Section: Radiodiagnosis

Original Research Article

LOW-DOSE COMPUTED TOMOGRAPHY VS. STANDARD-DOSE CT IN EVALUATING UROLITHIASIS: A COMPARATIVE STUDY ON DIAGNOSTIC ACCURACY AND RADIATION REDUCTION

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Abstract

Background: Urolithiasis, characterized by the formation of calculi in the kidneys and urinary tract, is a prevalent condition requiring accurate diagnostic imaging. While standard-dose computed tomography (SDCT) is highly sensitive and specific, its associated radiation exposure is a concern. Low-dose CT (LDCT) offers reduced radiation, but its diagnostic efficacy compared to SDCT remains underexplored. The aim is to evaluate the efficacy of LDCT in comparison with SDCT for detecting urolithiasis, with a focus on diagnostic accuracy and radiation dose reduction. **Materials and Methods:** A crossover study was conducted on 74 patients with clinically suspected or sonologically evident urolithiasis referred for NCCT KUB at a tertiary care hospital. Both SDCT and LDCT (70 mAs) scans were performed sequentially. Stone size, location, and associated findings were recorded and analyzed. Sensitivity, specificity, and diagnostic accuracy were calculated using SDCT as the reference standard. Radiation dose reduction was assessed using dose-length product and effective dose values. **Result:** The mean age of participants was 48.92 ± 15.63 years, with a male-to-female ratio of 38:36. SDCT demonstrated high sensitivity and specificity for all calculus sizes, with values of 94.88% and 100%, respectively. LDCT showed moderate to high sensitivity (76.78%) and specificity (83.33%). While LDCT effectively detected calculi ≥ 3 mm, its performance was suboptimal for calculi <3 mm. Radiation dose for LDCT was significantly reduced compared to SDCT, without compromising diagnostic accuracy for larger calculi. **Conclusion:** LDCT is a reliable diagnostic modality for detecting urolithiasis, particularly for calculi ≥ 3 mm, offering significant radiation dose reduction compared to SDCT. However, its limitations in detecting smaller calculi necessitate cautious application in clinical practice.

INTRODUCTION

Urolithiasis is a common urological condition characterized by the formation of calculi in the kidneys, ureters, bladder, or urethra. It affects both genders, with a higher prevalence in men, exhibiting a male-to-female ratio of 2:1. Approximately 12% of men and 6% of women are affected globally. In India, the rising incidence of urolithiasis is attributed to dietary changes, climate, and lifestyle factors (den Harder et al; Euler et al).[1,2]

Radiological imaging is crucial for diagnosing urolithiasis, as conventional radiography and ultrasonography (USG) often yield low diagnostic accuracy. USG, while cost-effective and non-invasive, is limited by factors such as obscuration by bowel loops and bone, as well as lower sensitivity and specificity, especially for small calculi (<5 mm). Moreover, it provides limited information on stone density and composition, which are critical for determining treatment options (Weisenthal et al; McLaughlin et al).[3,4]

Computed Tomography (CT) has become the gold standard for evaluating urolithiasis, offering a sensitivity of 94–100% and specificity of 97% (Brisbane et al).[5] Standard-dose CT (SDCT), however, exposes patients to significant radiation levels, ranging from 8 to 16 mSv per scan. Repeated imaging for diagnosis and follow-up increases cumulative radiation exposure, raising concerns about long-term health risks (Moore et al).[6]

Low-dose CT (LDCT) has emerged as a promising alternative, achieving substantial radiation dose reductions while maintaining high diagnostic accuracy. Studies have demonstrated that LDCT is comparable to SDCT in detecting stone size, location, and density. However, evidence comparing the two modalities systematically in the same patient population remains limited (Rodger et al).[7]

This study aims to evaluate the diagnostic accuracy of LDCT compared to SDCT in patients with clinically suspected urolithiasis. By addressing the trade-off between radiation dose and diagnostic performance, the study seeks to establish LDCT as a safer yet effective imaging modality in clinical practice.

MATERIALS AND METHODS

Study Design and Setting: This study was a crossover design conducted in the Department of Radiology at Mahatma Gandhi Medical College and Research Institute, Puducherry, India, between January 2020 and October 2021. The study included patients with clinically suspected or sonologically evident urolithiasis who were referred for non-contrast CT (NCCT) imaging of the kidneys, ureters, and bladder (KUB).

Study Population: A total of 74 patients were recruited based on the prevalence of urolithiasis (9%), ensuring adequate statistical power to validate the study findings.

Inclusion Criteria:

- Patients aged 18 years and above.
- Body Mass Index (BMI) less than 30 kg/m².
- Clinical suspicion or sonological evidence of urolithiasis.

Exclusion Criteria:

- Patients with a history of surgical intervention for urolithiasis.
- Pregnant individuals due to potential risks associated with ionizing radiation.
- Presence of metallic implants or contraindications for CT imaging.

Imaging Protocol

All CT imaging was performed using a 128-slice CT scanner (Wipro GE Optima 660). Each patient underwent two sequential scans.

Standard-Dose CT (SDCT):

Tube voltage: 120 kVp.

Automated tube current modulation to optimize dose.

Scan range: ~35 cm, extending from the T10 lower border to the pubic symphysis.

Low-Dose CT (LDCT):

Tube voltage: Fixed at 120 kVp.

Reduced tube current: 70 mAs.

Scan range: ~50 cm, extending cranio-caudally from the carina to the pubic symphysis.

Multiplanar 2D and 3D reformatted images were generated for both scans. Findings, including the number, size (<3 mm, 3–5 mm, >5 mm), and location of stones, were recorded for analysis.

Outcome Measures

Primary Outcomes:

Detection of renal or ureteric calculi, including their presence, number, size, and location.

Secondary Outcomes:

Identification of indirect signs of renal colic, such as renal enlargement, pyeloureteral dilatation, and periureteral or renal stranding.

Radiation Dose Measurement

Radiation dose parameters, including Volume CT Dose Index (CTDIvol) and Dose-Length Product (DLP), were recorded for both scans. The effective dose was calculated using the formula:

Effective Dose (mSv)=DLP×0.0155

where 0.0155 is the conversion factor for the abdominal region.

Blinding and Image Interpretation

All CT images were independently evaluated by an experienced radiologist who was blinded to the technical parameters of the imaging protocol. Diagnostic usefulness was assessed using a 4-point grading scale:

0 = Not seen.

1 = Inconclusive, not adequate for diagnosis.

2 = Adequate, sufficient for diagnosis.

3 = Comparable to SDCT in diagnostic quality.

Statistical Analysis

Data were systematically recorded in Microsoft Excel and analyzed using MedCalc (version 19.0). Continuous variables were expressed as mean ± standard deviation (SD), and categorical variables were presented as percentages. Diagnostic accuracy, including sensitivity, specificity, and area under the curve (AUC), was evaluated using Receiver Operating Characteristic (ROC) analysis. Statistical significance was determined at $P<0.05$.

RESULTS

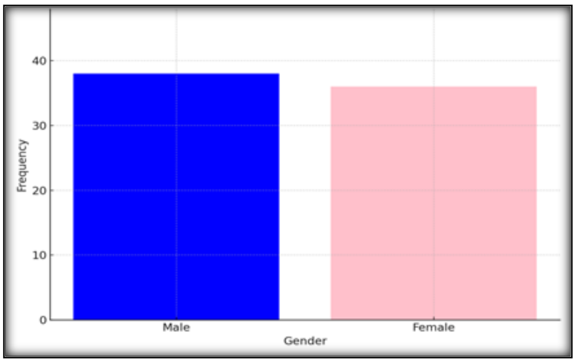

Figure 1: Gender Distribution in Study Population

A total of 74 patients with a mean age of 48.92 ± 15.63 years (95% CI: 45.30 to 52.54) participated in the study. Among these, 51.35% were females, and 48.65% were males, with a gender ratio of 38:36 [Table 1].

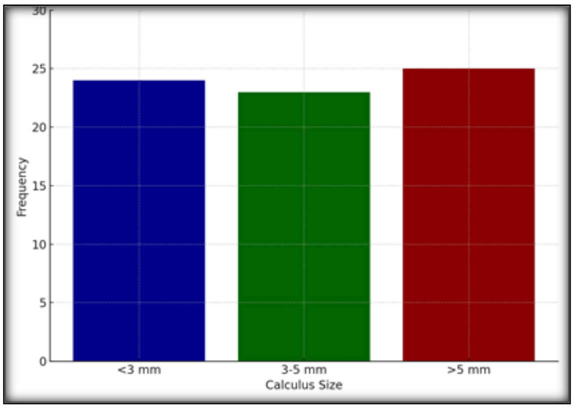

Figure 2: Profile of Calculus Size

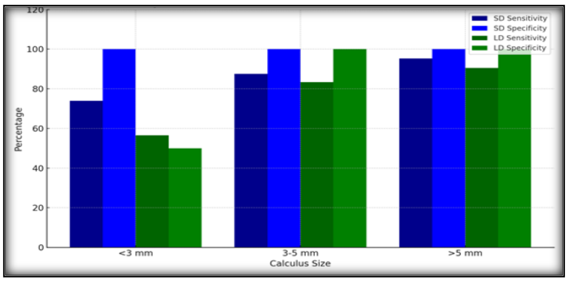

Figure 3: Comparison of Low-dose CT and Standard Dose CT in Detection

The sizes of calculi were classified into three categories: <3 mm, 3–5 mm, and >5 mm. Among the study participants, 32.43% of calculi were <3 mm, 31.08% were 3–5 mm, and 33.78% were >5 mm in size [Table 2].

The diagnostic accuracy of low-dose CT (LDCT) and standard-dose CT (SDCT) was compared. For calculi <3 mm, the sensitivity of SDCT was 73.91% with a specificity of 100%, whereas LDCT demonstrated a lower sensitivity of 56.52% and a specificity of 50% (P=0.8985). For calculi measuring 3–5 mm, both SDCT and LDCT showed high sensitivity and specificity, with values of 87.50% and 83.33%, respectively, and a specificity of 100% for both modalities (P<0.0001). Similarly, for calculi >5 mm, the sensitivity and specificity were high for both SDCT and LDCT, with sensitivities of 95.24% and 90.48% and a specificity of 100% (P<0.0001) [Table 3].

Overall, the diagnostic performance of SDCT showed high sensitivity (94.88%) and specificity (100%) across all calculus sizes, confirming its high diagnostic accuracy. LDCT, while exhibiting moderate to high accuracy with a sensitivity of 76.78% and specificity of 83.33%, proved effective, particularly for larger calculi [Table 4].

The results indicate that LDCT can be a reliable diagnostic tool for detecting urolithiasis while significantly reducing radiation exposure, although it may be less effective in detecting small calculi (<3 mm).

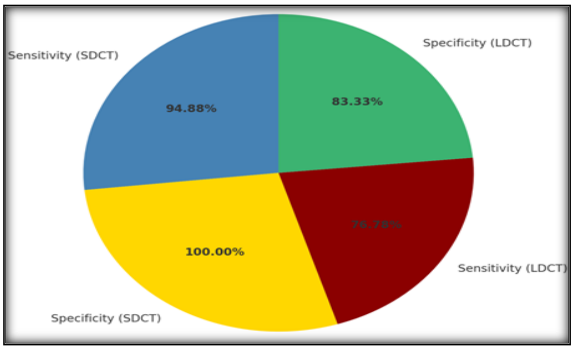

Figure 4: Summary of Diagnostic Accuracy

Table 1: Baseline Characteristics.

Variables	Frequency	95% CI / %
Age in years	48.92 ± 15.63 years	45.30 to 52.54
Gender (M:F)	38:36	48.65:51.35

Table 2: Profile of Calculus Size

Calculus Size	Frequency	%
<3 mm	24	32.43
3-5 mm	23	31.08
>5 mm	25	33.78

Table 3: Comparison of Low-dose CT and Standard Dose CT in Detection

Calculus Size	Diagnostic Accuracy	Area Under Curve	95% CI	Sensitivity	Specificity	P Value
<3 mm	SD	0.870	0.675 to 0.970	73.91	100	<0.0001
<3 mm	LD	0.533	0.324 to 0.733	56.52	50	0.8985
3-5 mm	SD	0.938	0.769 to 0.995	87.50	100	<0.0001
3-5 mm	LD	0.917	0.740 to 0.988	83.33	100	<0.0001
>5 mm	SD	0.976	0.811 to 1.000	95.24	100	<0.0001
>5 mm	LD	0.952	0.774 to 0.998	90.48	100	<0.0001

Table 4: Summary of Diagnostic Accuracy

CT Modality	Sensitivity (%)	Specificity (%)	Overall Diagnostic Accuracy (%)
Standard Dose CT	94.88	100	High
Low Dose CT	76.78	83.33	Moderate to High

DISCUSSION

Urolithiasis remains a significant clinical burden, necessitating accurate and reliable imaging modalities for diagnosis and management. Computed Tomography (CT) has been established as the gold standard for detecting renal and ureteral calculi due to its superior sensitivity and specificity compared to other imaging techniques (Aggarwal et al; Roberts et al).[8,9] However, the increasing reliance on CT imaging has raised concerns about cumulative radiation exposure, particularly in patients requiring repeated imaging for follow-up and management (Roberts et al).[9] This study compared low-dose CT (LDCT) with standard-dose CT (SDCT) in detecting urolithiasis, focusing on diagnostic accuracy and radiation dose reduction.

Diagnostic Performance of LDCT

Our study revealed that LDCT performs comparably to SDCT for detecting calculi ≥3 mm. For calculi in the 3–5 mm and >5 mm size categories, LDCT demonstrated sensitivities of 83.33% and 90.48%, respectively, with a specificity of 100% for both. These findings align with Moore et al,[11] who reported high sensitivity and specificity for LDCT in detecting clinically significant calculi. Similarly, Rob et al,[10] systematically reviewed the performance of LDCT and reported no significant compromise in accuracy for stones >3 mm.

However, the sensitivity of LDCT for detecting smaller calculi (<3 mm) was lower (56.52%), which is consistent with observations by Roberts et al,[9] and Rob et al.[10] Small calculi are often managed conservatively, but missing these stones could have clinical implications in cases of recurrent symptoms or obstruction. Zhang et al,[12] also highlighted similar challenges in smaller stone detection using LDCT, emphasizing the importance of cautious interpretation in such cases.

Radiation Dose Reduction

A significant advantage of LDCT is its substantial reduction in radiation exposure. In this study, the effective dose for LDCT was considerably lower than that for SDCT, which is consistent with the findings of Sohn et al,[14] who demonstrated a 73% reduction in radiation dose using LDCT protocols without compromising diagnostic accuracy. Similarly, Xiang et al,[14] confirmed substantial radiation reduction with LDCT, which is particularly critical given the growing awareness of the long-term risks of ionizing radiation, including cancer.

The dose-length product (DLP) values for LDCT in our study are aligned with previous findings by Andrabi et al,[13] where reduced radiation exposure was highlighted as a major advantage of LDCT. This makes LDCT particularly beneficial for younger patients and those with chronic or recurrent urolithiasis, minimizing cumulative radiation exposure over time.

Clinical Implications: LDCT's ability to detect larger stones accurately, coupled with its reduced radiation dose, makes it an ideal imaging modality for most cases of suspected urolithiasis (Aggarwal et al; Roberts et al).[8,9] The significant reduction in radiation exposure does not compromise its utility in diagnosing clinically significant calculi or detecting indirect signs of renal colic, such as renal enlargement, pyeloureteral dilatation, and periureteral or renal stranding (Roberts et al; Andrabi et al).[9,13]

However, the lower sensitivity of LDCT for detecting smaller calculi highlights a limitation. In cases where smaller stones may have clinical significance, SDCT or alternative imaging techniques may be preferred. Zhang et al,[12] and Xiang et al,[14] emphasized the potential role of advanced imaging methods, such as dual-energy CT, in addressing this limitation. Dual-energy CT provides detailed information on stone composition and size while maintaining low radiation doses, making it a promising alternative in clinical scenarios requiring high diagnostic precision.

CONCLUSION

This study demonstrated that low-dose CT (LDCT) is a reliable diagnostic modality for detecting urolithiasis, particularly for calculi ≥3 mm, with diagnostic accuracy comparable to standard-dose CT (SDCT). LDCT showed high sensitivity and specificity for clinically significant stones while achieving a significant reduction in radiation exposure, making it a safer alternative for routine use and follow-up imaging. However, its lower sensitivity for detecting stones <3 mm underscores the need for cautious application in cases where smaller calculi may have clinical relevance. Overall, LDCT balances diagnostic performance with patient safety, supporting its use as a preferred imaging technique in the management of urolithiasis.

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