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RELATIONSHIP BETWEEN URINARY STONES AND GRADE OF HYDRONEPHROSIS USING CT

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Abstract

Background:
Urinary stone disease (urolithiasis) is a common global health problem and a major cause of urinary tract obstruction leading to hydronephrosis. Hydronephrosis occurs as a result of obstruction caused by urinary stones and may lead to renal damage if untreated. The severity of hydronephrosis varies depending on several factors, including stone size, location, and number. Understanding this relationship is essential for early diagnosis and proper management.

Objectives:
- To evaluate urinary stone characteristics (size, location, and number) using CT-KUB.
- To determine the relationship between urinary stones and grades of hydronephrosis.

Methodology:
An analytical cross-sectional study was conducted in the Radiology Department of RYK Hospitals over a duration of 4 months. A total of 150 patients with confirmed urinary stones on non-contrast CT-KUB were included using consecutive sampling. Data regarding stone size, location, number, and hydronephrosis grade were collected and analyzed using SPSS. Statistical tests including regression analysis were applied, with $p < 0.05$ considered significant.

Results:
The mean stone size was 13.3 ± 9.2 mm. Hydronephrosis was present in 76.7% of patients out of 150, with Grade 1 being the most frequent. A statistically significant positive relationship was observed between stone size and hydronephrosis grade ($p < 0.001$). Stone location also showed a strong association, with pelvico-ureteric junction (PUJ) stones predominantly causing severe hydronephrosis (Grades 3 and 4). In contrast, the number of stones did not demonstrate a significant relationship with hydronephrosis severity ($p = 0.487$).

Conclusion:
CT-KUB is an effective modality for evaluating urinary stones and associated hydronephrosis. Stone size and location are significant predictors of hydronephrosis severity, whereas stone number is not. These findings can assist in early diagnosis and better clinical management of patients with urolithiasis.

Introduction:

Urinary stone disease also known as urolithiasis, is a major global health problem and represents one of the most frequent causes of acute flank pain encountered in emergency departments and radiology units. Epidemiological studies estimate that approximately 10–15% of the global population will experience urinary stones at least once in their lifetime, with recurrence rates reaching up to 50% within ten years after the first episode. Multiple factors contribute to the formation of urinary stones, including dietary habits, low fluid intake, genetic predisposition, metabolic abnormalities, obesity, climate conditions, and lifestyle changes associated with urbanization and industrialization. Regions such as South Asia and the Middle East demonstrate particularly high prevalence rates because chronic dehydration leads to increased urinary concentration and crystal formation([i]).

Urinary stones can vary widely in size, composition, location, and number. Common types include calcium oxalate stones, uric acid stones and cystine stones. Calcium-containing stones represent nearly 80% of all cases and are most frequently associated with metabolic disturbances such as hypercalciuria and hyperoxaluria. Regardless of their composition, stones can obstruct the urinary tract and interfere with the normal flow of urine. When obstruction occurs, pressure builds up within the renal collecting system, leading to dilatation of the renal pelvis and calyces, a condition known as hydronephrosis. Hydronephrosis is not a disease itself but rather a radiological and clinical manifestation of urinary tract obstruction. Persistent obstruction can impair renal function increase the risk of urinary tract infections and in severe cases lead to irreversible kidney damage ([ii]).

Hydronephrosis develops as a result of increased intraluminal pressure proximal to the site of obstruction. Initially, the renal pelvis and calyces dilate to accommodate the increased pressure but if the obstruction persists progressive thinning of the renal parenchyma occurs. The severity of hydronephrosis is typically graded on imaging studies into mild moderate and severe forms depending on the degree of pelvicalyceal dilatation and cortical thinning. . Clinicians should consider patients with Grade 3 or Grade 4 hydronephrosis on CT for prompt intervention such as ureteric stenting or nephrostomy to prevent progressive renal parenchymal injury ([iii]).

Accurate grading of hydronephrosis is essential because it provides important information about the duration and severity of obstruction and assists clinicians in determining appropriate treatment strategies. In patients with urinary stones hydronephrosis is often accompanied by other secondary signs such as ureteral dilatation, peri-renal fat stranding, decreased renal enhancement and delayed contrast excretion when contrast imaging is used. These features collectively help radiologists assess the impact of the obstructing stone on the urinary system ([iv]).

Advancements in medical imaging have significantly improved the diagnosis and management of urinary stone disease. In the past imaging modalities such as plain abdominal radiography and intravenous urography (IVU) were commonly used for evaluating renal stones. Nevertheless ultrasound has reduced sensitivity for detecting ureteric stones and may not reliably identify small calculi or accurately determine the level of obstruction. With the development of computed tomography (CT) the diagnostic evaluation of urinary stones has undergone a significant transformation. Because of these advantages CT-KUB has become the preferred imaging technique for both initial diagnosis and treatment planning in patients presenting with renal colic ([v]).

Among the various characteristics of urinary stones stone size has traditionally been considered one of the main determinants of obstruction. Larger stones are often assumed to produce greater blockage within the urinary tract and therefore lead to more severe hydronephrosis Stone location within the urinary tract is another important factor that may determine the degree of obstruction. Stones located in the ureter are more likely to cause acute obstruction compared to those located within the

renal calyces. The ureterovesical junction (UVJ) and ureteropelvic junction (UPJ) are common sites where stones become lodged due to anatomical narrowing. Obstruction at these points can lead to rapid development of hydronephrosis and severe symptoms. Additionally, the number of stones present within the urinary system may also influence the degree of obstruction. Multiple stones can obstruct different parts of the urinary tract simultaneously, leading to complex patterns of dilatation ([vi]).

However clinical observations suggest that this relationship is not always straightforward. Conversely larger stones located within the renal pelvis may not cause severe hydronephrosis if they do not completely block urine flow. This indicates that factors other than size may influence the severity of hydronephrosis. Patients with severe hydronephrosis may require urgent intervention such as ureteric stenting and nephrostomy or surgical stone removal whereas those with mild hydronephrosis may be managed conservatively with hydration and medical therapy. Therefore identifying factors that predict the severity of hydronephrosis is clinically important ([vii]).

Despite the widespread use of CT-KUB in clinical practice there remains limited structured evidence regarding how different characteristics of urinary stones relate to the severity of hydronephrosis. Most clinical decisions are often based on general assumptions rather than detailed imaging based correlations. This lack of evidence is particularly evident in developing countries where research data on CT based predictors of obstruction remain scarce. In many such settings delayed presentation of patients is common due to limited awareness, financial constraints and reduced access to specialized urological services. As a result patients often present with advanced obstruction and complications that could potentially have been prevented through earlier diagnosis and intervention ([viii]).

Stone composition may independently influence the degree of obstruction and could represent a confounding variable in the relationship between stone size and hydronephrosis grade ([ix]).Investigating the relationship between urinary stone characteristics and hydronephrosis grades can therefore provide valuable insights for clinical practice. By identifying which factors are most strongly associated with severe hydronephrosis clinicians can better predict the clinical course of patients presenting with renal colic. This information can assist in prioritizing patients for urgent intervention, improving resource allocation in busy emergency departments and ultimately preventing long-term renal damage. Radiologists also benefit from such evidence because it enhances the interpretative value of CT findings and allows for more comprehensive reporting. ([x]).

The present study focuses on evaluating CT-KUB findings in patients diagnosed with urinary stone disease and analyzing the association between stone characteristics and hydronephrosis severity. Particular attention is given to variables such as stone size, stone location, number of stones, and stone attenuation values. By systematically examining these parameters, the study aims to determine whether specific stone characteristics are significantly associated with higher grades of hydronephrosis. The study specifically seeks to determine whether stone size has a significant association with hydronephrosis severity and to evaluate the influence of additional factors such as stone location, stone number and stone size. Through this analysis the research intends to provide evidence-based insights that can support more accurate diagnosis and effective management of patients with urinary stones.

The central problem addressed in this study is the lack of structured local evidence regarding CT-based predictors of hydronephrosis severity in patients with urinary stones. Without such evidence clinicians may face challenges in predicting which cases require urgent treatment and which can be managed conservatively. By filling this gap the study aims to improve diagnostic confidence, assist in clinical decision-making and contribute to better patient outcomes.

In conclusion urinary stone disease is a growing global health concern that frequently leads to urinary tract obstruction and hydronephrosis. Modern imaging particularly CT-KUB has revolutionized the diagnosis and evaluation of this condition by providing detailed information about stone characteristics and associated complications and the introduction establishes the clinical relevance of urinary stones and hydronephrosis, highlights the diagnostic value of CT-KUB identifies gaps in current evidence and proposes an analytical investigation that examines the links between stone features and hydronephrosis grades. This chapter sets the foundation for a detailed review of existing literature and the methodology adopted for conducting this research.

1.1: OBJECTIVES

- To characterize urinary stones detected on computed tomography (CT) in terms of their anatomical location and features.
- To analyze how different grades of hydronephrosis correspond with the CT-identified urinary stones.

LITERATURE REVIEW

A study published in American Family Physician (2011) reported that the incidence of nephrolithiasis is increasing worldwide particularly among women and with advancing age. The study highlighted that kidney stones are strongly associated with chronic kidney disease and that recurrence prevention depends largely on the type of stone including calcium oxalate, cystine, struvite, and uric acid stones. It was further noted that even when stone composition is unknown factors such as urine pH and 24-hour urine analysis can help identify underlying causes and guide preventive strategies. The authors also emphasized that certain medications, including antibiotics and diuretics, may increase the risk of stone formation. Additionally, lifestyle factors such as diet, hydration and obesity play a significant role with proper dietary management and adequate fluid intake being essential in reducing the risk of recurrence (1).

Matlaga et al. reported IN 2003, that urinary calculi can be induced by various medications used in the treatment of different medical conditions. The study explained that these drugs may cause metabolic abnormalities that promote stone formation. Common agents associated with drug-induced calculi include loop diuretics, carbonic anhydrase inhibitors and laxatives when used excessively. Additionally, certain medications may crystallize in the urine and directly form stones due to urinary super saturation. Examples of such drugs include magnesium trisilicate, ciprofloxacin, sulfonamides and triamterene. The authors emphasized that identifying and correcting the underlying metabolic disturbance or discontinuing the causative medication can significantly reduce or prevent stone formation ([xi]).

Paulo et al. conducted a comprehensive literature review under the European Society of Radiology in 2020, to establish updated diagnostic reference levels (DRLs) for X-ray based medical imaging. The study analyzed recent evidence and data from national authorities to evaluate radiation dose standards across various imaging modalities. The authors emphasized the importance of optimizing radiation exposure while maintaining diagnostic image quality. This is particularly relevant in computed tomography, including CT KUB, where balancing radiation dose and diagnostic accuracy is essential. The implementation of standardized DRLs can help minimize unnecessary radiation exposure to patients while ensuring effective detection of pathologies such as renal calculi. Several metabolic abnormalities such as hypercalciuria, hyperoxaluria, hyperuricosuria, and hypocitraturia have been

implicated in stone formation. When a stone obstructs the urinary tract it interferes with the normal flow of urine leading to increased pressure within the renal collecting system and resulting in hydronephrosis ([xii]).
Truong et al. (2011) describe that this condition can result from intrinsic or extrinsic causes affecting any level of the urinary system. The obstruction increases intra-tubular pressure which if prolonged can compromise renal function. The severity of pathological changes depends on the duration and extent of obstruction with acute cases often being reversible. Whereas, chronic obstruction may lead to irreversible damage such as interstitial fibrosis and tubular atrophy. Early diagnosis and timely management are therefore essential to prevent long-term renal complications. When urine flow is blocked by an obstructing calculus pressure accumulates upstream of the obstruction. This pressure gradually causes dilatation of the renal pelvis and calyces and may eventually lead to thinning of the renal cortex if the obstruction persists ([xiii]).
Sabih et al. explain that these infections are often associated with factors such as urinary obstruction, catheterization or immune-compromised states which increase both the risk and complexity of treatment. Compared to uncomplicated UTIs complicated cases are more likely to involve resistant pathogens and may lead to serious outcomes including renal damage and sepsis if not managed appropriately. The author further highlight that accurate diagnosis, identification of predisposing factors and targeted antimicrobial therapy are essential for effective management and prevention of recurrence. The severity of hydronephrosis can vary depending on the duration and degree of obstruction. Chronic hydronephrosis may also predispose patients to urinary tract infections, pyelonephritis and renal insufficiency ([xiv]).
Onen (2020) discuss that hydronephrosis defined as dilation of the renal collecting system varies widely in severity and clinical significance. The author highlights that existing grading systems often lack consistency in predicting outcomes and guiding management decisions. Variability in imaging interpretation and differences in clinical presentation further complicate accurate assessment. Consequently, an effective grading system should not only reflect anatomical changes but also correlate with functional impairment and prognosis. Improved standardization is therefore essential to enhance diagnostic accuracy and optimize treatment strategies in affected patients. Several grading systems have been proposed, but one of the most widely used is the Society for Fetal Urology (SFU) grading system. Although originally developed for pediatric patients the SFU grading system has been widely adapted for adults and for CT imaging because of its simplicity and reliability. According to this system hydronephrosis is categorized into four grades ranging from mild pelvic dilatation to severe calyceal dilatation with cortical thinning ([xv]).
Brisbane et al. highlighted that imaging plays a crucial role in both the diagnosis and management of nephrolithiasis. The study emphasized that non-contrast computed tomography (CT) of the abdomen and pelvis provides the highest diagnostic accuracy for detecting kidney stones making it the preferred initial imaging modality in many clinical settings. However, the authors also noted the concern of radiation exposure associated with CT imaging. In comparison ultrasonography was reported to have lower sensitivity and specificity although it avoids ionizing radiation. Additionally, other modalities such as plain radiography (KUB) additionally, ultrasound findings are operator-dependent and may be limited by patient body habitus or bowel gas ([xvi]).
Alshoabi et al. conducted a study to evaluate the relationship between hydronephrosis and the detection of urinary stones using B-mode ultrasonography. The study included 210 patients who underwent abdominal ultrasound and were diagnosed with varying grades of hydronephrosis. The findings showed that ultrasonography was able to identify the cause of hydronephrosis in a significant proportion of cases with urinary stones accounting for the majority. However, the detection rate of stones varied across different grades of hydronephrosis indicating inconsistency in diagnostic performance. The authors highlighted that although ultrasound is a useful non-invasive imaging

modality, its sensitivity in detecting urinary calculi is limited and depends on the severity of obstruction (5).
Kaleem et al. conducted a cross sectional study in 2021 to evaluate hydronephrosis and investigate its leading causes in adults. CT imaging can evaluate the entire urinary tract and detect secondary signs of obstruction such as hydronephrosis, hydroureter, peri-renal fat stranding, and renal enlargement. Studies comparing CT with other imaging modalities have consistently demonstrated its superior diagnostic performance. The sensitivity and specificity of CT for detecting urinary stones have been reported to be greater than 95%, making it the preferred imaging technique in emergency settings. CT-KUB not only identifies urinary stones but also provides detailed anatomical information about the urinary tract. One of its most important advantages is the ability to assess the degree of hydronephrosis associated with an obstructing stone ([xvii]).
Tzelves et al. summarized a UAE guidelines for urolithiasis in 2021, Several secondary CT findings have been described in patients with obstructing ureteral stones. These include peri-renal fat stranding, decreased renal attenuation, renal enlargement and delayed excretion of contrast when contrast-enhanced studies are performed. These findings collectively help determine the severity of obstruction and guide clinical management. Because CT imaging provides both stone characteristics and hydronephrosis grading in a single examination it is particularly useful for studying the relationship between stone properties and the severity of obstruction ([xviii]).
Y Iwahashi et al. investigated the role of hydronephrosis as a predictive factor for impacted ureteral stones. The study retrospectively analyzed 160 patients undergoing ureteroscopic management and evaluated both qualitative grading and quantitative measurement of hydronephrosis. The findings demonstrated that the area of hydronephrosis was a more reliable predictor of impacted stones compared to conventional grading systems. Additionally, factors such as increased ureteral wall thickness and larger hydronephrosis area were identified as significant independent predictors. The authors concluded that quantitative assessment of hydronephrosis can improve preoperative evaluation and aid in clinical decision-making for patients with ureteral calculi. In contrast, larger stones located in the renal pelvis may not always produce severe obstruction because urine can sometimes pass around them ([xix]).

2.1: Rationale

Hydronephrosis is a common radiological finding associated with urinary tract obstruction most frequently caused by urolithiasis. Accurate assessment of the severity of hydronephrosis is essential as it directly influences clinical decision-making including the need for urgent intervention and the choice of treatment modality. Non-contrast computed tomography of the kidneys, ureters and bladder (CT KUB) is widely regarded as the gold standard imaging technique for evaluating urinary stones providing detailed information regarding stone size, location and density. In many clinical settings treatment decisions are often based on general assumptions such as larger stones causing more severe obstruction. However emerging evidence suggests that this relationship is not always straightforward as smaller stones may produce significant obstruction when located at narrow anatomical sites like the pelvic-ureteric junction.Therefore this study aims to evaluate the relationship between CT-based stone characteristics and the severity of hydronephrosis. By establishing a clearer imaging-based correlation this research seeks to contribute to more accurate prediction of disease severity and to support improved clinical decision-making in the management of urolithiasis.

2.2: HYPOTHESIS

Hypothesis 1: Stone size has a significant impact on the grade of hydronephrosis, with larger stones associated with more severe hydronephrosis on CT-KUB.
Hypothesis 2: Stone location significantly influences hydronephrosis severity, and stones positioned at narrow anatomical sites (such as the PUJ and VUJ) result in higher hydronephrosis grades.
Hypothesis 3: The number of urinary stones is associated with hydronephrosis where multiple stones contribute to greater obstruction and more severe hydronephrosis.

2.3: OPERATIONAL DEFINITIONS

1. **Urinary stone (urolithiasis):** A hyperdense focus within the renal collecting system, ureter, or bladder on non-contrast CT-KUB with attenuation typically >120 HU, consistent with calculus.
2. **Stone size:** Maximal diameter (in mm) measured on multiplanar CT reconstructions (axial or coronal) using electronic calipers. For analysis, sizes will also be categorized (e.g. <5 mm, 5–10 mm, 11–19 mm, ≥20 mm), similar to prior studies.
3. **Hydronephrosis grade (CT-adapted SFU):**
    - Grade 0 – no dilatation
    - Grade 1 – mild pelvic dilatation, calyces normal
    - Grade 2 – pelvic dilatation with mild calyceal dilatation, normal parenchyma
    - Grade 3 – marked calyceal dilatation, normal or mildly thinned cortex
    - Grade 4 – severe calyceal dilatation with significant cortical thinning/parenchymal atrophy
4. **Hydroureter:** Dilatation of the ureter proximal to the obstructing stone, as seen on CT.

RESEARCH METHODOLOGY

3.1: Research Design: Analytical cross-sectional study. Radiology and Urology Departments of hospitals where CT-KUB is routinely performed in RYK**.**
3.2: Sample size: A minimum sample of 150 patients (male and female)
3.3: Study Population and Sample Population: the target population of this study consisted of adult patients presenting with urinary stone disease who underwent non contrast CTKUB, for evaluation of suspected urolithiasis and hydronephrosis in the radiology in RYK.
3.4: Sample Size: A sample size of 150 participants was included in this study over a duration of 4 months. Consecutive sampling. All CT-KUB examinations meeting inclusion criteria during the study period were included ensuring real-world representativeness.
3.5: Duration of study: The duration of this study was four months, beginning in January and concluding in April. All stages of the study, including topic selection, data gathering, data analysis, and final result compilation, were finished during this time. This period of time was thought to be adequate to accomplish the study's goals and guarantee accurate and trustworthy results.

3.6: Selection Criteria:

3.6.1: Inclusion criteria"

Adults (≥18 years) with at least one urinary stone identified on non-contrast CT-KUB.CT-KUB performed for flank pain, hematuria or suspected urolithiasis. Adequate image quality and complete scan coverage of kidneys, ureters and bladder.

3.6.2: **Exclusion Criteria:**

Known congenital urinary tract anomalies (e.g. horseshoe kidney, duplex system) that markedly alter drainage patterns. Previous ipsilateral nephrectomy or ureteric reimplantation. Non-calculous causes of obstruction (e.g. ureteric tumor, extrinsic

compression) as primary pathology. Severe chronic kidney disease with markedly shrunken kidneys where grading hydronephrosis is unreliable. Prior stenting or nephrostomy in the affected kidney before CT.

3.7: Ethical Considerations:

The study protocol was submitted to the **Institutional Review Board (IRB)/Ethical Review Committee** for approval. No additional radiation exposure or intervention is required for research purposes; only existing CT studies are used. The study was conducted after ethical clearance ensuring anonymity and secure handling of patient information. Data will be stored on password-protected computers with access limited to the research team.

3.8: Data collection Method

3.8.1: Identification of patients:

- Retrieve CT-KUB studies from the Radiology Information System (RIS)/PACS for the defined study period using relevant search terms (e.g. “renal colic,” “urolithiasis,” “CT-KUB”).

3.8.2: Radiological review:

- All CT scans were reviewed by consultant radiologist and one radiology trainee blinded to clinical outcomes.
- Discrepancies in grading resolved by consensus.

3.8.3: Measurements:

- Stone detection and characterization:
- Number of stones per renal unit.
- Maximal diameter in mm.
- Location (renal pelvis/PUJ/proximal/mid/distal ureter/VUJ/bladder).

3.8.4: Hydronephrosis grading:

- Each renal unit received a SFU-adapted grade (0–4) on CT

3.8.5: Clinical and demographic data:

- Age, sex
- Presenting symptom (flank pain, hematuria others)
- Side (right/left/bilateral)

3.8.6: Data Recording: Data entered into a pre-designed proforma and then into a secure statistical database using SPSS.

3.9: Data Analysis: (SPSS) Statistical analysis was performed to enter and evaluate data.Bivariate analysis: Association between stone size and hydronephrosis. Spearsman’s rank correlation (for ordinal grade vs continous size). ANNOVA for continouse variables. Ordinal logistic regression with hydronephrosis grade as outcome and stone size, location, attenuation, and relevant confounders as predictors. $P < 0.05$ is considered statistically significant.

3.10: VARIABLES

3.10.1: Independent Variables

- Stone size (continuous and categorical)
- Stone location (categorical)
- Number of stones (single vs multiple)
- Side (right/left)

3.10.2: Dependent Variable

- Hydronephrosis grade (ordinal: 0–4)

3.10.3: Potential Confounders

- Age
- Sex
- Presence of bilateral stones
- Prior history of urolithiasis

RESULTS

Demographic and Clinical Characteristics

A total of 150 patients who underwent non-contrast computed tomography of the kidneys, ureters, and bladder (CT-KUB) with confirmed urinary stones were included in this study. The demographic profile and clinical characteristics of the study population are presented in Table 1. Of the 150 participants, 78 (52.0%) were female and 72 (48.0%) were male. Patient age ranged from 19 to 85 years, with a mean age of 41.0 ± 15.0 years. The largest proportion of patients fell within the 36–45 years age group (n=39, 26.0%), followed by the 15–25 years group (n=31, 20.7%). This age distribution is consistent with established literature indicating that urinary stone disease predominantly affects adults in the third to fifth decades of life.

Table 1: Demographic and Clinical Characteristics of Study Participants (N=150)

Characteristic	Category	Frequency n (%)
Gender	Male	72 (48.0%)
	Female	78 (52.0%)
Age Group (years)	15–25	31 (20.7%)
	26–35	28 (18.7%)
	36–45	39 (26.0%)
	46–55	19 (12.7%)
	56–65	28 (18.7%)
	66–85	5 (3.3%)
Mean Age ± SD	*41.0 ± 15.0 years (Range: 19–85 years)*	
Stone Location	Renal	67 (44.7%)
	PUJ	41 (27.3%)
	VUJ	40 (26.7%)
	Renal/VUJ	2 (1.3%)
Number of Stones	Single	108 (72.0%)
	Multiple (2 stones)	34 (22.7%)
	Multiple (3 stones)	8 (5.3%)
Hydronephrosis Grade	Grade 0 (None)	35 (23.3%)
	Grade 1 (Mild)	51 (34.0%)
	Grade 2 (Moderate)	24 (16.0%)

	Grade 3 (Severe)	31 (20.7%)
	Grade 4 (Very Severe)	9 (6.0%)
Hydronephrosis Presence	Present (Grade ≥1)	115 (76.7%)
	Absent (Grade 0)	35 (23.3%)

PUJ = Pelviureteric Junction; VUJ = Vesicoureteric Junction; SD = Standard Deviation; HN = Hydronephrosis

Stone Characteristics

Stone size across the sample ranged from 1.0 mm to 69.0 mm, with an overall mean of 13.3 ± 9.2 mm. Regarding stone location, the majority of stones were found in the renal parenchyma or pelvis (n=67, 44.7%), followed by the pelviureteric junction (PUJ; n=41, 27.3%) and vesicoureteric junction (VUJ; n=40, 26.7%). Two patients (1.3%) had stones simultaneously affecting both the renal and VUJ regions. Regarding stone number, single stones were most prevalent (n=108, 72.0%), followed by two stones (n=34, 22.7%) and three or more stones (n=8, 5.3%).

Hydronephrosis Findings

Hydronephrosis was detected in 115 out of 150 patients (76.7%). The Society for Fetal Urology (SFU)-adapted grading system was applied to all CT-KUB images. Grade 1 (mild) hydronephrosis was the most frequently observed finding (n=51, 34.0%), followed by Grade 0 meaning no hydronephrosis (n=35, 23.3%), Grade 3 severe (n=31, 20.7%), Grade 2 moderate (n=24, 16.0%), and Grade 4 very severe (n=9, 6.0%). The high rate of hydronephrosis in this cohort underscores the significant obstructive potential of urinary stones detected on CT imaging. Relationship between Stone Size and Hydronephrosis Grade.

A clear progressive trend was observed between stone size and hydronephrosis grade. The mean stone size increased monotonically with rising hydronephrosis grade: Grade 0 patients had a mean stone size of 6.4 ± 5.5 mm, whereas Grade 4 patients had a mean size of 23.0 ± 11.2 mm. Simple linear regression demonstrated a statistically significant positive association between stone size and hydronephrosis grade ($\beta = 0.057$, SE = 0.010, $t = 5.87$, $R^2 = 0.189$, $p < 0.001$). These findings indicate that stone size independently predicted approximately 18.9% of the variance in hydronephrosis grade, supporting hypothesis H1 that larger stones are associated with higher grades of hydronephrosis.

Table 2: Mean Stone Size by Hydronephrosis Grade

Hydronephrosis Grade	N	Mean Size (mm)	SD (mm)	Range (mm)
Grade 0 (None)	35	6.4	5.5	1.0–25.0
Grade 1 (Mild)	51	13.5	6.9	2.0–38.0
Grade 2 (Moderate)	24	16.1	13.3	3.0–69.0
Grade 3 (Severe)	31	16.0	6.6	3.0–47.0
Grade 4 (Very Severe)	9	23.0	11.2	12.0–47.0

*SD = Standard Deviation; * p < 0.001 (Kruskal-Wallis test)*

Relationship between Stone Location and Hydronephrosis Grade

Stone location demonstrated a highly significant and distinct association with hydronephrosis grade ($\beta = -0.450$, SE = 0.081, $t = -5.58$, $R^2 = 0.174$, $p < 0.001$).

Stones at the PUJ were strongly associated with severe obstruction: 31 of 41 PUJ cases (75.6%) presented with Grade 3 hydronephrosis, and 9 cases (22.0%) presented with Grade 4. Conversely, renal stones predominantly resulted in Grade 1 hydronephrosis (35 of 67 renal cases, 52.2%), with no cases of Grade 3 or 4 noted. VUJ stones were most commonly associated with Grade 1 (n=15, 37.5%) and Grade 2 (n=18, 45.0%) hydronephrosis. These findings strongly support hypothesis H2 and confirm that stones at junction sites produce significantly more severe obstruction compared with intra-renal calculi.

Table 3: Distribution of Hydronephrosis Grade by Stone Location

Stone Location	Grade 0	Grade 1	Grade 2	Grade 3	Grade 4
Renal	27 (40.3%)	35 (52.2%)	5 (7.5%)	0 (0.0%)	0 (0.0%)
PUJ	1 (2.4%)	0 (0.0%)	0 (0.0%)	31 (75.6%)	9 (22.0%)
VUJ	7 (17.5%)	15 (37.5%)	18 (45.0%)	0 (0.0%)	0 (0.0%)
Renal/VUJ	0 (0.0%)	1 (50.0%)	1 (50.0%)	0 (0.0%)	0 (0.0%)

PUJ = Pelviureteric Junction; VUJ = Vesicoureteric Junction; Values represent n (%)

Role of Stone Number in Hydronephrosis Severity

Stone number did not demonstrate a statistically significant association with hydronephrosis grade. Simple linear regression for number of stones versus hydronephrosis grade produced a non-significant result ($\beta = 0.122$, SE = 0.175, t = 0.70, $R^2 = 0.003$, $p = 0.487$). This finding indicates that whether a patient had a single stone or multiple stones did not significantly predict the grade of hydronephrosis on CT-KUB imaging, partially refuting hypothesis H3 regarding stone multiplicity.

Table 4: Regression Analysis Predictors of Hydronephrosis Grade

Predictor Variable	β Coefficient	Std. Error	t-Statistic	p-Value (R^2)
Stone Size	0.057	0.010	5.87	**p<0.001; R^2=0.189***
Stone Location	-0.450	0.081	-5.58	**p<0.001; R^2=0.174***
No. of Stones	0.122	0.175	0.70	p=0.487; R^2=0.003 (NS)

*β = Unstandardized coefficient; SE = Standard Error; NS = Not Significant; * Statistically significant at p < 0.05*

Graphical Illustrations

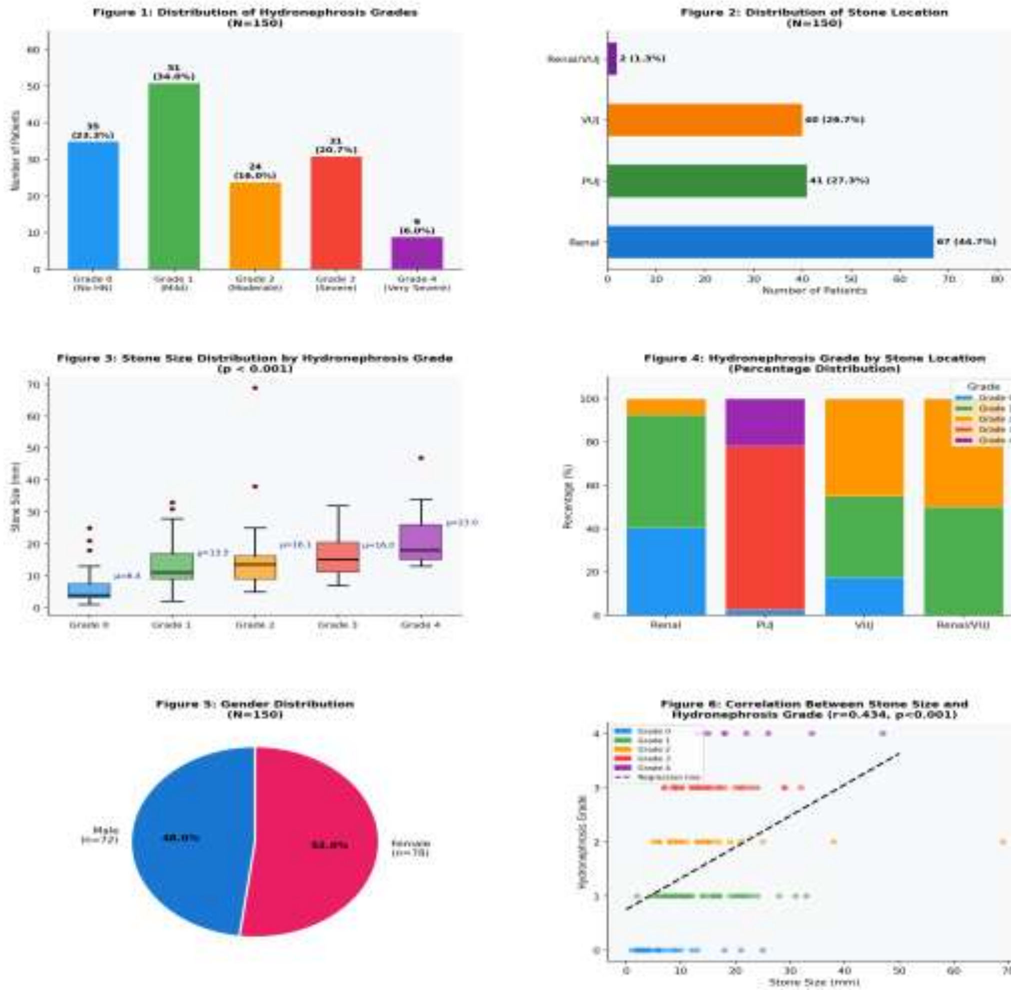

Figure 1: Grade distribution; Figure 2: Stone location; Figure 3: Stone size boxplot by grade; Figure 4: Stacked grade by location; Figure 5: Gender distribution; Figure 6: Scatter with regression line (stone size vs. grade, r = 0.434, p < 0.001).

DISCUSSION

The findings of this study provide important insights into the relationship between urinary stone characteristics and the severity of hydronephrosis as assessed by non-contrast CT-KUB imaging. The present study enrolled 150 patients with confirmed urolithiasis and analyzed key stone parameters including size, location and number in relation to CT-based hydronephrosis grades. The results demonstrate that both stone size and stone location are statistically significant independent predictors of hydronephrosis severity while stone number does not carry significant predictive value.The demographic profile of the study sample reflects patterns well recognized in epidemiological literature. The mean patient age was 41.0 ± 15.0 years with the highest frequency in the 36–45 age group which is consistent with reports indicating peak stone incidence in the fourth decade of life ([xx]). A slight female predominance (52.0%) was observed in this cohort. Although urolithiasis has traditionally been reported to be more common in males in Western populations several South Asian studies have noted comparable or slightly higher female prevalence possibly attributable to dietary differences hormonal factors or healthcare-seeking behavior patterns within the regional context ([xxi]).

One of the central findings of this study is the statistically significant positive association between stone size and hydronephrosis grade ($p < 0.001$, $R^2 = 0.189$). As stone size increased, hydronephrosis grade escalated progressively with Grade 4 cases

demonstrating a mean stone size of 23.0 mm compared to only 6.4 mm in Grade 0 cases. This finding aligns with the work of Alshoabi et al., who similarly reported a significant positive association between nephrolith size and hydronephrosis grade in their cross-sectional study ([xxii]). It also demonstrated that ureteral stones exceeding 5 mm were more frequently associated with higher degrees of obstruction ([xxiii]).
However, the R^2 value of 0.189 suggests that stone size alone explains approximately 19% of the variability in hydronephrosis grade, indicating that additional variables contribute significantly to obstruction severity. This is consistent with observations such as stone position and degree of impaction may modulate the relationship between stone size and hydronephrosis ([xxiv]). Notably, several patients in this cohort with relatively large intra-renal stones demonstrated only mild hydronephrosis reinforcing the concept that intra-renal stones even when large may not fully obstruct the collecting system, allowing partial drainage to continue. ([xxv]).

The relationship between stone location and hydronephrosis grade was among the most striking findings of this research. PUJ stones were overwhelmingly associated with Grade 3 (75.6%) and Grade 4 (22.0%) hydronephrosis, while renal stones were predominantly associated with Grade 1 hydronephrosis (52.2%) and produced no Grade 3 or Grade 4 cases whatsoever. VUJ stones occupied an intermediate position, producing mostly Grade 1 and Grade 2 obstructions. . This limits the generalizability of findings to diverse clinical settings with different patient demographics, radiology equipment and imaging protocols ([xxvi]).These results are in agreement with established literature. The site of ureteral stone impaction significantly influenced the degree of obstruction and treatment outcomes. The anatomical narrowing at the PUJ makes it particularly susceptible to complete occlusion when a stone becomes lodged at this location, resulting in rapid pressure accumulation proximal to the obstruction and consequent severe pelvicalyceal dilatation ([xxvii]).
The location regression demonstrated an R^2 of 0.174 confirming that stone location independently explains approximately 17.4% of variance in hydronephrosis grade. When taken together with stone size these two variables collectively account for a meaningful proportion of obstruction severity providing radiologists with key imaging features to guide urgency of clinical management ([xxviii]).
Contrary to hypothesis H3, the number of stones did not significantly predict hydronephrosis grade ($p = 0.487$). This finding suggests that having multiple stones does not necessarily compound the degree of obstruction beyond what a single stone would produce. A possible explanation is that in many patients with multiple stones the additional calculi were smaller accessory fragments located in non-obstructing positions within the renal parenchyma while the primary obstructing stone was the principal driver of any hydronephrosis. This observation is consistent with previous studies that found no statistically significant difference in hydronephrosis severity between patients with single versus multiple stones ([xxix]).The findings of this study have meaningful implications for radiological practice and urological management. Stones located at the ureteropelvic junction (UPJ) demonstrated a strong association with higher grades of hydronephrosis underscoring the importance of careful assessment of stone location during CT interpretationThe high prevalence of hydronephrosis observed in this cohort (76.7%) further highlights the necessity for routine and systematic evaluation of the renal collecting system in CT-KUB studies. Integrating these imaging parameters into structured reporting frameworks may enhance diagnostic consistency and facilitate more timely and appropriate clinical decision-making ([xxx]).

CONCLUSION

This cross-sectional study of 150 patients with urinary stone disease assessed by non-contrast CT-KUB demonstrates a significant relationship between stone

characteristics and hydronephrosis severity. Stone size showed a statistically significant positive association with hydronephrosis grade ($p < 0.001$), increasing from a mean of 6.4 mm in Grade 0 to 23.0 mm in Grade 4, and accounting for 18.9% of the variability, confirming its role as a key predictor of obstruction. Stone location emerged as the strongest associated factor, with PUJ stones frequently linked to severe hydronephrosis (Grade 3: 75.6%; Grade 4: 22.0%), whereas renal stones were more commonly associated with mild (Grade 1) obstruction, highlighting the clinical importance of location-based stratification. In contrast, stone number was not significantly associated with hydronephrosis severity ($p = 0.487$), indicating that multiplicity is not an independent predictor. Overall, hydronephrosis was observed in 76.7% of patients, emphasizing the obstructive potential of urolithiasis and the need for systematic grading in CT-KUB reporting. These findings support the role of CT-KUB in defining the relationship between stone features and urinary tract obstruction, and suggest that incorporating stone size and location into structured radiology reports may enhance clinical decision-making, aid in identifying patients at risk of acute kidney injury, and promote timely urological intervention, while contributing locally relevant evidence and supporting standardized reporting protocols in urolithiasis management.

LIMITATIONS OF THE STUDY

This study has several limitations that should be acknowledged. Its retrospective cross-sectional design restricts the ability to establish temporal relationships or causality between stone characteristics and hydronephrosis progression. Stone attenuation (Hounsfield units) was not consistently available, limiting its inclusion as a predictive factor despite its clinical relevance. Being a single-center study the findings may not be fully generalizable to other populations or clinical settings. In addition, subjective variation in hydronephrosis grading may have introduced measurement differences, particularly between adjacent grades. The lack of renal function data such as serum creatinine and eGFR prevented correlation between imaging findings and functional impairment. Moreover, stone composition was not evaluated, although it may influence obstruction severity and act as a confounding factor.

RECOMMENDATIONS

Standardized CT-KUB reporting should include stone size, location and hydronephrosis grade. PUJ stones and Grade 3–4 hydronephrosis require urgent clinical attention. Future studies should be prospective, multi-center and include stone attenuation and renal function data. Larger samples with multivariable analysis are recommended. Standard imaging protocols and AI tools may improve accuracy and consistency.

IMAGES FOR ANATOMICAL REFERENCES

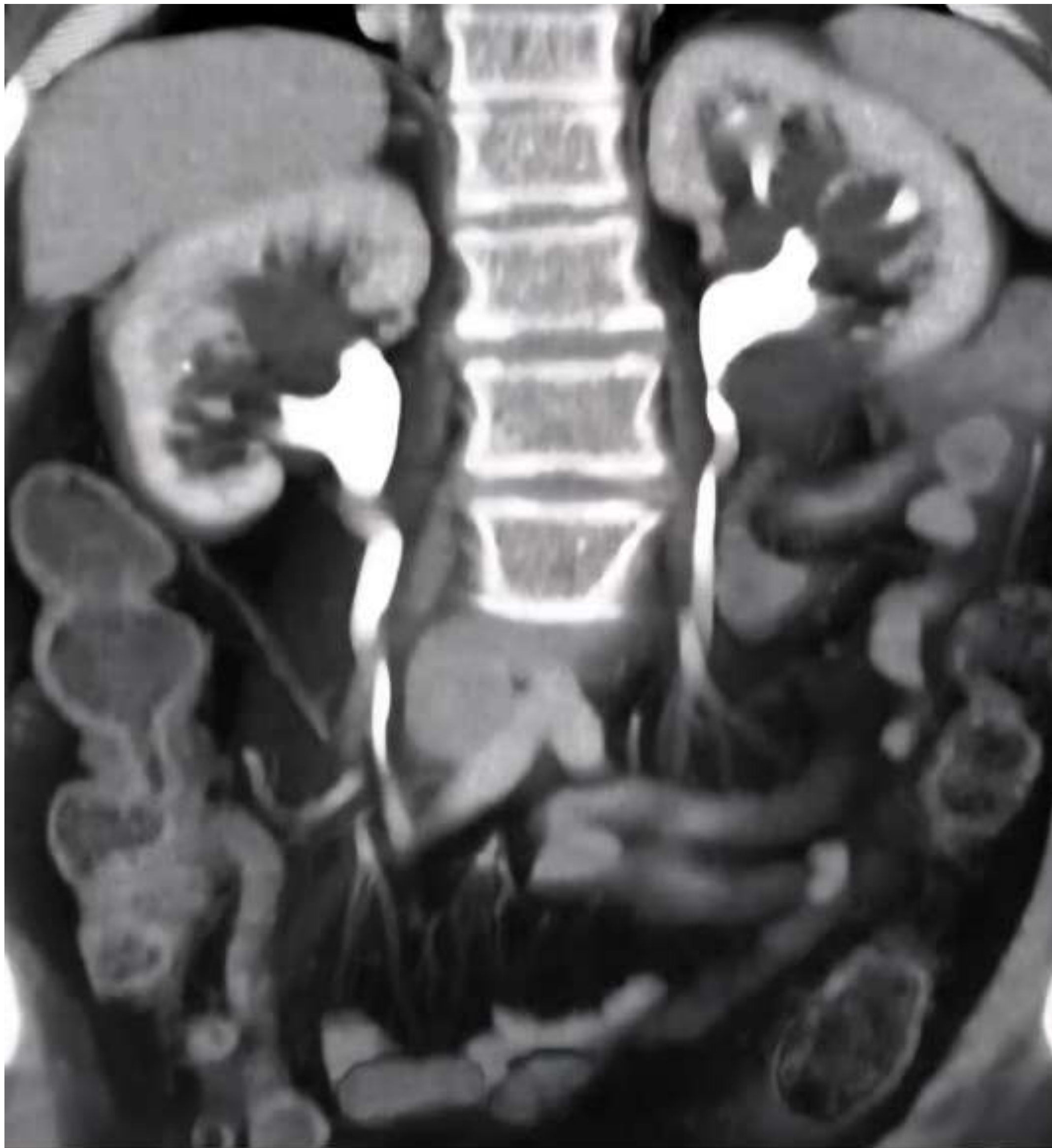

Figure Description:

Coronal CT-KUB image showing both kidneys with contrast-filled pelvicalyceal systems and ureters.

There is dilatation of the renal pelvis and calyces, consistent with hydronephrosis.

The ureters appear as opacified tubular structures descending inferiorly.

The vertebral column is centrally visualized for anatomical reference.

Findings suggest obstructive uropathy, likely due to ureteric calculus.

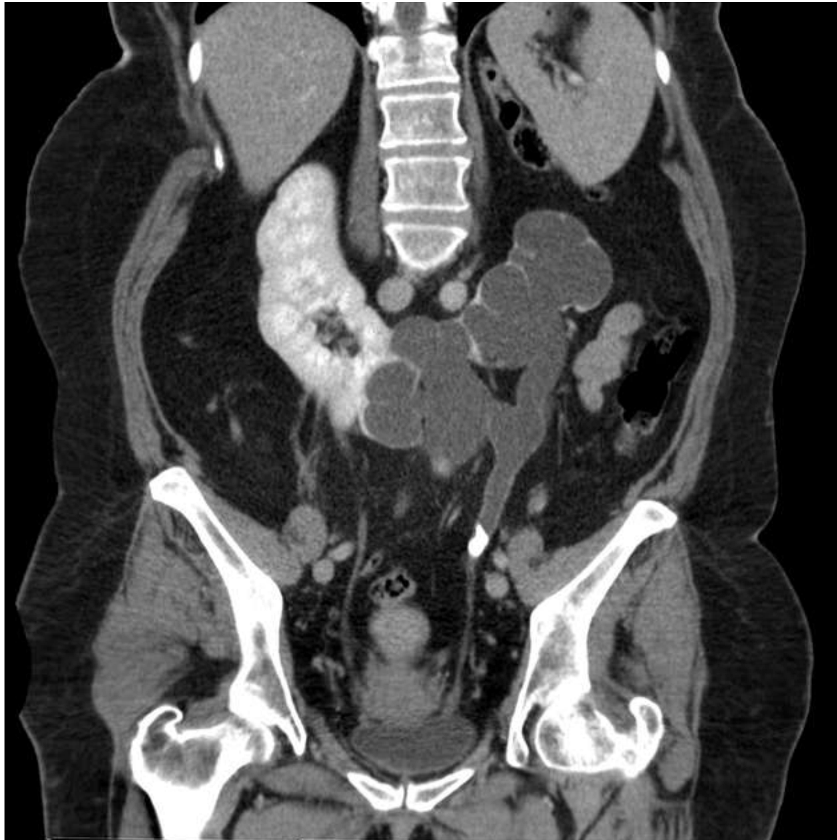

Figure Description:
Coronal CT-KUB image demonstrating both kidneys, ureters, and urinary bladder.
A hyperdense focus is seen along the ureter, consistent with a ureteric calculus.
There is associated proximal dilatation of the ureter and renal pelvis, indicating hydronephrosis.
Surrounding abdominal and pelvic structures are visualized for anatomical reference.
Findings are suggestive of obstructive uropathy secondary to ureteric stone.

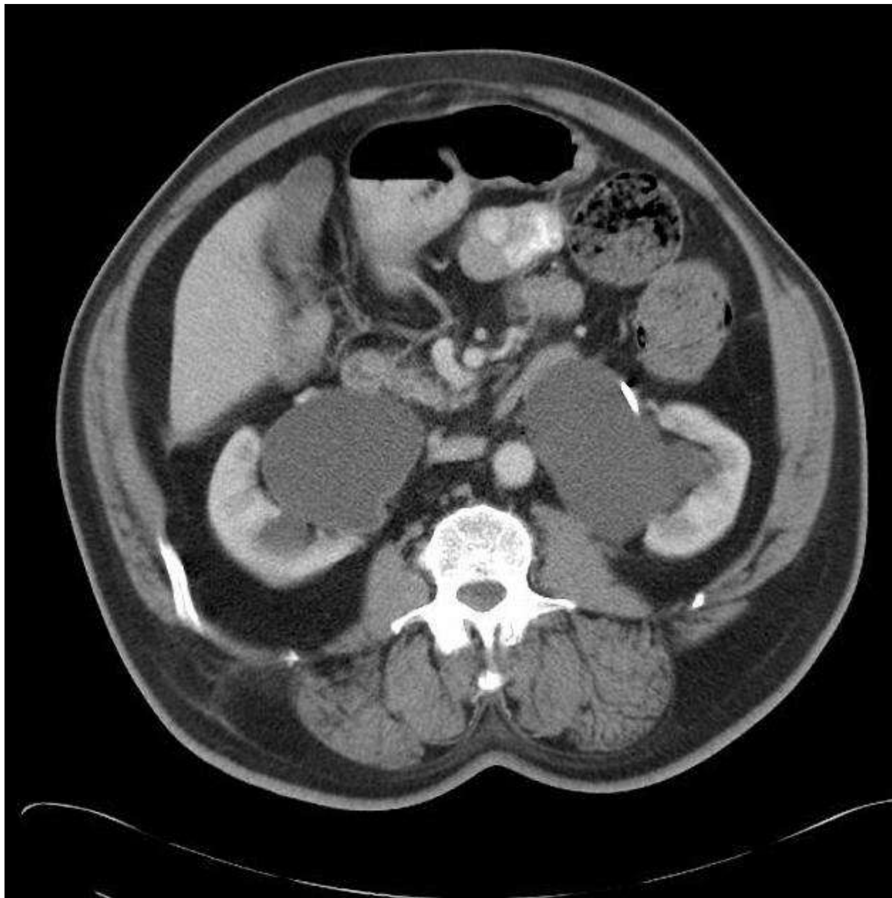

Figure Description:
Axial CT-KUB image showing both kidneys and surrounding abdominal structures.
A hyperdense focus is noted along the ureter, consistent with a ureteric calculus.
There is associated dilatation of the renal pelvis, indicating hydronephrosis.
The vertebral body is centrally visualized for anatomical reference.
Findings are suggestive of obstructive uropathy secondary to ureteric stone.

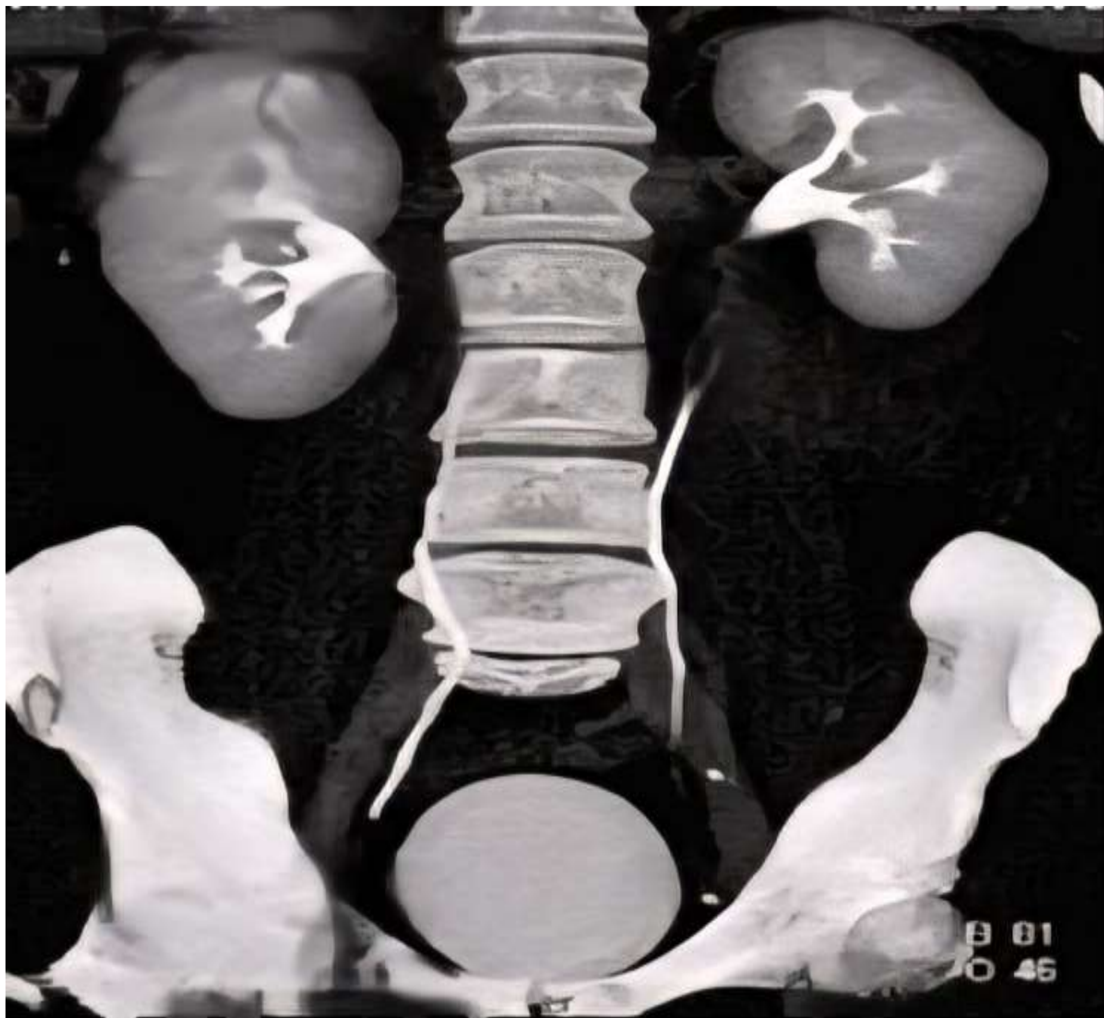

Figure Description:
This image shows an Intravenous Urography, a contrast-enhanced study of the urinary tract. The contrast outlines the kidneys, calyces, and ureters. Both kidneys appear to be functioning as they excrete contrast. The ureters are visible as thin tubes leading to the bladder. The bladder is seen as a contrast-filled structure in the pelvis.

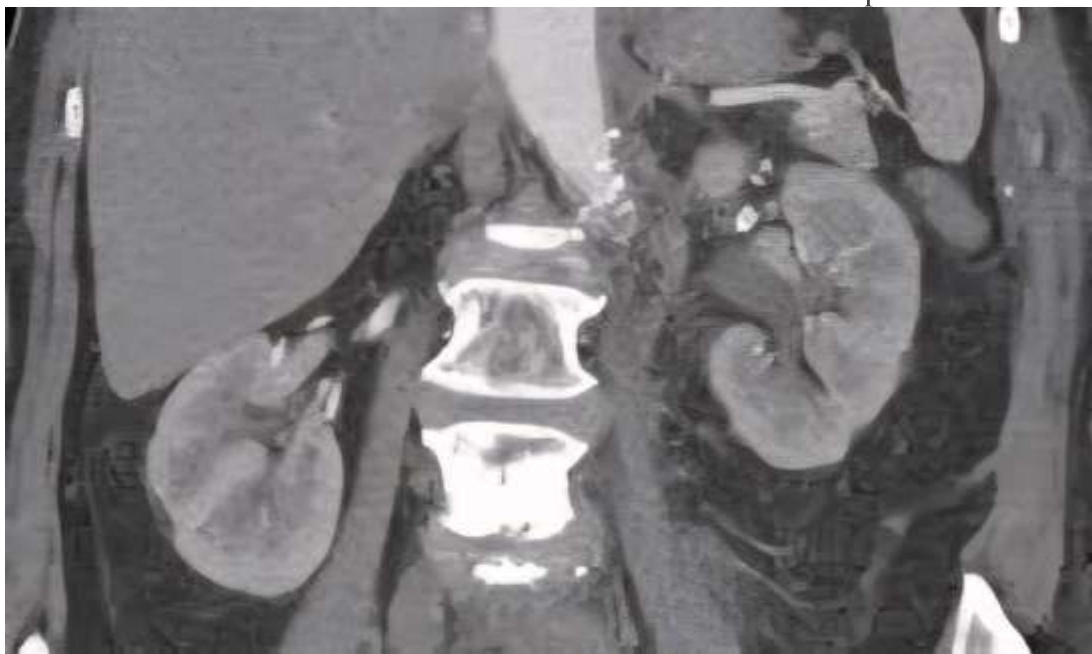

Figure Description:

This image shows a CT scan KUB in coronal view. The kidneys are clearly visualized on both sides with internal structures. No contrast outlining of the collecting system is seen, suggesting a non-contrast study. The vertebral column is visible centrally as a dense structure. This modality is commonly used for detecting renal stones and evaluating the urinary tract.

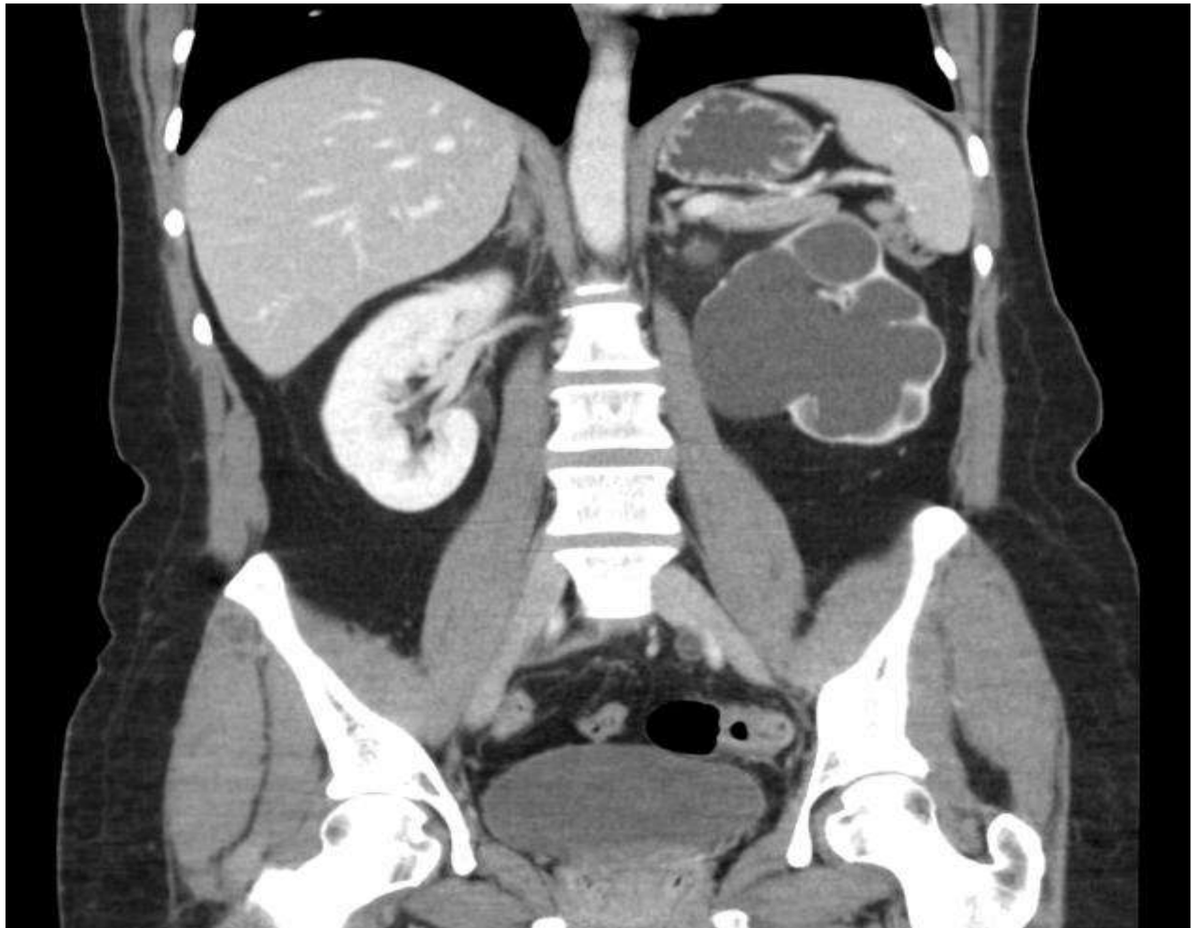

Figure Description:
This image shows a CT scan KUB in coronal view. One kidney appears normal, while the opposite kidney shows multiple cystic, dilated areas suggestive of pathology. The vertebral column is seen centrally with surrounding abdominal structures. No contrast opacification of the collecting system is evident, indicating a likely non-contrast study. This imaging is useful for evaluating renal abnormalities and detecting stones

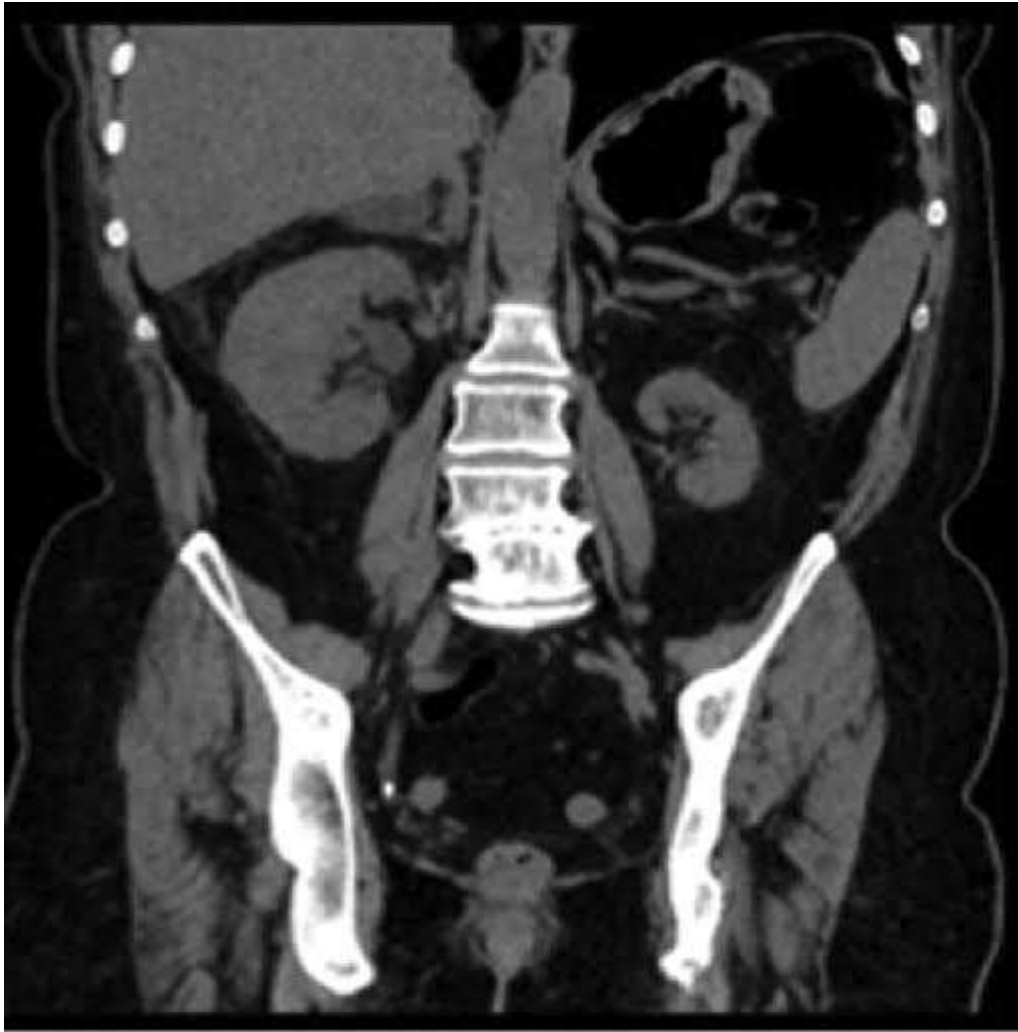

Figure Description:
This image shows a CT scan KUB in coronal view. Both kidneys are visualized with preserved shape and position. No contrast opacification is seen, indicating a non-contrast study. The vertebral column is centrally located with surrounding pelvic bones. This imaging modality is commonly used to assess renal pathology, especially stones

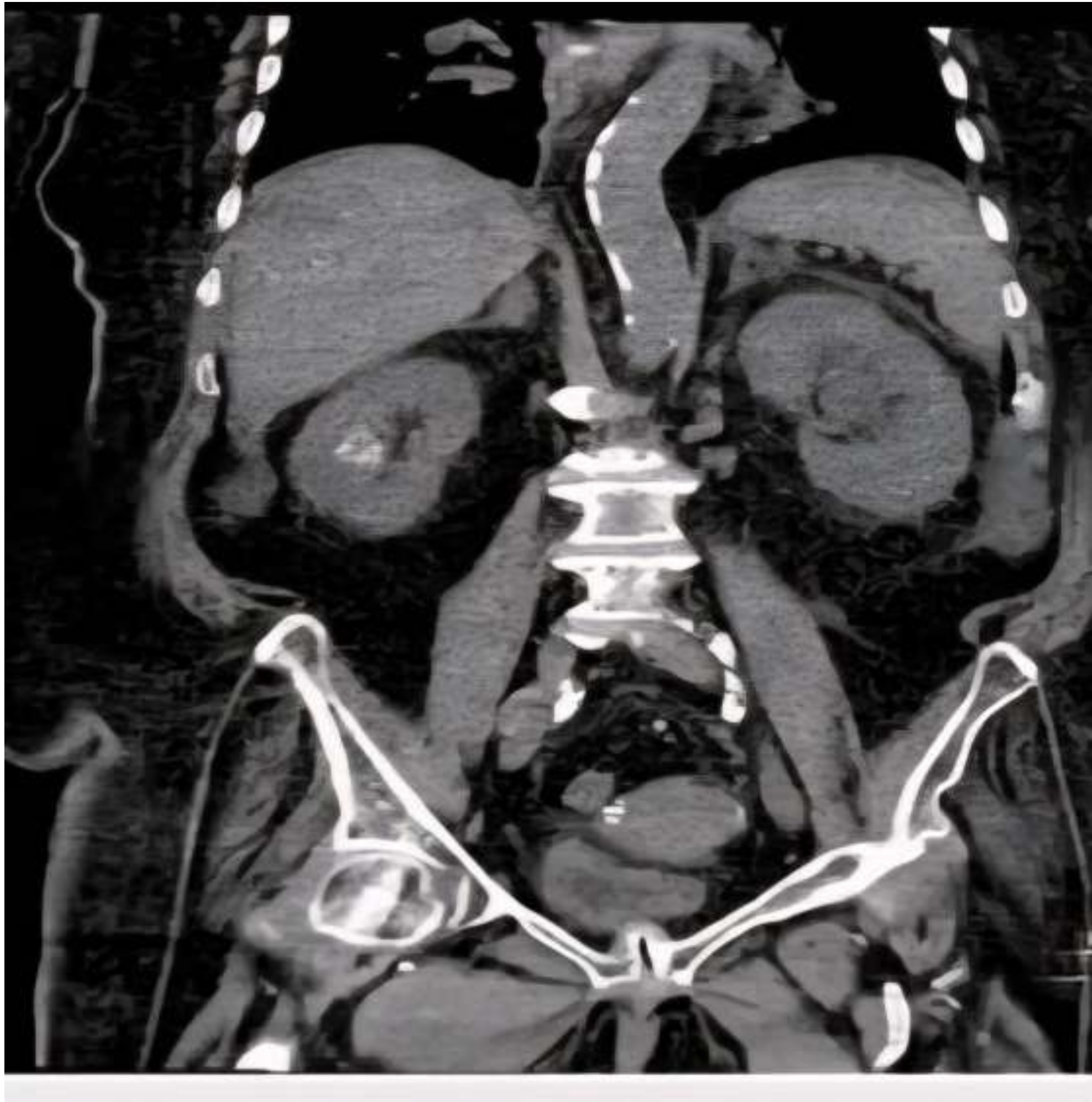

Figure Description:
This image shows a contrast-enhanced CT scan KUB in coronal view. Both kidneys are visualized with enhancement of the renal parenchyma. Major vessels like the aorta are also opacified, indicating contrast use. The vertebral column is seen centrally with surrounding abdominal structures. This study helps evaluate renal anatomy, vascularity, and associated pathologies.

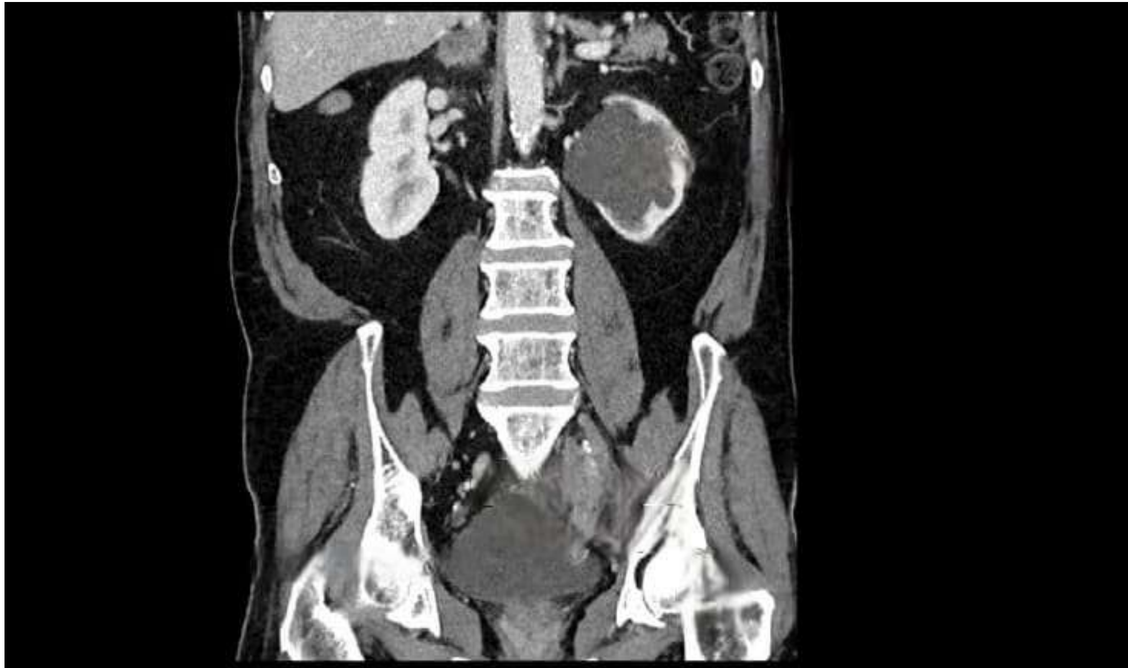

Figure Description:
This image shows a contrast-enhanced CT scan KUB in coronal view. One kidney demonstrates a well-defined cystic lesion, while the opposite kidney appears normal. The renal parenchyma is enhanced, indicating contrast administration. The vertebral column is centrally visualized with surrounding pelvic structures. This modality is useful for assessing renal masses and structural abnormalities

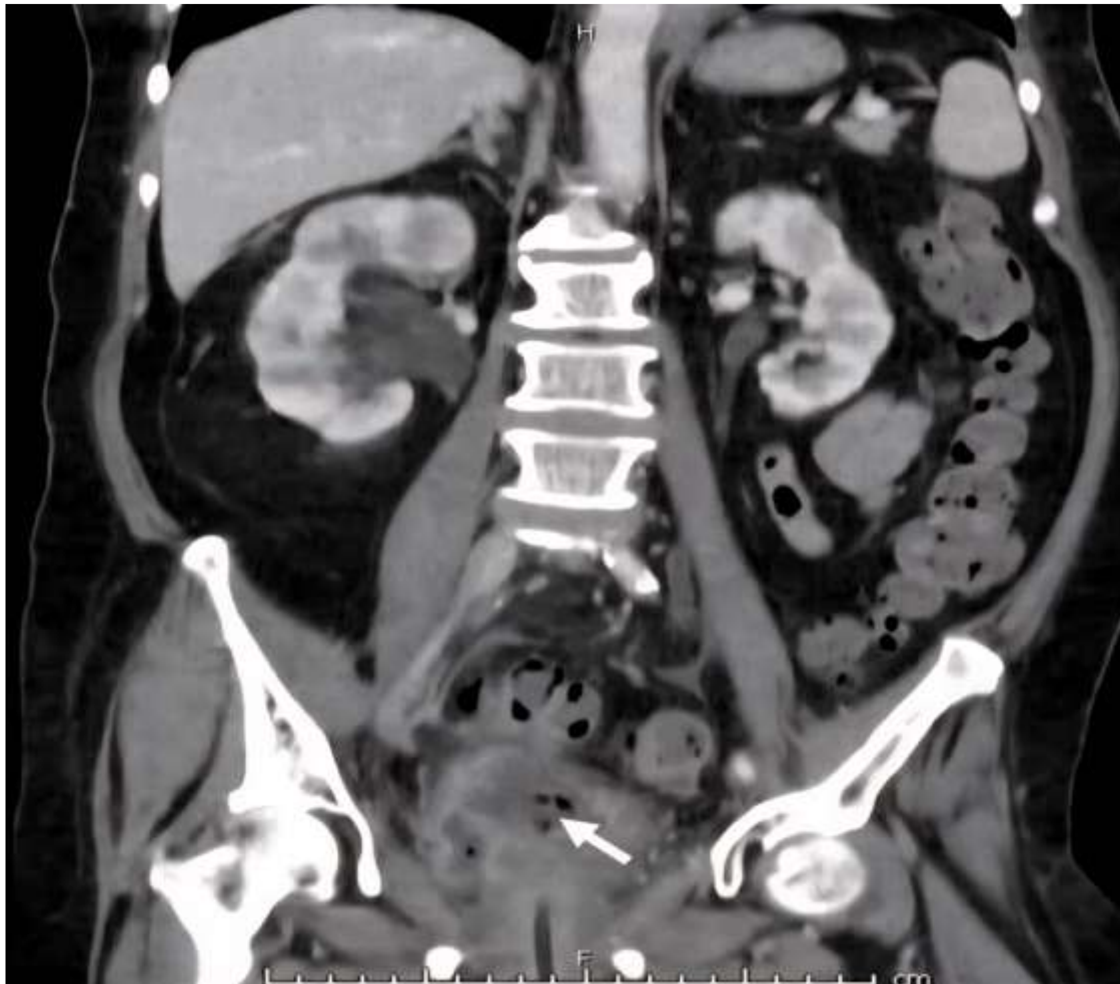

Figure Description:
This image shows a contrast-enhanced CT scan KUB in coronal view. Both kidneys demonstrate contrast enhancement, indicating functioning renal parenchyma. The vertebral column is centrally visualized with surrounding abdominal and pelvic structures. An arrow highlights a focal area in the pelvic region, suggesting a possible pathology. This imaging is useful for evaluating renal and pelvic abnormalities

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