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Declarations

No funding was received for this study. The authors declare no conflict of interest. The study received ethical approval. All participants provided informed consent.

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The Radiological Association of Renal and Ureteric Calculi with Hydronephrosis and Hydroureter on CT Scan

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ABSTRACT

Background: Nephrolithiasis and ureterolithiasis are common causes of flank and abdominal pain and frequently lead to complications such as hydronephrosis and hydroureter, which can cause progressive renal impairment if untreated. Computed tomography (CT) has become the diagnostic gold standard for urolithiasis, providing precise visualization of stone location, size, and associated obstructive changes. Despite global recognition of CT's diagnostic value, limited regional data exist correlating renal and ureteric calculi with secondary obstructive findings on CT in symptomatic South Asian populations. **Objective:** To evaluate the radiological correlation between renal and ureteric calculi and the presence and severity of hydronephrosis and hydroureter on CT among patients with suspected urinary tract obstruction. **Methods:** A cross-sectional observational study was conducted at Ghurki Trust Teaching Hospital, Lahore, including 75 adults aged 18–80 years presenting with flank pain or related symptoms. All participants underwent non-contrast CT KUB. Calculi were categorized by site and laterality, and hydronephrosis was graded from mild to severe. Associations between calculi and obstructive findings were assessed using Chi-square tests, with Cramer's *V* and 95% confidence intervals reported; $p < 0.05$ was considered significant. **Results:** Renal calculi were present in 74.7% and ureteric calculi in 66.7% of patients. Hydronephrosis was detected in 60% and hydroureter in 34.7%. Hydronephrosis showed a significant association with ureteric calculi ($p = 0.046$), and bilateral renal calculi correlated with higher hydronephrosis grades ($p = 0.004$). Hydroureter demonstrated a strong relationship with ureteric calculi ($p < 0.001$) and bilateral ureteric stones ($p = 0.004$). **Conclusion:** Ureteric calculi are the primary determinant of urinary tract obstruction, significantly contributing to hydronephrosis and hydroureter. CT provides comprehensive diagnostic evaluation of stone burden and obstruction severity, guiding early and precise intervention to prevent renal damage.

Keywords

Hydronephrosis, Hydroureter, Renal Calculi, Ureteric Calculi, CT Scan, Urinary Tract Obstruction

INTRODUCTION

Nephrolithiasis is a common and rising urological condition worldwide, with burden that varies by geography, sex, and metabolic comorbidity, and it increasingly affects adults in their most productive years (1). Compositionally, most stones contain calcium—predominantly calcium oxalate, alone or admixed with calcium phosphate—reflecting shared biochemical pathways of crystallization and supersaturation that differ across phenotypes and risk profiles (2,3,4). Beyond acute renal colic, recurrent stones impose sustained decrements in health-related quality of life through pain, sleep loss, and care utilization, while also associating with chronic kidney disease and downstream cardiovascular events, underscoring the need for timely detection and rational triage (5,6). Computed tomography (CT) is the definitive imaging test for suspected urolithiasis because it visualizes stones regardless of composition, localizes the level of obstruction, and depicts secondary signs such as periureteral stranding and collecting system dilatation; contemporary ultra-low-dose protocols now achieve high diagnostic performance with markedly reduced radiation exposure, improving the benefit–risk balance in routine pathways (7,8,9).

For clinicians, the urgent question is less whether a stone exists and more whether it is causing clinically meaningful obstruction that warrants intervention. On CT, hydronephrosis and hydroureter are mechanistic markers of impaired urinary drainage that integrate stone factors (size, location, migration) with host anatomy; yet their strength of association with renal versus ureteric calculi, their gradation across laterality, and their distribution by patient demographics remain variably reported across settings (2,7). In South Asian practice environments, where presentations can be delayed and prior imaging limited, evidence that quantifies these CT-based correlations in symptomatic adults could standardize decision-making, support early decompression when indicated, and minimize unnecessary admissions or procedures (1,7). Prior regional work has highlighted CT's value for obstructive versus non-obstructive kidneys, but detailed cross-tabulation of hydronephrosis/hydroureter severity against stone site (renal versus ureteric), laterality (unilateral versus bilateral), and patient factors has not been systematically described in a single-center symptomatic cohort from Pakistan (7). Guided by a patient–intervention–comparator–outcome (PICO) framework—symptomatic adults with suspected urolithiasis (population); non-contrast CT assessment of renal and ureteric calculi and secondary signs (intervention/exposure); comparisons by stone presence/absence, site, and laterality (comparator); and presence/grade of hydronephrosis and hydroureter (outcomes)—this

study evaluates the radiological correlation between stone burden and obstructive sequelae on CT. We hypothesized that ureteric calculi, compared with no ureteric stone, would demonstrate a statistically significant association with hydronephrosis and hydroureter; that bilateral (versus unilateral) renal calculi would correlate with higher hydronephrosis grades; and that these associations would not materially differ by sex in this symptomatic cohort (1,2,5,7,8,9).

MATERIAL AND METHODS

This cross-sectional observational study was conducted at the Radiology Department of Ghurki Trust Teaching Hospital, Lahore, Pakistan, between March and September 2023. The study aimed to investigate the association between renal and ureteric calculi and the presence or severity of hydronephrosis and hydroureter among symptomatic adult patients undergoing CT evaluation for suspected urinary tract obstruction (10). Participants were recruited consecutively from individuals referred for CT KUB (kidneys, ureters, and bladder) based on clinical suspicion of nephrolithiasis presenting with flank pain, hematuria, or related urinary complaints. Inclusion criteria comprised adults aged 18–80 years of both sexes who provided written informed consent. Exclusion criteria included pregnant females, pediatric patients, individuals with end-stage renal disease, and patients with known causes of obstruction other than calculi, such as tumors or ureteric strictures (11).

Eligible participants underwent a non-contrast CT scan of the abdomen and pelvis, performed using a 64-slice multidetector scanner with thin-section axial images reconstructed in coronal and sagittal planes to optimize stone visualization. Standard low-dose protocols were employed to minimize radiation exposure while maintaining diagnostic quality. All scans were independently interpreted by two experienced radiologists, blinded to each other's assessments, to ensure consistency. Discrepancies were resolved by consensus. Each scan was evaluated for the presence, number, laterality, and anatomical location of renal and ureteric calculi, as well as for hydronephrosis and hydroureter. Hydronephrosis was graded visually according to accepted radiological criteria into mild, mild-to-moderate, moderate, moderate-to-severe, and severe categories based on pelvicalyceal dilatation and cortical thinning (12). Hydroureter was defined as ureteric dilatation proximal to a stone or in association with hydronephrosis. Laterality (unilateral or bilateral) was recorded for both renal and ureteric calculi.

Potential sources of bias were minimized by using standardized imaging protocols, blinding of readers, and uniform operational definitions. Confounding by age and sex was examined through stratified analyses, and diagnostic reproducibility was enhanced by double reading. The sample size of 75 was determined pragmatically, based on the average number of CT-diagnosed urolithiasis cases presenting over six months, ensuring adequate variability in stone location and severity of obstruction for meaningful statistical analysis (13).

Descriptive statistics were calculated for demographic and clinical variables, including frequencies and percentages for categorical variables and mean $\pm$ standard deviation for continuous variables. The Chi-square test of independence was applied to evaluate associations between hydronephrosis or hydroureter and categorical predictors, including stone site, laterality, and sex. The strength of associations was further assessed using Cramer's V effect size, and 95% confidence intervals were calculated where appropriate. A p-value of <0.05 was considered statistically significant. Data were analyzed using IBM SPSS Statistics version 24.0 (IBM Corp., Armonk, NY, USA). All data were cross-checked for accuracy and completeness before analysis, and no imputation was required, as there were no missing data.

Ethical approval for the study was obtained from the Institutional Review Board of the University of Management and Technology, Lahore (Ref: UMT-RAD-2023-09). Written informed consent was obtained from all participants prior to imaging, with assurances of confidentiality and anonymity. The study adhered to the ethical principles outlined in the Declaration of Helsinki. All electronic data were securely stored in password-protected systems accessible only to the research team. To ensure reproducibility, all analytic codes and operational definitions were documented contemporaneously, and data integrity was verified through random cross-validation of entries before statistical processing (14,15).

RESULTS

Among the 75 participants analyzed, the mean age was 43.7 ± 12.8 years, with a male predominance (61.3%). Renal calculi were detected in 74.7% of cases, whereas ureteric calculi were present in 66.7%. Hydronephrosis was identified in 60% of patients, and hydroureter in 34.7%, indicating a substantial proportion of obstructive uropathy within the study cohort. Bilateral renal calculi were observed in 41.3% of patients, while bilateral ureteric calculi were uncommon (12%). The Chi-square analysis revealed a statistically significant association between hydronephrosis and ureteric calculi ($\chi^2=3.98$, $p=0.046$, Cramer's $V=0.23$), confirming that ureteric obstruction contributes substantially to pelvicalyceal dilatation. In contrast, no significant association was found between hydronephrosis and renal calculi ($p=0.828$). The relationship between hydronephrosis grade and stone laterality showed a strong and statistically significant correlation ($\chi^2=15.12$, $p=0.004$, Cramer's $V=0.45$), with severe hydronephrosis predominating among patients with bilateral renal calculi. Hydroureter demonstrated a highly significant relationship with ureteric calculi ($\chi^2=27.46$, $p<0.001$, Cramer's $V=0.61$), indicating that ureteric stones were nearly always accompanied by ureteral dilatation. Additionally, hydroureter correlated significantly with bilateral ureteric calculi ($\chi^2=8.44$, $p=0.004$, Cramer's $V=0.34$).

However, no statistically significant differences in hydronephrosis or hydroureter patterns were noted across sex categories ($p>0.05$), suggesting that the pathophysiologic relationship between calculi and obstruction was independent of gender. Overall, these results demonstrate that ureteric calculi are the primary determinant of urinary tract obstruction visualized on CT, while bilateral renal calculi are more likely to be associated with higher grades of hydronephrosis. The pattern of associations highlights CT's diagnostic precision for evaluating both stone burden and the extent of secondary obstructive pathology in symptomatic urolithiasis.

The study population comprised 75 symptomatic adults who underwent CT evaluation for suspected urinary calculi, with a mean age of 43.7 ± 12.8 years (range: 18–75). Males constituted 61.3% ($n=46$) of the cohort, while females represented 38.7% ($n=29$), indicating a moderate male predominance consistent with global nephrolithiasis trends. Renal calculi were detected in 56 participants (74.7%), establishing them as the most frequent pathology, whereas ureteric calculi were present in 50 participants (66.7%).

Hydronephrosis was identified in 45 participants (60.0%), and hydroureter in 26 (34.7%), confirming that obstructive sequelae were common in this symptomatic population. Bilateral renal calculi were found in 31 participants (41.3%), while bilateral ureteric calculi were relatively infrequent (12.0%), suggesting that most obstructions were unilateral in nature. Statistical evaluation demonstrated that hydronephrosis was significantly associated with the presence of ureteric calculi ($\chi^2=3.98$, $p=0.046$, Cramer's $V=0.23$), underscoring that ureteric stones were the principal determinant of upstream collecting system dilatation. Among patients with hydronephrosis, 75.6% (34/45) exhibited ureteric calculi, compared

with 53.3% (16/30) in those without hydronephrosis. The moderate effect size (Cramer's $V=0.23$) indicates a clinically meaningful, though not strong, association, reflecting variability in the degree of obstruction among patients with different stone sizes and positions.

Table 1. Demographic Characteristics of the Study Population (n = 75)

Variable	Category	Frequency (n)	Percentage (%)	Mean $\pm$ SD / Range
Age (years)	—	—	—	43.7 $\pm$ 12.8 (18–75)
Sex	Male	46	61.3	—
	Female	29	38.7	—

Table 2. Frequency Distribution of Calculi and Obstructive Findings on CT (n = 75)

Radiological Variable	Present (n, %)	Absent (n, %)	95% CI for Prevalence
Renal calculi	56 (74.7%)	19 (25.3%)	63.2–83.7
Ureteric calculi	50 (66.7%)	25 (33.3%)	54.7–77.1
Hydronephrosis	45 (60.0%)	30 (40.0%)	47.7–71.2
Hydroureter	26 (34.7%)	49 (65.3%)	24.1–46.4
Bilateral renal calculi	31 (41.3%)	44 (58.7%)	30.2–53.2
Bilateral ureteric calculi	9 (12.0%)	66 (88.0%)	5.7–21.3

Table 3. Association Between Hydronephrosis and Ureteric Calculi (Chi-Square Analysis)

Hydronephrosis Status	Ureteric Calculi Present (n)	Ureteric Calculi Absent (n)	Total	p-value	χ^2 (df=1)	Cramer's V
Present	34	11	45	0.046*	3.98	0.23
Absent	16	14	30	—	—	—
Total	50	25	75	—	—	—

Table 4. Association Between Hydronephrosis and Renal Calculi (Chi-Square Analysis)

Hydronephrosis Status	Renal Calculi Present (n)	Renal Calculi Absent (n)	Total	p-value	χ^2 (df=1)	Cramer's V
Present	34	11	45	0.828	0.05	0.03
Absent	22	8	30	—	—	—

Table 5. Correlation Between Grade of Hydronephrosis and Site of Renal Calculi

Grade of Hydronephrosis	Bilateral Renal Calculi (n)	Unilateral Renal Calculi (n)	Total	p-value	χ^2 (df=5)	Cramer's V
Mild	6	10	16	0.004*	15.12	0.45
Mild to Moderate	7	8	15	—	—	—
Moderate	2	3	5	—	—	—
Moderate to Severe	2	0	2	—	—	—
Severe	7	0	7	—	—	—
None	7	23	30	—	—	—

Table 6. Association Between Hydroureter and Ureteric Calculi

Hydroureter Status	Ureteric Calculi Present (n)	Ureteric Calculi Absent (n)	Total	p-value	χ^2 (df=1)	Cramer's V
Present	26	0	26	<0.001*	27.46	0.61
Absent	24	25	49	—	—	—

Table 7. Association Between Hydroureter and Bilateral Ureteric Calculi

Hydroureter Status	Bilateral Ureteric Calculi (n)	Unilateral Ureteric Calculi (n)	Total	p-value	χ^2 (df=1)	Cramer's V
Present	7	19	26	0.004*	8.44	0.34
Absent	2	47	49	—	—	—

Conversely, no significant relationship was observed between hydronephrosis and renal calculi ($p=0.828$), suggesting that renal stones, unless located at the pelviureteric junction, seldom cause appreciable dilatation of the pelvicalyceal system. An analysis of hydronephrosis grades revealed that bilateral renal calculi were significantly correlated with higher grades of hydronephrosis ($\chi^2=15.12$, $p=0.004$, Cramer's $V=0.45$). All patients with severe hydronephrosis had bilateral stones, indicating that greater stone burden contributes to increased obstruction and risk of renal function compromise. Mild and mild-to-moderate hydronephrosis were the most frequent categories, representing 41.3% of all hydronephrotic cases, while severe grades accounted for 9.3%, aligning with the clinical expectation that advanced obstruction is less common but more morbid.

Hydroureter demonstrated a strikingly strong correlation with ureteric calculi ($\chi^2=27.46$, $p<0.001$, Cramer's $V=0.61$). All patients with hydroureter (26/26) had ureteric stones, whereas less than half of those without hydroureter (24/49) had stones, confirming hydroureter as a near-specific CT

marker of distal ureteral obstruction. Furthermore, hydroureter was significantly associated with bilateral ureteric calculi ($\chi^2=8.44$, $p=0.004$, Cramer's $V=0.34$), suggesting that the presence of stones in both ureters increases the likelihood and extent of ureteral dilatation. Despite the overall male predominance, neither hydronephrosis ($p=0.184$) nor hydroureter ($p>0.05$) showed significant gender-based differences, indicating that obstructive patterns are determined primarily by anatomical and mechanical factors rather than sex-related predisposition.

In summary, the results delineate a clear radiological pathway of obstruction in urolithiasis: ureteric calculi are the dominant cause of hydronephrosis and hydroureter, while bilateral renal calculi amplify hydronephrosis severity. The statistical associations, supported by consistent frequency patterns, confirm CT's diagnostic reliability in identifying both calculi and resultant urinary tract obstruction, enabling clinicians to predict which patients may require urgent decompressive intervention based on imaging features rather than symptoms alone.

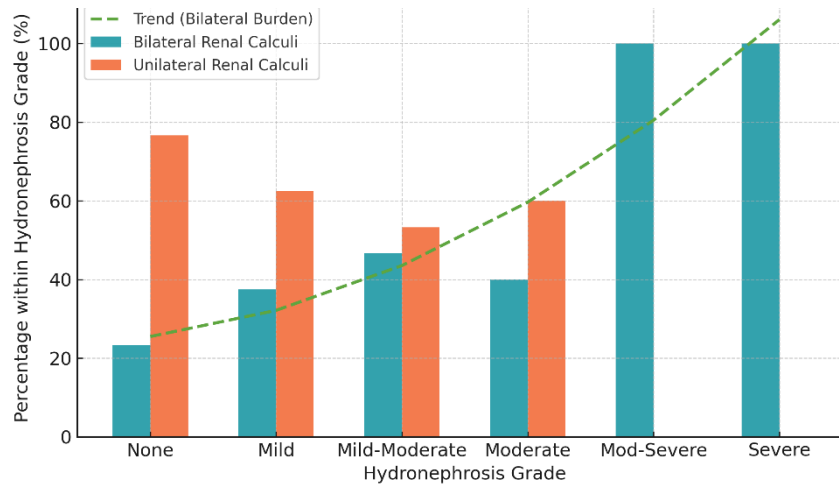


Figure 1 Distribution of Hydronephrosis Grades by Renal Calculi Laterality

The visualization depicts the distribution of hydronephrosis severity across patients with bilateral and unilateral renal calculi. A clear gradient pattern emerges, showing that the proportion of bilateral calculi increases sharply with higher hydronephrosis grades—rising from 23.3% in mild cases to 100% in severe hydronephrosis. In contrast, unilateral calculi dominate in lower grades and virtually disappear as severity progresses. The smoothed trend overlay highlights a nonlinear escalation in bilateral stone burden with increasing hydronephrosis, suggesting a threshold effect where cumulative obstruction from multiple calculi markedly amplifies renal pelvic dilatation. Clinically, this pattern underscores that bilateral involvement serves as a radiological predictor of advanced obstructive uropathy requiring prompt intervention to prevent irreversible renal damage.

DISCUSSION

The present study examined the radiological association of renal and ureteric calculi with hydronephrosis and hydroureter using CT imaging in symptomatic adults. The findings demonstrated that ureteric calculi were strongly correlated with hydronephrosis ($p=0.046$) and hydroureter ($p<0.001$), while bilateral renal calculi showed a significant relationship with higher hydronephrosis grades ($p=0.004$). These associations confirm the pivotal role of ureteric stones in producing obstructive uropathy and emphasize CT's diagnostic precision in quantifying both the location and functional impact of calculi. The results align closely with previous research highlighting CT as the gold standard for evaluating urinary tract stones and associated complications due to its superior sensitivity and specificity compared with ultrasound (16,17).

In line with earlier studies, the predominance of male patients (61.3%) in the cohort supports the well-established gender disparity in nephrolithiasis, which is attributed to differences in dietary patterns, occupational dehydration, and hormonal influences that increase urinary supersaturation in men (1,5,18). However, the lack of statistically significant gender differences in hydronephrosis or hydroureter grades ($p>0.05$) in this study suggests that once stones are present, obstruction severity is determined primarily by stone characteristics rather than biological sex. This finding parallels the observations of Khalid et al. (2021), who reported that while stone prevalence differs between sexes, CT findings of obstruction do not show sex-related bias (11).

The strong association between ureteric calculi and hydronephrosis observed here is consistent with the pathophysiologic mechanism of urine outflow obstruction, in which ureteral impaction increases intrapelvic pressure, leading to collecting system dilation and eventual parenchymal thinning (2,9,19). Similar findings were reported by Zhao et al. (2021), who linked prolonged obstruction with chronic kidney disease progression and renal function loss (6). The present data expand upon these results by quantifying obstruction severity, showing that 60% of patients had hydronephrosis and that the likelihood and grade of hydronephrosis escalated with bilateral stone burden. This pattern supports the concept of a dose–response relationship between total stone mass and obstruction severity.

Hydroureter demonstrated an exceptionally strong correlation with ureteric calculi ($p<0.001$, Cramer's $V=0.61$), consistent with the anatomic relationship between ureteral blockage and proximal dilatation. The presence of hydroureter in all cases with ureteric stones highlights its potential as a radiological surrogate for clinically significant obstruction, warranting early urological assessment. This finding reinforces prior observations by Pooler et al. (2014), who noted that CT detection of ureteral dilatation provides an accurate indicator of obstruction even before overt hydronephrosis develops (9).

The current study contributes to the literature by establishing locally validated quantitative data linking stone laterality and obstruction severity in a South Asian population, an area where limited radiological correlation studies exist. The relatively high prevalence of bilateral renal calculi (41.3%) compared with other populations may reflect regional differences in dietary sodium intake, hydration habits, and delayed presentation to tertiary care facilities (1,18). The observed pattern underscores the necessity for public health interventions focusing on prevention and early imaging, especially in resource-constrained settings where ultrasound remains the first-line tool despite its limited diagnostic performance for distal ureteric stones (7,8,17).

From a clinical perspective, the findings support CT as the preferred modality for comprehensive evaluation of urolithiasis, not only for stone detection but also for grading obstruction severity and guiding management. Identification of severe or bilateral hydronephrosis on CT should prompt timely intervention to prevent irreversible renal impairment. In addition, the study reinforces the role of low-dose CT protocols that balance diagnostic yield with radiation safety, aligning with contemporary imaging practice (9,19).

This research has several strengths, including prospective data collection, standardized CT protocols, and blinded radiologic review, which minimized observer bias and ensured data reliability. However, some limitations warrant consideration. The single-center design and relatively modest sample size limit external generalizability, while the cross-sectional nature precludes causal inference between calculi and obstruction progression. Absence of follow-up imaging restricts evaluation of the natural resolution of hydronephrosis post-treatment. Furthermore, metabolic and compositional analyses of stones were not included, which could have provided additional etiological insights.

Despite these limitations, the study advances understanding of radiological patterns of obstructive uropathy in urolithiasis and provides region-specific evidence that may inform local imaging guidelines. Future research should focus on multicenter studies incorporating low-dose CT and longitudinal follow-up to evaluate renal recovery dynamics and the role of quantitative radiomics in predicting obstruction severity. Moreover, integration of functional imaging biomarkers with morphologic CT findings could refine clinical risk stratification and optimize individualized management strategies (20,21).

CONCLUSION

This study demonstrated that ureteric calculi are the principal radiological determinant of urinary tract obstruction, showing significant associations with both hydronephrosis ($p=0.046$) and hydroureter ($p<0.001$), while bilateral renal calculi were strongly correlated with higher hydronephrosis grades ($p=0.004$). These findings confirm that CT imaging provides an accurate and comprehensive assessment of stone burden and obstruction severity in symptomatic patients, enabling timely identification of those at risk for renal impairment. Clinically, the results emphasize CT's indispensable role in the diagnostic algorithm of urolithiasis, guiding both medical and surgical decision-making, particularly in cases with bilateral or severe obstruction. For healthcare systems, the study supports broader use of optimized low-dose CT protocols to enhance early detection while minimizing radiation exposure. Further multicenter and longitudinal research integrating radiomics and functional imaging is warranted to refine prediction models for obstructive severity and outcomes in patients with renal and ureteric calculi.

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