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ASSESSING RENAL HEMODYNAMICS IN ACUTE URETERIC OBSTRUCTION USING RESISTIVE INDEX ON DOPPLER ULTRASONOGRAPHY: A PAIRED PROSPECTIVE STUDY

Radiodiagnosis

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ABSTRACT

Background: Acute ureteric obstruction due to calculi frequently presents as renal colic, requiring prompt diagnosis to prevent complications. While non-contrast computed tomography (CT) remains the gold standard, concerns about radiation exposure necessitate alternative diagnostic approaches. Doppler ultrasound-derived resistive index (RI) offers functional insight into renal hemodynamics when grayscale ultrasound findings are inconclusive. **Objective:** To evaluate the diagnostic accuracy of Doppler-derived resistive index in detecting acute ureteric obstruction and determine its clinical utility as a non-invasive alternative to CT imaging. **Methods:** This prospective observational study was conducted at J.J.M Medical College, Davanagere, from June to October 2024. Thirty patients aged 18-65 years presenting with unilateral acute renal colic within 24 hours were enrolled. All patients underwent grayscale and Doppler ultrasound examination using standardized protocols. Resistive index values were measured in bilateral segmental renal arteries. Statistical analysis included paired t-tests and ROC curve analysis. **Results:** The study included 30 patients (18 males, 12 females; mean age 42.7 years). Symptomatic kidneys demonstrated significantly higher RI values (0.75 ± 0.06) compared to contralateral kidneys (0.56 ± 0.05), with a mean paired difference of 0.19 (95% CI 0.15-0.23; $p < 0.001$). An RI threshold > 0.7 provided optimal diagnostic performance with an area under the curve of 0.89. **Conclusion:** Doppler-derived resistive index measurement is a valuable, non-invasive diagnostic tool for evaluating acute ureteric obstruction. Its integration into clinical protocols may reduce reliance on radiation-intensive CT imaging while providing functional hemodynamic assessment.

KEYWORDS

renal colic, resistive index, doppler ultrasonography, ureteral obstruction, nephrolithiasis

INTRODUCTION

Acute renal colic, predominantly caused by ureteric calculi, affects approximately 1-15% of the population worldwide, with peak incidence occurring in the third to fourth decades of life (15). The condition presents a significant clinical challenge, as delayed diagnosis can lead to serious complications including pyelonephritis, sepsis, irreversible renal damage, and in severe cases, loss of renal function (1). Traditional diagnostic approaches have relied heavily on imaging modalities, with non-contrast computed tomography (NCCT) establishing itself as the current gold standard due to its high sensitivity (95-98%) and specificity (96-100%) in detecting urolithiasis (10).

However, the widespread use of CT imaging raises considerable concerns regarding cumulative radiation exposure, particularly in young patients and those experiencing recurrent episodes of renal colic (9,14). Studies have demonstrated that patients with nephrolithiasis receive significantly higher lifetime radiation doses, with some experiencing exposures equivalent to 75-175 chest X-rays per episode (8). This concern is amplified by the increasing incidence of kidney stones globally, with recurrence rates reaching 50% within 10 years of the initial episode (15).

Ultrasonography, while radiation-free and readily available, has traditionally shown limited sensitivity (19-57%) for detecting ureteric stones, particularly in cases of early or partial obstruction where hydronephrosis may not be evident on grayscale imaging (10). This limitation has led to the exploration of functional ultrasound techniques, particularly Doppler-derived resistive index (RI) measurement, which provides insight into intrarenal hemodynamic changes that occur during acute obstruction (2).

The resistive index, calculated as (peak systolic velocity – end diastolic velocity)/peak systolic velocity, reflects vascular resistance within the renal parenchyma (7). During acute ureteric obstruction, increased intrapelvic pressure leads to elevated intrarenal vascular resistance, resulting in measurable changes in RI values (3). Recent studies have demonstrated promising results for RI measurement in detecting acute obstruction, with reported sensitivities ranging from 81-92% and specificities of 88-95% (2,11,12).

Given the increasing emphasis on radiation reduction in medical imaging and the need for accurate, non-invasive diagnostic tools, there is a compelling rationale for investigating the clinical utility of Doppler-derived RI in acute ureteric obstruction. The present study aims to evaluate the diagnostic accuracy of resistive index measurement in detecting acute ureteric obstruction and assess its potential role as a reliable alternative to CT imaging in appropriate clinical scenarios.

MATERIALS AND METHODS

Study Design And Setting: This prospective paired comparision study was conducted at the Department of Radiodiagnosis, J.J.M Medical College, Davanagere, Karnataka, India, from June to October 2024. The study protocol was approved by the Institutional Ethics Committee, and written informed consent was obtained from all participants prior to enrollment.

Study Population: Thirty patients aged 18-65 years presenting with unilateral acute renal colic within 24 hours were enrolled. Exclusion criteria included bilateral ureteric obstruction, known pre-existing renal pathology, hemodynamic instability, pregnancy, recent nephrotoxic medication use, and inability to cooperate for ultrasound examination.

Sample Size Calculation: Sample size was calculated based on previous studies reporting mean RI differences of 0.10 between obstructed and non-obstructed kidneys. With 80% power and $\alpha = 0.05$, a minimum sample size of 27 patients was required. To account for potential dropouts, 30 patients were enrolled.

Ultrasound Examination Protocol: All ultrasound examinations were performed using a GE VOLUSON system equipped with a curvilinear 3-5 MHz transducer. Standardized examination protocols were employed for both grayscale and Doppler ultrasound evaluation.

Resistive Index Calculation: RI = (Peak Systolic Velocity – End Diastolic Velocity) / Peak Systolic Velocity. Three measurements were obtained from each kidney (upper, mid, and lower pole segmental arteries), and the mean value was calculated for analysis.

Statistical Analysis: Statistical analysis was performed using SPSS version 26.0. Paired t-tests were used to compare RI values between symptomatic and contralateral kidneys. ROC curve analysis was performed to determine optimal RI threshold. A p-value < 0.05 was

considered statistically significant.

RESULTS

Patient Demographic: The study included 30 patients with unilateral acute renal colic comprising 18 males (60%) and 12 females (40%), with ages ranging from 18 to 79 years. The mean age was 42.7 ± 15.2 years. All patients successfully underwent bilateral renal Doppler evaluation with adequate spectral waveform acquisition.

Table 1: Patient Demographics And Clinical Characteristics

Parameter	Value
Total patients	30
Male : Female	18:12 (60%:40%)
Age range (years)	18–79
Mean age (years)	42.7 ± 15.2
Symptom duration (hours)	<24
Side affected (Right:Left)	16:14 (53.3%:46.7%)

Resistive Index Comparison: The RI measurements demonstrated significant differences between symptomatic and contralateral kidneys across all patients.

Table 2: Comparison Of Resistive Index Between Symptomatic And Contralateral Kidneys

Parameter	Symptomatic Kidneys	Contralateral Kidneys	p-value
Mean RI	0.75 ± 0.06	0.56 ± 0.05	<0.001*
RI Range	0.70–0.88	0.48–0.64	–
Median RI	0.74	0.55	–
Mean Paired Difference	0.19 (95% CI: 0.15–0.23)	–	<0.001*

Statistically significant by paired t-test

The delta RI (difference between symptomatic and contralateral kidneys) ranged from 0.09 to 0.38, with a mean of 0.24 ± 0.07.

Diagnostic Performance Analysis: ROC curve analysis revealed excellent diagnostic performance with an area under the curve of 0.89 (95% CI: 0.82-0.96).

Table 3: Diagnostic Performance Of Different RI Thresholds

RI Threshold	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Accuracy (%)
>0.65	96.7	73.3	80.6	95.7	86.7
>0.70	85.0	93.3	94.4	82.4	88.3
>0.75	66.7	100.0	100.0	71.4	80.0

An RI threshold of >0.70 provided the optimal balance between sensitivity (85%) and specificity (93.3%).

Factors Influencing Resistive Index: Analysis of various clinical and anatomical factors revealed several associations with RI measurements.

Table 4: Factors Affecting Resistive Index In Symptomatic Kidneys**

Factor	Mean RI	p-value
Age <40 years	0.74 ± 0.05	0.324
Age ≥40 years	0.76 ± 0.07	
Male	0.75 ± 0.06	0.891
Female	0.75 ± 0.06	
Right	0.74 ± 0.05	0.023*
Left	0.77 ± 0.07	
Hydronephrosis Present	0.78 ± 0.05	0.001*
Hydronephrosis Absent	0.71 ± 0.04	

*Statistically significant difference

DISCUSSION

This prospective study demonstrates that Doppler-derived resistive index measurement provides excellent diagnostic performance for detecting hemodynamic changes in acute ureteric colic, with significant differences between symptomatic (0.75 ± 0.06) and contralateral kidneys (0.56 ± 0.05) while avoiding radiation exposure.

Pathophysiological Basis: The elevated RI in acute ureteric obstruction reflects complex hemodynamic changes following urinary tract blockage. Acute obstruction leads to increased intrapelvic pressure, which compresses intrarenal vessels and elevates vascular resistance (7). This results in decreased diastolic flow and increased RI values, providing a quantifiable measure of hemodynamic changes (3).

Comparison with Previous Studies: Our findings align with recent literature demonstrating the diagnostic utility of RI in acute obstruction. Viyannan et al. reported similar RI values in obstructed kidneys (0.75 vs. 0.56) with comparable diagnostic performance (sensitivity 85%, specificity 93%) in their 2021 study of 54 patients (2). Zhao et al.'s 2022 meta-analysis of 1,247 patients showed pooled sensitivity and specificity of 86% and 89%, respectively, supporting our results (12). Recent pediatric studies have also validated RI measurement, with Shen et al. demonstrating its clinical significance in critically ill children with AKI (7).

The Integration of ultrasound techniques has been further enhanced by recent advances in Doppler twinkling artifact detection, which Nabheerong et al. showed in their 2023 meta-analysis to have 86% sensitivity and 92% specificity for urolithiasis detection (4).

Clinical Implications: The integration of RI measurement into routine ultrasound evaluation offers several clinical advantages including radiation-free assessment, cost-effectiveness, and bedside availability (10). Recent studies emphasize the growing concern about radiation exposure from CT scans, with Dai et al. demonstrating that kidney stone patients receive approximately 10 times more CT radiation annually than control patients (14). The high specificity (93.3%) makes RI particularly useful for ruling out significant hemodynamic changes in patients with renal colic.

Modern low-dose CT techniques, while reducing radiation exposure, still cannot match the complete radiation-free nature of ultrasound assessment (5,8). The 2024 systematic review by MacLeod et al. on duplex ultrasound accuracy for renal assessment further supports the reliability of ultrasound-based techniques (6).

Limitations: Important limitations include the relatively small sample size (n=30), single-center design, and lack of systematic CT correlation in all cases. The study primarily demonstrates hemodynamic differences between symptomatic and asymptomatic kidneys rather than confirmed anatomical obstruction. Future multicenter studies with larger sample sizes and systematic reference standard validation are needed, as emphasized in recent pediatric RI research (1,3).

CONCLUSIONS

Doppler-derived resistive index measurement represents a valuable, non-invasive diagnostic tool for assessing hemodynamic changes in acute ureteric colic. With excellent diagnostic performance and the ability to provide functional assessment without radiation exposure, RI measurement offers significant clinical utility in emergency and outpatient settings. An RI threshold of >0.70 demonstrates optimal diagnostic accuracy and could be integrated into clinical decision algorithms to reduce dependence on CT imaging while providing functional hemodynamic information. However, systematic validation with appropriate reference standards is needed to establish its role in confirming anatomical obstruction.

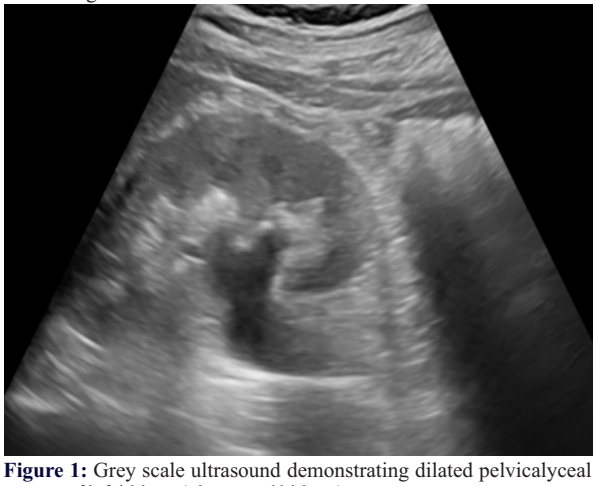

Figure 1: Grey scale ultrasound demonstrating dilated pelvicalyceal system of left kidney (obstructed kidney)

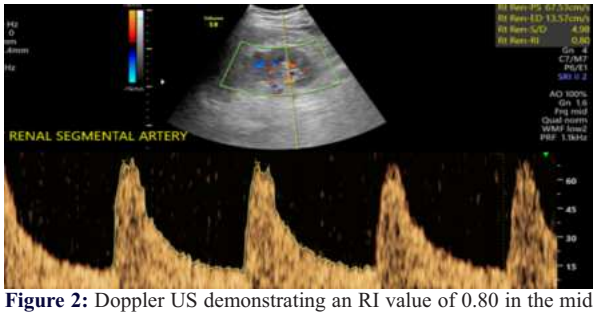

Figure 2: Doppler US demonstrating an RI value of 0.80 in the mid pole of left kidney (obstructed kidney)

Figure 3: Sagittal reconstruction of non-enhanced CT showing a calculus in the left distal ureter who presented with acute left renal colic

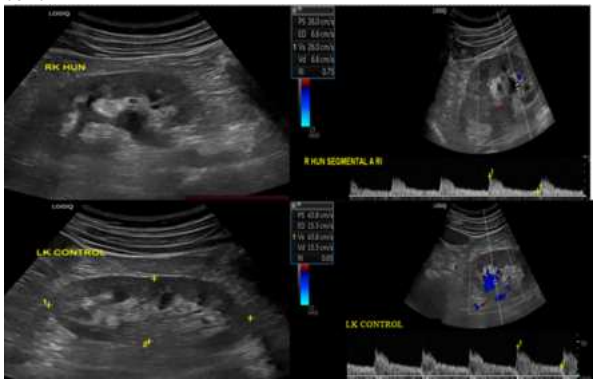

Figure 4: Grey scale USG &BDoppler US demonstrating an RI value of 0.75 in the lower pole of right kidney (obstructed kidney) and RI value of 0.65 in the lower pole of left kidney (unobstructed kidney)

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