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## Ultrasonography versus low-dose computed tomography in diagnosis and size measurement of urolithiasis

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### Abstract

**Introduction:** Urolithiasis poses significant global health challenges. This study evaluates ultrasonography versus low-dose CT in diagnosing urinary tract stones.

**Method:** This prospective comparative study was conducted at the Radiology Department of Universal College of Medical Sciences Teaching Hospital (UCMS-TH), Bhairahawa, Nepal from Sep 2021 to Mar 2023. Ethical approval was obtained. Adult patients with suspected urolithiasis referred for imaging who had both ultrasound (USG) and non-contrast computed tomography (NCCT) KUB within one-week were included. Sample estimation was done by Buderer's formula for expected sensitivity/specificity. Patients with interventions or spontaneous stone passage between investigations, pregnancy were excluded. Analysis was performed using IBM SPSS 20 to compare accuracy of USG to NCCT for urolithiasis by calculating sensitivity, specificity. Chi-square test was performed, statistical significance set at  $p < 0.05$ .

**Result:** Out of 160 urolithiasis patients, males were 88(55%), mean age 39.29 years ( $SD=13.73$ ), mean BMI of 23.82 ( $SD=2.12$ ), stone size on USG 7.12 mm ( $SD=6.15$ ) and on CT 7.63 mm ( $SD=5.56$ ). Accuracy for detecting stones was high by CT, sensitivity 96.1% compared to 44.9% by USG. The CT showed higher accuracy in detecting ureteral stones and small stones  $< 3$  mm. For larger stones of  $> 9$  mm both CT and USG were equally effective. Statistically significant differences ( $p < 0.001$ ) were noted for localization and size of stones favouring CT.

**Conclusion:** This study found that CT was superior than USG in detecting urolithiasis, particularly small stones and ureteral calculi, highlighting higher sensitivity and accuracy of CT as a diagnostic tool for urinary stones.

### How to cite

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## Introduction

Urolithiasis is a universal problem affecting patients across geographical, cultural, and racial boundaries.<sup>1,2</sup> With a lifetime incidence of 5-20% and a recurrence rate of nearly 50%<sup>2,3</sup> urolithiasis poses significant health challenges globally. Radiological evaluation is pivotal in diagnosing and monitoring these patients, guiding critical management decisions.<sup>4</sup> However, in the modern era of advanced imaging technologies, the choice of modality for diagnosing urolithiasis can often be complex and unclear.<sup>5</sup> Clinicians must balance the benefits of each imaging technique against healthcare costs, radiation exposure, and patient safety in different clinical scenarios.

Selecting the appropriate imaging modality involves considering factors such as the clinical context, patient body habitus, and tolerance to ionizing radiation. While numerous modalities, including CT, ultrasonography (USG), MRI, and KUB radiography, are available, each has distinct advantages, limitations, and associated costs. Currently, unenhanced multidetector CT (MDCT) is regarded as the gold standard for detecting urolithiasis, boasting a sensitivity of 97% and specificity of 98–99%.<sup>6,7</sup> Beyond its superior diagnostic accuracy, CT provides comprehensive anatomical information, detects secondary signs of stone passage, and identifies alternative pathologies. However, its high radiation dose, ranging from 8 to 16 mSv,<sup>4,8</sup> raises concerns, prompting the adoption of low-dose CT protocols to reduce radiation exposure without compromising diagnostic efficacy.

Ultrasound (USG), on the other hand, is a widely available, affordable, and radiation-free alternative, particularly suitable for paediatric and pregnant patients. USG offers the advantage of enabling repeated evaluations but has limitations, including reduced sensitivity for smaller stones and technical challenges in visualizing the mid-ureter due to bowel gas interference.<sup>10,11</sup> This study aims to compare the efficacy of USG with low-dose CT in diagnosing and measuring the size of urinary tract stones, using CT as the gold standard reference.

## Method

This prospective comparative study was conducted at the Radiology Department of Universal College of Medical Sciences Teaching Hospital (UCMS-TH), Bhairahawa, from September 1, 2021, to March 30, 2023. Adult patients with suspected urolithiasis who were referred for imaging were included in the study. A total of 160 cases were considered, irrespective of age and sex, for the study.

For sample estimation using Buderer's formula (<https://wnarifin.github.io/ssc/sssnsp.html>) for expected overall USG sensitivity/specificity<sup>1,9</sup> at 93% and 95%, confidence level 95%, a margin of error 10% and prevalence of urolithiasis in Asia at 16%<sup>3</sup> the estimated sample was 157, and so we used a final sample size of 160.

Patients with flank pain suspected of urolithiasis who underwent both recent ultrasound (USG) and non-contrast computed tomography (NCCT) KUB within a one-week interval were included in the study. Patients who had undergone interventions or experienced spontaneous stone passage between investigations, were pregnant, and did not provide written consent were excluded.

Ethical approval was obtained from the Institutional Review Committee (UCMS/IRC/151/21). Permission was also granted by the Radiology Department at UCMS-TH. All participants provided written informed consent. Patients were assured that they could withdraw from the study at any time without any consequences. Confidentiality was maintained, personal information was anonymized, and all data were used exclusively for research purposes. Participants were not burdened financially, and there were no associated risks or benefits for the participants.

Ultrasound imaging was performed using the LOGIQ P6 PRO ultrasound machine, equipped with a low-frequency (2-5 MHz) curvilinear probe. Standardized imaging protocols were followed, and all scans were conducted by experienced radiologists. Key findings from the USG included the number, location, and size of

the stones, as well as the presence of hydronephrosis.

Non-contrast Computed Tomography (NCCT) of the kidneys, ureters, and bladder (KUB) was conducted using a 16-slice Multidetector GE Brivo CT scanner. The imaging protocol was standardized, and the scan covered the region from the diaphragm to the ischium, with patients positioned supine. The following parameters were used: Tube voltage: 100 kVp, Tube current: 150-200 mAs, Rotation time: 750 ms and Slice thickness: 5 mm. Three-dimensional reconstructions of unenhanced CT images were reformatted in coronal and sagittal projections to enhance visualization. Radiological findings included the number, location, and size of urolithiasis, as well as the presence of hydronephrosis. Locations were categorized as kidney (K), proximal ureter (PU), mid ureter (MU), distal ureter (DU), vesicoureteric junction (VUJ), and urinary bladder.

Stone size measurement was taken in two dimensions including long axis and short axis. For cases with multiple stones, the largest stone size was recorded.

Statistical analysis was performed using IBM SPSS 20. The data were compared to assess the diagnostic accuracy and effectiveness of USG versus low-dose NCCT in the diagnosis and measurement of urolithiasis. Sensitivity, specificity, positive predictive value and negative predictive value of USG were compared to CT as the gold standard, chi-square test was performed, statistical significance was set at  $p < 0.05$ .

## Result

The study included 160 patients with urolithiasis, males were 88(55%), age 39.29 years (SD=13.73), BMI 23.82(SD=2.12), stone size by USG 7.12(SD=6.15) and CT 7.63 mm (SD=5.56), Figure 1, Table 1.

Both USG and CT found 124 patients had stones, and 8 had negative results in both, 5 had stones in USG but negative in CT. The USG showed a sensitivity of 44.9%, specificity of 61.5%, and accuracy of 82.0%. The high positive predictive value (96.1%) of USG shows it is reliable, but it may miss smaller stones having a low negative predictive value (5.0%), compared to CT is being more accurate and reliability in diagnosing urolithiasis, Table 2.

In our study, both USG and CT detected a single stone in 97 patients. Five patients having single stone visualized by USG was not present in CT. Multiple stones were correctly identified in 27 patients by both modalities. USG missed 28 cases of stones which was detected by CT, Table 3. Thus, CT was more reliable for both single and multiple stone detection.

Localization of stone across all location was significantly higher by CT than USG,  $p < 0.001$ . The CT was more accurate in detecting stones in the upper, mid, and lower ureters, and USG is most effective at identifying kidney stones, Table 4.

Overall CT detected more smaller stones than USG, while both were effective for larger stones. For stones  $< 3\text{mm}$ , CT (60%) was more sensitive compared to USG (40%). For 3.1–6 mm stones, USG detected 46 compared to 38 by CT (70.2%), for 6.1–9mm stones, both modalities were comparable identifying 33 stones (74.2%) and for  $> 9\text{mm}$  stones with USG detecting 45 and CT 43 cases, Table 5.

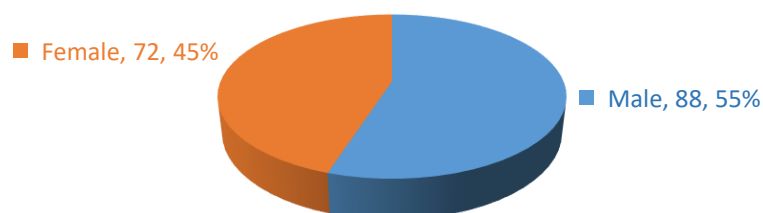


Figure 1. Gender distribution of patients with urolithiasis

Table 1- Mean age, BMI of patients with urolithiasis diagnosed by USG and CT, n=160

Descriptive statistics	Age y	BMI	USG stone mm	CT stone mm
Mean	39.29	23.82	7.12	7.63
SD	13.73	2.12	6.15	5.56

Table 2. Diagnosis of urolithiasis based on USG and CT findings, n=160

Stone seen in USG	Stone seen in CT		p-value
	Yes, n(%)	No, n(%)	
Yes	124(96.1)	5(3.9)	0.185
No	28(90.3)	3(9.7)	
Total	152(95)	8(5)	

Table 3. Single and multiple stones in patients with urolithiasis as per USG and CT findings, n=160

Stone seen in USG	Stone seen in CT		p-value
	Yes, n(%)	No, n(%)	
Single	97(95.1)	5(4.9)	
Multiple	27(100)	0	<0.001
None	28(90.3)	3(9.7)	
Total	152(95)	8(5)	

Table 4. Diagnosis of urolithiasis according to location as per USG and CT findings, n=160

Site of stone in USG	Site of stone in CT, n(%)					p-value
	Kidney	Upper ureter	mid ureter	lower ureter	None	
Kidney	56(82.4)	3(4.4)	4(5.9)	0	5	
upper ureter	0	20(100)	0	0	0	
mid ureter	0	0	5(100)	0	0	<0.001
lower ureter	0	0	0	36(100)	0	
None	4(12.9)	4(12.9)	11(35.5)	8(25.8)	4(12.9)	
Total	60(37.5)	27(16.9)	20(12.5)	44(27.5)	9(5.6)	

**Table 5. Diagnosis of urolithiasis depending on size of stones as per USG and CT findings, n=160**

Size of stone mm in USG	Size of stone mm in CT					p-value
	<3	3.1-6	6.1-9	>9	None	
<3	2(40%)	0	0	0	3(60)	
3.1-6	8(17)	33(70.2)	4(8.5)	1(2.1)	1(2.1)	
6.1-9	0	5(16.1)	23(74.2)	3(9.7)	0	<0.001
>9	0	0	6(13)	39(84.8)	1(2.2)	
None	4(12.9)	19(61.3)	3(9.7)	1(3.2)	4(12.9)	
<b>Total</b>	14(8.8)	57(35.6)	36(22.5)	44(27.5)	9(5.6)	

## Discussion

Diagnostic accuracy of USG vs. CT in present study for evaluation and comparison in detecting and measuring the size of urinary calculi revealed USG had a sensitivity of 81.6%, specificity of 100%, and a positive predictive value (PPV) of 96.1%. However, its negative predictive value (NPV) was only 9.7%, indicating a higher likelihood of missed diagnoses, particularly for smaller stones or those in certain anatomical locations. Conversely, CT identified calculi in 96.1% of patients, cementing its status as the gold standard for urolithiasis imaging.

Similar findings have been reported by other studies reporting USG's sensitivity of 69.79% and specificity of 100%.<sup>1</sup> Sonography sensitivity range from 12% to 93%, depending on stone size and location.<sup>9</sup> Despite technological advances improving USG's sensitivity, its limitations remain significant compared to CT.

Urolithiasis remains a significant health concern globally, affecting the urinary tract with complications including obstruction, infection, sepsis, and even renal failure. Timely diagnosis and management are critical for mitigating these risks and preserving renal function. Imaging plays a pivotal role in diagnosing, planning treatment, and monitoring post-treatment outcomes in urolithiasis. Among available imaging modalities, USG and low-dose computed tomography of the kidneys, ureters, and bladder (CT KUB) have become central to clinical practice.<sup>7</sup>

Demographics and risk factors among 160 participants in our study showed a predominantly male (55%) with a male-to-female ratio of 1.3:1, consistent with prior findings.<sup>12,14</sup> This gender disparity in urolithiasis may be attributed to differences in urinary tract anatomy, hormonal influences, and metabolic factors. Male urinary tracts often exhibit lower pH and reduced renal function, predisposing them to stone formation.

Age distribution of participants ranged from 12 to 82 years, with a mean age of 39 years. Most cases were concentrated in the 30–50-year age group. This aligns with other studies suggesting middle-aged individuals are most affected.<sup>15</sup> This trend may result from occupational stress, dehydration, and lifestyle factors contributing to stone formation.<sup>13</sup>

The mean BMI in present study was 23.82 kg/m<sup>2</sup>, indicating a normal weight distribution among participants, though body habitus can influence imaging outcomes.

Stone size measurement is a critical factor influencing management decisions. In this study, the mean stone size was 7.12 mm on USG and 7.63 mm on CT KUB, with CT detecting stones approximately 0.51 mm larger than USG on average. The majority of stones (70.2%) were 3.1–6 mm in size. While USG identified 14.28% of stones smaller than 3 mm, its limitations in detecting these small calculi were evident. This finding aligns other studies which reported that USG often misses smaller stones.<sup>13</sup>

CT's ability to detect stones smaller than 3 mm underscores its superior sensitivity, with a statistically significant association between stone sizes measured by USG and CT ( $p < 0.001$ ) as we found in present study.

Stone location and detection challenges are important factor in clinical practice. In present study, CT outperformed USG in detecting stones across all anatomical locations. USG detected 56 calculi in the kidneys with 82.4% accuracy, 20 in the upper ureter (74.1% accuracy), 5 in the mid-ureter (25% accuracy), and 36 in the lower ureter (81.8% accuracy). Mid-ureter stones were particularly challenging for USG to detect, which is consistent with findings that mid-ureter stones often remain undetected by USG.<sup>16,17</sup>

CT's superiority lies in its ability to visualize stones across all urinary tract regions and to differentiate between stones and other calcifications, such as phleboliths, using specific signs like the soft-tissue rim and comet-tail sign.<sup>18,19</sup> Moreover, CT can detect secondary signs of obstruction, including hydronephrosis, perinephric stranding, and dilatation of the collecting system, enhancing its diagnostic utility.<sup>15,18</sup>

The role of CT in urolithiasis imaging offers unparalleled advantages including the ability to detect radiolucent stones like uric acid and cystine stones and accurate measure of stone attenuation values ( $>200$  HU) to distinguish stones from surrounding tissues.<sup>5</sup> Multidetector-CT also provides high-resolution reformatted images, facilitating precise localization of stones within the urinary tract. Its role extends to identifying post-intervention residual stones, differentiating stones from stents, and evaluating secondary signs of obstruction.

Some of the notable limitations of CT are stones with soft-tissue attenuation like matrix or indinavir stones can be missed.<sup>15</sup> However, these instances are rare and do not significantly impact CT's overall diagnostic superiority.

Factors influencing USG findings for its diagnostic accuracy include operator expertise, patient body habitus, and the presence of bowel

gas or calcifications obscuring visualization.<sup>20-23</sup> Despite these limitations, USG remains a valuable tool for initial assessment due to its safety, accessibility, and lack of ionizing radiation. However, its role in urolithiasis diagnosis is largely complementary to CT rather than standalone.

Ultrasound remains a valuable, non-invasive, and accessible first-line modality, especially in cases with low clinical suspicion or for patients from low socioeconomic backgrounds. This study emphasizes the complementary roles of USG and CT, advocating for tailored imaging approaches based on clinical needs. While USG is limited in detecting smaller stones and ureteric calculi, it is effective for hydronephrosis evaluation. Further research is essential to optimize imaging strategies, reduce radiation exposure, and enhance cost-effectiveness for patient care.

Limitations of the present study are variability in operator skill and patient factors, such as obesity or anatomical anomalies, could have influenced USG findings. Additionally, stone migration or size changes between USG and CT scans may have introduced discrepancies. Also, the recruitment of participants from a single centre and the pragmatic constraints of achieving the target sample size may limit the generalizability of findings to broader populations or diverse clinical settings.

Expanding the study to multiple centres and including larger sample sizes could provide more robust data and generalizable conclusions. Further research is essential to optimize imaging strategies, reduce radiation exposure, and enhance cost-effectiveness for patient care.

## Conclusion

In conclusion, non-contrast CT KUB stands out for diagnosing urolithiasis, offering superior accuracy and reliability across all stone sizes and locations. However, ultrasound remains a valuable, non-invasive, and accessible first-line modality. Research on optimizing imaging strategies, radiation exposure, and cost-effectiveness for patient care will add value.

### Author contribution

Concept design: RG; Acquisition, analysis, interpretation of data: RG, ST; Drafting of manuscript: RG, ST, MT; Revision, review- RG, ST, MT, SL; Final approval of the version to be published and accountable for all aspects of the work: RG, ST, MT, SL.

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### Conflict of Interest

None

### Funding

None

### Supplementary material

The data and supplementary material that support the findings of this study are available from the corresponding author upon reasonable request.

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