and frequencies, percentages. The association between categorical variables were measured using chi-square test. The association between continuous variables were measured using an independent t-test. Correlation was measured using the Pearson correlation coefficient. ROC was used to predict the

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cut-off value and diagnostic performance. P value of < 0.05 was considered significant.

RESULTS

A total of 140 participants (70 cases with confirmed ureteric obstruction and 70 controls) were included in the final analysis. The majority of cases were in the 21-30-year age group (22, 31.4%), while controls were most commonly in the 51–60-year group (18, 25.7%), with no significant difference (p = 0.73). Females constituted 51.4% of the cases and 50.0% of the controls, while males comprised 48.6% of the cases and 50.0% of the controls, indicating no significant sex difference (p = 0.86).

All cases presented with renal colic (70, 100%), whereas all controls were asymptomatic or attended for routine evaluation (70, 100%). Among cases, most patients had a pain duration of 2 days (59, 84.3%). On CT evaluation, the most common site of obstruction was the vesicoureteric junction (VUJ) (28, 40.0%), followed by the proximal ureter (14, 20.0%). [Table 1]

Table 1: Demographic and clinical profile

Parameter	Category	Cases (n = 70)	Controls (n = 70)	P value
Age (years)	21–30	22 (31.4%)	16 (22.9%)	0.73
	31–40	12 (17.1%)	15 (21.4%)	
	41–50	10 (14.3%)	11 (15.7%)	
	51–60	14 (20.0%)	18 (25.7%)	
	61–70	12 (17.1%)	10 (14.3%)	
Sex	Female	36 (51.4%)	35 (50.0%)	0.86
	Male	34 (48.6%)	35 (50.0%)	
Chief complaint	Renal colic	70 (100%)	0 (0%)	—
	Routine check-up / asymptomatic	0 (0%)	70 (100%)	
Duration of pain (days)	1 (cases only)	11 (15.7%)	—	—
	2 (cases only)	59 (84.3%)	—	
Site of obstruction	Vesicoureteric junction (VUJ)	28 (40.0%)	—	—
	Proximal ureter	14 (20.0%)	—	
	Middle ureter	8 (11.4%)	—	
	Distal ureter	12 (17.1%)	—	
	Ureteropelvic junction (PUJ)	8 (11.4%)	—	

The overall study population had a mean age of 43.32 ± 14.79 years. Among cases, the mean duration of pain was 2.34 ± 0.74 days. The overall mean kidney size was 10.50 ± 0.81 cm. When compared between groups, kidney size was 10.53 ± 0.80 cm in cases and 10.47 ± 0.81 cm in controls, with no significant difference (p = 0.66). Among cases, the mean stone size was 0.95 ± 0.31 cm. [Table 2]

Table 2: Baseline demographic and imaging parameters

Parameter	Group	Mean ± SD	P value
Age (years)	Overall	43.32 ± 14.79	—
Duration of pain (days)	Cases only	2.34 ± 0.74	—
Kidney size (cm)	Overall	10.50 ± 0.81	—
	Cases	10.53 ± 0.80	0.66
	Controls	10.47 ± 0.81	
Stone size (cm)	Cases only	0.95 ± 0.31	—

PSV in the interlobar artery was higher in obstructed kidneys (33.45 ± 9.07 cm/s) than in unobstructed kidneys (30.51 ± 8.82 cm/s) among cases. Overall, cases demonstrated a higher PSV compared to controls; however, this difference was not significant (p = 0.102). Among cases, the arterial RI was mildly elevated in obstructed kidneys compared to unobstructed kidneys, with no significant difference (p = 0.26). Similarly, the mean RI in cases was higher than in controls, but without significance (p = 0.26). Controls showed minimal right–left variation (right: 0.560 ± 0.052, left: 0.571 ± 0.040).

Peak venous flow was higher in obstructed kidneys (26.10 ± 10.98 cm/s) than in unobstructed kidneys (20.30 ± 12.68 cm/s). When compared between groups, venous flow differed significantly between cases and controls (p = 0.001).

VII was significantly reduced in obstructed kidneys compared to unobstructed kidneys (p = 0.001). Overall, cases had a lower VII than controls (p = 0.001), while controls demonstrated minimal side-to-side variation (right: 0.441 ± 0.061, left: 0.420 ± 0.072). [Table 3]

Table 3: Comparison of arterial and venous Doppler parameters

Parameter	Group	Mean ± SD	P value
PSV of interlobar artery (cm/s)	Obstructed kidney (cases)	33.45 ± 9.07	—
	Unobstructed kidney (cases)	30.51 ± 8.82	—
	Cases (both kidneys)	35.10 ± 10.07	0.102
	Controls (both kidneys)	32.46 ± 9.31	
Arterial RI	Obstructed kidney (cases)	0.621 ± 0.061	—

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	Unobstructed kidney (cases)	0.590 ± 0.060	—
	Controls – right kidney	0.560 ± 0.052	—
	Controls – left kidney	0.571 ± 0.040	—
	Cases (both kidneys)	0.616 ± 0.02	0.26
	Controls (both kidneys)	0.570 ± 0.09	
Peak venous flow (cm/s)	Obstructed kidney (cases)	26.10 ± 10.98	—
	Unobstructed kidney (cases)	20.30 ± 12.68	—
	Cases (both kidneys)	14.74 ± 6.98	0.001
	Controls (both kidneys)	16.15 ± 8.05	
Venous impedance index (VII)	Obstructed kidney (cases)	0.250 ± 0.059	0.001
	Unobstructed kidney (cases)	0.412 ± 0.073	
	Controls – right kidney	0.441 ± 0.061	—
	Controls – left kidney	0.420 ± 0.072	—
	Cases (both kidneys)	0.300 ± 0.029	0.001
	Controls (both kidneys)	0.430 ± 0.061	

Peak venous flow at a cut-off of ≥ 16 cm/s showed good diagnostic performance with an AUC of 0.88, sensitivity of 86%, specificity of 88%, and overall accuracy of 87.0% (LR+ 7.17, LR– 0.16).

VII at a cut-off of ≤ 0.35 demonstrated superior accuracy with an AUC of 0.93, sensitivity of 92%, specificity of 91%, and diagnostic accuracy of 91.5% (LR+ 10.22, LR– 0.09). [Table 4]

Table 4: ROC curve analysis and diagnostic performance of venous Doppler parameters

Parameter	Peak venous flow	Venous impedance index
Cut-off value	≥ 16 cm/s	≤ 0.35
AUC	0.88	0.93
Youden index	0.74	0.83
Sensitivity	86%	92%
Specificity	88%	91%
PPV	87.80%	91.10%
NPV	86.30%	91.90%
Diagnostic accuracy	87.00%	91.50%
Positive LR	7.17	10.22
Negative LR	0.16	0.09

Across all subgroups, peak venous flow values were higher than peak arterial flow, with venous velocities ranging from 35.4 ± 5.8 cm/s (PUJ) to 39.1 ± 7.4 cm/s (VUJ). Arterial RI values were comparable across sites of obstruction, varying narrowly between 0.615 ± 0.05 (PUJ) and 0.630 ± 0.06 (VUJ). The VII showed small but consistent reductions in distal obstructions, with the lowest values at VUJ (0.290 ± 0.03) and distal ureter (0.295 ± 0.03), while slightly higher values were seen in PUJ obstruction (0.310 ± 0.02).

In early obstruction without PCS dilatation, venous flow (36.95 ± 6.75 cm/s) and venous impedance (0.305 ± 0.027) were already altered, despite relatively preserved arterial RI (0.628 ± 0.042). [Table 5]

Table 5: Distribution of renal Doppler parameters according to level of obstruction

Subgroup	Peak arterial flow (cm/s)	Peak venous flow (cm/s)	Arterial RI	Venous impedance index
PUJ	31.20 ± 7.5	35.40 ± 5.8	0.615 ± 0.05	0.310 ± 0.02
Proximal ureter	32.50 ± 6.9	36.10 ± 6.2	0.620 ± 0.06	0.295 ± 0.03
Middle ureter	34.00 ± 7.1	37.90 ± 6.6	0.618 ± 0.04	0.300 ± 0.02
Distal ureter	33.80 ± 8.2	38.50 ± 7.0	0.623 ± 0.05	0.295 ± 0.03
VUJ	33.00 ± 9.1	39.10 ± 7.4	0.630 ± 0.06	0.290 ± 0.03
Early obstruction without PCS dilatation	34.25 ± 8.90	36.95 ± 6.75	0.628 ± 0.042	0.305 ± 0.027

Peak arterial flow (r = –0.12, p = 0.29), peak venous flow (r = –0.08, p = 0.44), and arterial RI (r = 0.10, p = 0.35) did not show significant correlations with the degree of obstruction. In contrast, the VII demonstrated a significant negative correlation (r = –0.26, p = 0.03). [Table 6]

Table 6: Correlation between Doppler parameters and degree of obstruction

Doppler parameter	Pearson's r	P value
Peak arterial flow	–0.12	0.29
Peak venous flow	–0.08	0.44
Arterial RI	0.1	0.35
Venous impedance index	–0.26	0.03

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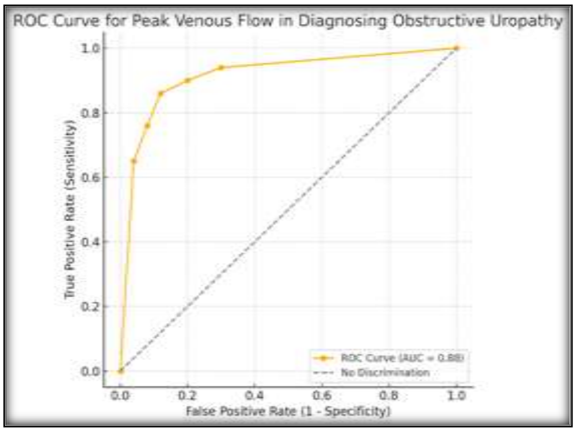

Figure 1: ROC curve analysis of peak venous flow for diagnosing obstructive uropathy

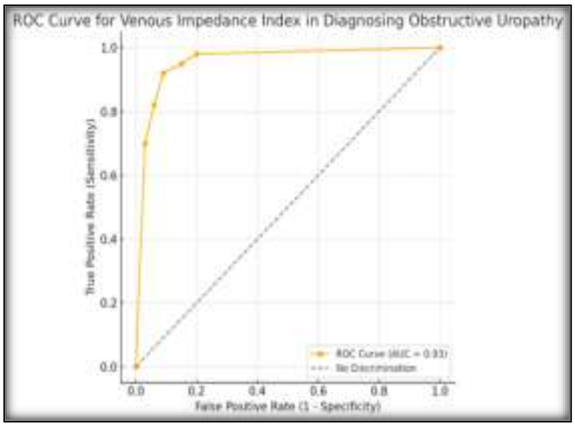

Figure 2: ROC curve analysis of VII for diagnosing obstructive uropathy

DISCUSSION

This study found that venous Doppler parameters, particularly peak venous flow and venous impedance index (VII), showed higher diagnostic performance than arterial indices for detecting early acute ureteric obstruction. The majority of patients were young to middle-aged adults. Previous studies show similar results: Vadana et al. reported a mean age of 32 years, and Katal et al. found a mean age of 33.6 ± 7.1 years.[16,17] Shahzad et al. reported a mean age of 43.02 ± 15.62 years, and Fazal et al. documented a mean age of 31.9 ± 6.12 years.[18,19] Gender distribution in our study was nearly equal, differing from prior reports of male predominance: Shahzad et al. observed 64.7% male.[18] Akram et al. reported 68.4% male, and Amirthalingam observed 66% male.[20,21] This suggests that although men are generally more prone to stone formation, women may also present with acute renal colic in certain settings. All patients in our study presented with acute renal colic, mostly within 48 hours of onset. In Vadana et al.'s study, patients reported similar early presentations, with features indicative of acute obstruction, allowing for early Doppler assessment prior to overt anatomical changes.[16] Oktar et al. demonstrated significant venous Doppler alterations in acute obstruction.[22] Akcar et al. noted that intrarenal resistive indices were stable regardless of symptom duration.[23] These findings emphasise that Doppler assessment is valuable in early-stage obstruction, even before significant anatomical changes occur.

Our study identified the VUJ as the most common site of obstruction, followed by proximal and distal ureteric segments. Bateman and Cuganesan reported distal ureteric calculi as predominant, while Amirthalingam documented distal ureter obstruction in most cases.[24,21] Shahzad et al. also reported a higher incidence of right-sided distal stones.[18] Overall, distal ureteric obstructions, particularly at the VUJ, induce more pronounced Doppler alterations, consistent with our observations.

In our study, kidney size did not differ significantly between obstructed and non-obstructed kidneys. Akcar et al. reported negligible differences in renal dimensions between obstructed and contralateral kidneys in their cohort,[23] while Fazal et al. reported no significant difference.[19] The mean stone size in our study was <1 cm, yet hemodynamic alterations were evident. Katal et al. reported that 79.1% of stones were <1 cm in diameter with detectable increases in RI and ΔRI.[17] Shahzad et al. documented a high prevalence of stones under 1 cm, with most cases exhibiting Doppler abnormalities despite minimal anatomical obstruction, confirming that small stones can produce significant obstruction.[18]

In our study, PSV and RI were marginally elevated in obstructed kidneys, but the difference was not significant. Bateman and Cuganesan observed PSV changes without diagnostic significance.[24] Akcar et al. and Fazal et al. did not consider PSV a significant parameter for detecting acute obstruction, as it lacked consistent correlation with obstruction severity.[23,19] Ilyas et al. reported an increase in PSV in obstructed kidneys, which was significant in their cohort; however, the predictive value remained inferior to that of RI and ΔRI.[25] Thus, while PSV may reflect localised hemodynamic changes, its standalone role in diagnosing obstructive uropathy appears limited, particularly in early obstruction.

In the present study, the RI was elevated in obstructed kidneys compared to unobstructed kidneys; however, the differences were not significant. Akcar et al. reported significant RI elevation in obstructed kidneys (mean RI = 0.71) compared to contralateral (0.61) and control kidneys (0.60).[23] Katal et al. noted RI ≥ 0.70 with ΔRI 0.10 ± 0.04, yielding high sensitivity (86.54%) and specificity (100%).[17] Our findings suggest arterial indices alone have limited utility in early obstruction, aligning with Vadana et al., who found no significant RI differences.

Venous indices in our study, particularly peak venous flow and VII, demonstrated significant differences between obstructed and non-obstructed kidneys. Peak venous flow was elevated, and VII was significantly reduced. Bateman and Cuganesan reported similar results, observing that peak venous flow in obstructed kidneys was 69% higher than in

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the unobstructed kidney and 86% higher than in controls, with strong statistical significance.[24] Oktar et al. also demonstrated elevated peak venous signals in acutely obstructed kidneys, attributing these changes to increased intrarenal pressure and impaired venous drainage.[22] Vadana et al. noted significant increases in venous flow velocity in obstructed kidneys.[16] These findings affirm that peak venous flow, though less commonly evaluated than RI, demonstrates high diagnostic performance in identifying obstructive hemodynamics.

Bateman and Cuganesan reported a significant reduction in venous impedance in obstructed kidneys (mean VII = 0.38) compared to unobstructed kidneys (0.80), while Vadana et al. reported VII as a significant marker for obstruction, even when RI did not show a difference.[24,16] Oktar et al. reported significantly lower VII 0.25 ± 0.07 in acute obstruction compared to unobstructed and chronic cases.[22] Our findings concur with these studies, confirming VII as a sensitive and specific marker for early obstruction.

Our study observed significant venous Doppler alterations even in the absence of pelvicalyceal system dilatation, suggesting that functional changes may occur before detectable structural changes. Akcar et al. highlighted that RI and ΔRI were useful in early obstruction,[23] while Vadana et al,[16] and Bateman and Cuganesan similarly reported reduced VII without overt dilatation.[24] Katal et al. demonstrated that RI ≥ 0.70 and ΔRI ≥ 0.08 could detect obstruction before PCS dilatation.[17] These findings reinforce the role of venous Doppler in early diagnosis when conventional ultrasound may be normal.

A negative correlation was observed between VII and duration of renal colic in our study, suggesting that prolonged obstruction leads to progressively lower venous impedance. Peak arterial and venous flow, as well as RI, showed weak, non-significant correlations. Akcar et al. similarly noted RI stability across symptom duration,[23] while Oktar et al. found venous indices altered in acute obstruction.[22] VII may reflect the temporal progression of obstruction, whereas arterial parameters remain time-insensitive.

Strengths

The strengths of this study include CT-confirmed obstruction, exclusion of PCS dilatation to focus on early disease, standardized Doppler measurements, and use of ROC analysis to quantify diagnostic accuracy.

Limitations

The study was limited by its single-centre design, absence of long-term post-obstruction follow-up, and lack of inter-observer variability assessment for Doppler measurements.

CONCLUSION

Doppler ultrasound is a valuable, non-invasive modality for detecting early functional changes in obstructive uropathy, even before pelvicalyceal dilatation becomes evident. This study highlights the role of hemodynamic assessment in improving diagnostic accuracy in acute renal colic. Among the parameters evaluated, venous indices, particularly venous impedance index and peak venous flow, demonstrated higher diagnostic performance than arterial parameters. Venous Doppler evaluation shows potential to improve early detection of obstructive uropathy and may reduce reliance on radiation-based imaging. Further multicentric studies with larger populations and longitudinal follow-up are warranted to validate these findings and explore the prognostic role of Doppler indices in renal functional outcomes.

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