International Journal of Medical and Pharmaceutical Research

Online ISSN-2958-3683 | Print ISSN-2958-3675
Frequency: Bi-Monthly
Available online on: https://ijmpr.in/

Original Article

Comparative Prospective Study of Low-Dose and Standard-Dose Unenhanced Helical Computed Tomography in Diagnosis of Urolithiasis

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OPEN ACCESS

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Received: 20-04-2026
Accepted: 11-05-2026
Available online: 22-05-2026

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ABSTRACT

Background: Urolithiasis comprises a significant disease burden on the health care system, with its lifetime prevalence increasing over recent decades. Non-contrast computed tomography is the preferred imaging modality for diagnosing urinary tract calculi. Given the recurrent nature of the disease and cumulative radiation exposure from repeated imaging, this study compared the efficacy of low-dose and standard-dose computed tomography (CT) for the diagnosis of urinary tract calculi.

Methodology: This was a single center, prospective, comparative, observational study was conducted among 100 patients (> 18 years of age) of suspected renal or ureteric colic, over a period of one year. All participants underwent both low-dose computed tomography (25 mAs) and standard-dose computed tomography (130 mAs). Standard-dose images were interpreted by one reviewer, while low-dose images were independently reviewed by two blinded reviewers. Diagnostic findings were compared using the exact McNemar test, and inter-observer agreement was assessed using kappa statistics.

Results: Standard-dose computed tomography had sensitivity, specificity, and accuracy of 97.75%, 90.91%, and 97%, respectively. For low-dose computed tomography, sensitivity was 93.26% and 95.51%, specificity was 81.82%, and accuracy was 92% and 94% for the two reviewers. No significant difference was observed between the two techniques in diagnosing ureteric calculi. Low-dose computed tomography reduced radiation exposure by approximately 80.81% compared with standard-dose computed tomography.

Conclusion: Low-dose computed tomography is comparable to standard-dose computed tomography for diagnosing urinary tract calculi while substantially reducing radiation exposure.

Keywords*: computed tomography, low-dose CT, urolithiasis, ureteral calculi, diagnostic imaging.*

INTRODUCTION

Urolithiasis comprises a significant disease burden on the health care system. According to the 2012 National Health and Nutrition Examination Survey, renal calculi affect 10.6% of men and 7.1% of women in the United States, which is 70% increase in prevalence over approximately two decade (Scales et al., 2012). Although historically urinary calculi has been the disease of men, but presently the incidence rate ratio of men to women has declined from 3.4 to 1.3 (Strope et al., 2010). Urinary calculi are frequently recurrent, with recurrence rates of 30%-40% within five years, and worse clinical outcomes in the future and thus, imposing considerable economic burden (Zisman, 2017).\

Non-contrast computed tomography (NCCT) has become the imaging modality of choice for evaluating patients with suspected urolithiasis, superseding conventional radiography, ultrasonography, and excretory urography (Renard-Penna et al., 2015). NCCT detects calculi as small as one mm, provides information on stone location and composition, requires no intravenous contrast, and identifies alternative pathology (Curhan, 2014). However, the use of CT has increased in the emergency department, rising from 19.6% to 45.5% over a decade has significantly increased ionizing radiation exposure to the population (Curhan, 2014; Hyams et al., 2011). This has resulted in radiation exposure which has increased drastically from 15% of all radiation in the early 1980s to 48% by 2006, and much of this is associated to CT scans («NCRP Report No. 160, Ionizing Radiation Exposure of the Population of the United States, Medical Exposure—Are We Doing Less with More, and Is There a Role for Health Physicists?», u.å.).

Although radiation exposure of a single CT is relatively low, risk of radiation-induced hazards increases as a result of accumulated doses from repeated studies for recurrent stone-formers (Elkoushy & Andonian, 2017). Hence, the International Commission on Radiological Protection (ICRP) has allocated thresholds for safe exposure of 50 mSv for a single year or 20 mSv per year for a period of 5 years («1990 Recommendations of the International Commission on Radiological Protection», 1991). However, 17–20% of patients with urinary calculi received more than 50 mSv during their first year of follow-up. Radiation exposure related risks include induction of malignancies, including solid cancer and leukaemia, and some degenerative diseases such as cataracts. Animal studies have reported the induction of DNA mutations in germ cells, where they may cause adverse health effects in their offsprings (Elkoushy & Andonian, 2017).

Recently, several studies have reported the attempts to reduce the radiation dose (Drake et al., 2014; Tack et al., 2003). It has been reported that low-dose CT (LDCT) considerably decreases the exposure to radiation compared with that of standard-dose CT (SDCT) (Kim et al., 2005). As the patients are often relatively young and are at significant lifetime risk for recurrent episodes of renal colic, clinicians need to be attentive to the radiation dose given to these patients. There are studies available in western world that compare the SDCT and LDCT for the assessment of patients with urolithiasis (Huang et al., 2014; Kim et al., 2005; Poletti et al., 2007). However, there are no studies that compare the standard-dose and low-dose CT with reference to adult Indian population. Therefore, this study was planned to compare the efficacy of low-dose and standard-dose computed tomography (CT) for the diagnosis of urinary tract calculi.

METHODS:

Study Design and Setting: This was a single-center, prospective, comparative, observational study conducted on patients of suspected renal or ureteric colic presenting in emergency and out-patient department (OPD) in the Department of Urology, BGS Global Institute of Medical Sciences, Bangalore, India, from June 2025 to May 2026. The study was approved by the Institutional Ethics Committee (IEC), and written informed consent was obtained from all participants prior to enrollment.

Study Participants: Adult patients (>18 years) presenting to the emergency department or urology outpatient department (OPD) with suspected renal or ureteric colic were screened. Inclusion criteria: suspected renal or ureteric colic, age >18 years, ability to provide informed consent. Exclusion criteria: abdominal pain due to trauma, BMI >30 kg/m², pregnancy.

Sample Size: A total of one-hundred twelve consecutive patients presenting with the symptoms of urinary calculi and admitted in the Department of Urology were screened for eligibility and finally, 100 patients meeting the inclusion criteria were included in the study.

Study Procedure: Patients meeting the inclusion criteria were briefed about the study, given a patient information sheet, and written informed consent was obtained. All 100 patients underwent low-dose CT in addition to standard-dose CT and were informed about the additional radiation exposure. Baseline parameters including age, gender, weight, height, occupation, address, and registration number were recorded in a case record form. Body mass index (BMI) was calculated and categorized as underweight (<18.5), normal (18.5-24.9), overweight (25-29.9), or obese (≥30) (Garrow & Webster, 1985). A complete physical examination was carried out.

CT Imaging Parameters: Standard-dose CT and low-dose CT were performed from the lung bases to the pelvis using a Somatom 128 slices 4 scanner (Siemens, Erlangen, Germany). The following examination parameters were used for standard-dose CT: unenhanced; 130 mAs, 130 kV, collimation of 5 mm, reconstruction interval of 5 mm; and pitch of 0.8. Exposure was reduced by decreasing the tube current to 25 mAs for low-dose CT while keeping the other parameters constant. Each examination was obtained in two or three breath-holds with a scan time of 40–50s. The average scanned length, for both standard-dose and low-dose CT, was 40 ± 5 cm for men and 35 ± 5 cm for women.

CT Imaging and Interpretation: SDCT images were analyzed by an abdominal radiologist with 18 years of experience, blinded to LDCT findings. LDCT images were independently reviewed by two radiologists with 13 and 10 years of experience, blinded to SDCT results. CT scans were prospectively analyzed for the presence, location, and maximal in-plane diameter of renal and ureteric calculi, along with abnormalities unrelated to urolithiasis. Secondary signs including hydronephrosis, perinephric stranding, and tissue rim sign were independently evaluated in both protocols. LDCT images were analyzed in random order using the same workstation and visualization software (Cedara I-softview, version 6.1, Cedara software). Ureteral segments were defined as proximal (pelvic-ureteric junction to lowermost kidney), mid (lowermost kidney to sacral promontory), distal (sacral promontory to ureterovesical junction), and ureterovesical junction separately.

Effective Dose Calculation:

Low-Dose CT: Effective radiation doses were calculated using the normalized weighted CT dose index (nCTDIw) of 0.070 mGy/mAs at 130 kV, as specified by the manufacturer. Radiation exposure was then calculated as follows:

DLP (mGy·cm) = CTDIvol × L.

Where, DLP is the dose–length product, $CTDI_{vol}$ is the volume CT dose index (*IEC 60601-2-44*, u.å.), and L is the scan length.

Effective dose (E) was derived as: E = DLPair × f (Huda & Bissessur, 1990), where f is the tissue-specific conversion factor (0.0110 for women; 0.0072 for men)

Standard-Dose CT: Using 130 mAs instead of 25 mAs, the same calculation as used for low-dose CT was performed to determine the effective dose delivered by standard-dose CT.

Statistical Analysis: Statistical analysis was performed using IBM SPSS Statistics version 23.0. Sensitivity, specificity, and accuracy were calculated for each protocol. The McNemar test compared diagnostic performance between SDCT and LDCT. Interobserver agreement was evaluated using Cohen's kappa, interpreted as: very good ($\kappa > 0.80$), good ($\kappa = 0.61$-0.80), moderate ($\kappa = 0.41$-0.60), fair ($\kappa = 0.21$-0.40), or poor ($\kappa \leq 0.20$). A two-tailed p-value <0.05 was considered statistically significant.

RESULTS:

Of 112 patients screened, 100 met inclusion criteria and underwent both SDCT and LDCT. Eighty-nine were confirmed to have urinary calculi, 11 had alternative diagnoses (appendicitis n=5, diverticulitis n=4, pancreatitis n=1, cholecystitis n=1), all confirmed on CT. SDCT did not detect more alternative diagnoses than LDCT. The study population was predominantly male (56.18%, M:F ratio 1.28:1). Study population had age in the range of 19 – 79 years. Mean age in males and females was 46.10 ± 13.54 and 45.56 ± 14.84 years, respectively. BMI was normal in 76.40%, with BMI in the range of 17.79 – 29.72 Kg/m^2 (Table 1).

Table 1: Diagnosis and Demographic Profile (n=100/89)

Characteristic	Category	n / Mean ± SD
Diagnosis (n=100)	Urinary calculi	89
	Appendicitis	5
	Diverticulitis	4
	Pancreatitis / Cholecystitis	1 / 1
Gender (n=89)	Male	50 (56.18%)
	Female	39 (43.82%)
Age (years) mean ± SD		45.86 ± 14.04
Height (m) mean ± SD		1.68 ± 0.07
Weight (kg) mean ± SD		67.97 ± 9.99
BMI (kg/m²) mean ± SD		23.81 ± 2.77

Most patients had acute (75.28%), colicky (65.17%), radiating pain (65.17%), predominantly in the back (55.06%). Nausea/vomiting was the commonest associated symptom (56.18%) (Table 2).

Table 2: Clinical Features (n=89)

Feature	Category	n (%)
Pain onset	Acute	67 (75.28%)
	Chronic	22 (24.72%)
Pain character	Colicky	58 (65.17%)
	Non-colicky	31 (34.83%)
Radiation	Yes	58 (65.17%)
	No	31 (34.83%)
Pain location (predominant)	Back	49 (55.06%)
Nausea / Vomiting		50 (56.18%)
History of Haematuria		32 (35.96%)
History of Urolithiasis		26 (29.21%)
Fever		16 (17.98%)

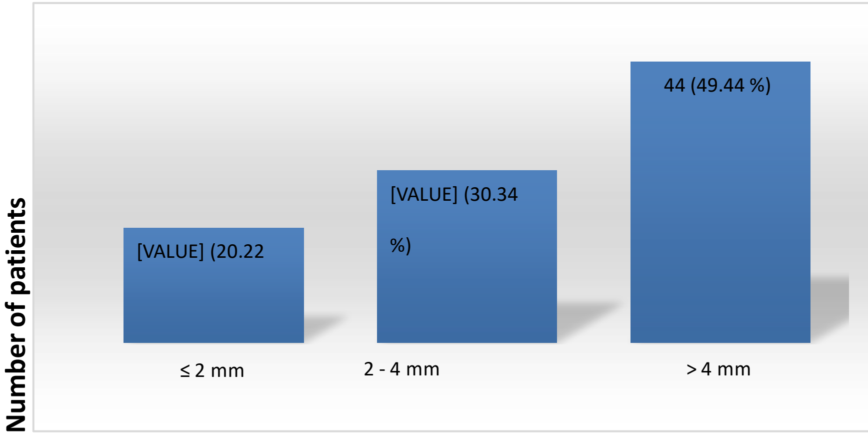

Figure 1: Distribution of urinary calculi (according to size) in the study population (n = 89)

Majority (i.e., 79.77 %) of the study population had urinary calculi of the size > 2 mm. While, only 18 patients had urinary calculi ≤ 2 mm. Mean size and range of calculi size was 5.23 ± 3.69 mm and 1 – 12 mm, respectively. (Figure 1)

Table 3: Diagnostic performance of SDCT and LDCT in detection of urinary calculi and influence of calculi size (n = 89)

Parameter	**SDCT**	**LDCT -Reviewer 1**	**LDCT -Reviewer 2**
True positive	87	83	85
True negative	10	9	9
False positive	1	2	2
False negative	2	6	4
Sensitivity (%)	97.75	93.26	95.51
Specificity (%)	90.91	81.82	81.82
Accuracy (%)	97.00	92.00	94.00
Sensitivity for calculi ≤ 2 mm (%)	94.44 (17/18)	72.22 (13/18)	83.33 (15/18)
Sensitivity for calculi > 2–4 mm (%)	100 (27/27)	100 (27/27)	96.29 (26/27)
Sensitivity for calculi > 4 mm (%)	100 (44/44)	97.73 (43/44)	100 (44/44)

SDCT sensitivity, specificity, and accuracy were 97.75%, 90.91%, and 97.00%, respectively (one false-positive, two false-negatives). LDCT sensitivity was 93.26% (Reviewer 1) and 95.51% (Reviewer 2); specificity was 81.82% for both; accuracy was 92% and 94%, respectively. No statistically significant difference was found between SDCT and LDCT in sensitivity (p=0.1336 and p=0.4795) or specificity (p=1.000). For stones >2 mm, SDCT sensitivity was 100%, LDCT achieved 98.59% (both reviewers). For stones ≤2 mm, SDCT sensitivity was 94.44% versus 72.22% and 83.33% for LDCT Reviewers 1 and 2, respectively (p-value = 0.1336 for reviewer 1; p-value = 0.4795 for reviewer 2). (Table 3)

Majority of the calculi were located in the ureter (52.81%), followed by the kidney (34.83%), and on the left side (52.81%). In the ureter, middle (38.29%) and distal (34.04%) locations predominated. SDCT achieved 100% sensitivity across all locations. The sensitivity of LDCT for detection of kidney, ureteral, and uretero-vesical junction calculi was 96.77%, 95.74%, and 50% for reviewer 1, and 100%, 95.74%, and 100% for reviewer 2, respectively. Sensitivity for detecting both kidney and ureter calculi was 87.5% and 100%, respectively, for both reviewers, while that for both ureter and uretero-vesical junction calculi was 100% for both reviewers. No significant difference was found between SDCT and LDCT sensitivities for reviewer 1 in detecting calculi in kidney, ureter, uretero-vesical junction, and both kidney and ureter (all p > 0.05). Similarly, no significant difference was observed for reviewer 2 in detecting ureteric calculi (p > 0.05). Interobserver agreement between the two LDCT reviewers was very good for kidney, ureter, both kidney and ureter, and both ureter and uretero-vesical junction calculi (kappa = 0.91, 0.91, 0.92, and 1, respectively), and good for uretero-vesical junction calculi (kappa = 0.71).

The sensitivity of SDCT for detection of calculi in any part of ureter was 100%. The sensitivity of LDCT for proximal, middle, and distal ureteric calculi was 92.31%, 94.44%, and 100% for reviewer 1, and 100%, 100%, and 87.50% for reviewer 2, respectively. No significant difference was observed between SDCT and LDCT in detecting calculi in different parts of ureter (all p > 0.05).

LDCT was comparable to SDCT in visualizing hydronephrosis and tissue rim sign; however, perinephric stranding was less clear on LDCT. Interobserver agreement between the two LDCT reviewers was very good for hydronephrosis and perinephric stranding (kappa = 0.92 and 0.93, respectively) and good for tissue rim sign (kappa = 0.73).

Table 4: Diagnostic performance of SDCT and LDCT according to calculi location and secondary signs in urinary calculi patients (n = 89)

Parameter	SDCT	LDCT -Reviewer 1	LDCT - Reviewer 2
Sensitivity according to urinary tract location (%)			
Kidney (n = 31)	100 (31/31)	96.77 (30/31)	100 (31/31)
Ureter (n = 47)	100 (47/47)	95.74 (45/47)	95.74 (45/47)
Uretero-vesical junction (n = 2)	100 (2/2)	50 (1/2)	100 (2/2)
Both kidney and ureter (n = 8)	100 (8/8)	87.5 (7/8)	100 (8/8)
Both ureter and uretero-vesical junction (n = 1)	100 (1/1)	100 (1/1)	100 (1/1)
Sensitivity according to ureteric location (%)			
Proximal ureter (n = 13)	100 (13/13)	92.31 (12/13)	100 (13/13)
Middle ureter (n = 18)	100 (18/18)	94.44 (17/18)	100 (18/18)
Distal ureter (n = 16)	100 (16/16)	100 (16/16)	87.50 (14/16)
Visibility of secondary signs (%)			
Hydronephrosis	93.25 (83/89)	91.01 (81/89)	93.25 (83/89)
Perinephric stranding	73.03 (65/89)	47.19 (42/89)	50.56 (45/89)
Tissue rim sign*	93.02 (80/86)	90.69 (78/86)	93.02 (80/86)

*Tissue rim sign assessed in 86 patients

Effective Radiation Dose

Average scan length between the upper pole of kidneys and lower bladder was considered as 40 cm for men and 35 cm for women. For LDCT, radiation dose was estimated using a normalized weighted CT dose index (nCTDIw) of 0.070 mGy/mAs at 130 kV. Dose-length product (DLP) was calculated as: DLP (mGy · cm) = CTDIvol × L

For women, the effective dose was:

$E_{women} = 160.125 \times 0.0110 = 1.76$ mSv

For men:

$E_{men} = 205.875 \times 0.0072 = 1.48$ mSv.

Using the same method with 130 mAs for SDCT, the effective dose was 9.15 mSv for women and 7.71 mSv for men. LDCT reduced radiation dose by 80.81% compared with SDCT.

DISCUSSION

In the present study, majority of the study participants were males (56.18 %) and male to female ratio was 1.28:1. This observation is in accordance with previous studies which reported increased prevalence of urinary calculi in male gender (Safarinejad, 2007; Sharma et al., 2018; Tanthanuch et al., 2005; Zeng & He, 2013). Mean age in this study was 45.86 ± 14.04 years, with the majority in the 35-65 year age group, which is in line with findings reported in earlier studies (Abomelha et al., 1990; Kolhe & Bhamre, 2017; Sreenevasan, 1990). The predisposition of middle-aged individuals reflects greater physical exertion, dehydration, irregular diet, and occupational stress (Iguchi et al., 1996; Kale et al., 2014). In present study, mean BMI was 23.81 ± 2.77 kg/m² with 76.40% having normal BMI. Similarly, a study (Sharma et al., 2018) reported mean BMI of 25.07 Kg/m^2. And another study (Poletti et al., 2007) reported normal BMI in majority of the patients (i.e., 54 %). Obesity and weight gain increase the risk of urolithiasis. In particular, a BMI of 30 or greater was associated with a greater risk of urolithiasis (Trinchieri, 2008).

All patients presented with pain with 75.28% had acute, 65.17% colicky, and 65.17% radiating pain, predominantly in the back (55.06%). A study (Kaur et al., 2014) reported radiating pain in 87.5% and flank pain in 60% of patients. Nausea/vomiting was the most frequent associated symptom (56.18%), followed by haematuria (35.96%), history of urolithiasis (29.21%), and fever (17.98%). Several studies (Kaur et al., 2014; Kolhe & Bhamre, 2017) reported similar findings. Most calculi (79.77%) were >2 mm; mean size was 5.23 ± 3.69 mm (range 1–12 mm). A study (Weinrich et al., 2018) reported mean size 4.2 ± 2.2 mm, another study (Kim et al., 2005) found 81.37% of calculi >2 mm.

Calculi were predominantly ureteral (52.81%), followed by renal (34.83%), and left-sided (52.81%); in the ureter, middle (38.29%) and distal (34.04%) segments predominated. A study (Kolhe & Bhamre, 2017) similarly found the ureter most affected (41.08%), while a study (Weinrich et al., 2018) reported left-sided predominance (51.97%) with majority in the distal ureter (64.92%). Predominance of ureteral calculi, particularly in the middle ureter, was also noted in earlier studies (Kim et al., 2005), whereas another study reported calculi to be more commonly located in the kidney followed by the ureter (Poletti et al., 2007).

The present study reports that LDCT (25 mAs) attains sensitivity of 93.26 % - 95.51 %, a specificity of 81.82 %, and accuracy of 92 % - 94 %. These values are slightly lower than that observed with SDCT (130 mAs) but not statistically significant. Comparable findings have been reported previously, with LDCT sensitivity ranging from 89.5%-94.7% and accuracy from 93.4%-98.1% (Tack et al., 2003), while another study reported sensitivity of 94.1%, specificity of 100%, and accuracy of 95.1% using LDCT at 40 mAs (Weinrich et al., 2018).

This study found that for calculi >2 mm, LDCT sensitivity was 98.59% (both reviewers), comparable to SDCT (100%). For calculi ≤2 mm, SDCT sensitivity was 94.44% versus 72.22% and 83.33% for LDCT Reviewers 1 and 2 ($p=0.1336$ and 0.4795, respectively). These smaller, clinically less significant stones have a higher likelihood of spontaneous passage. Similar findings have been reported previously, with LDCT sensitivity of 68%-79% for stones ≤2 mm and 100% for stones >2 mm (Kim et al., 2005). Another study reported sensitivities of 83%, 97%, and 100% for stones measuring <3 mm, 3-4.9 mm, and >5 mm, respectively (Poletti et al., 2007).

LDCT sensitivity for kidney, ureteral, and uretero-vesical junction calculi was 96.77%, 95.74%, and 50% (Reviewer 1) and 100%, 95.74%, 100% (Reviewer 2). Comparable sensitivities for LDCT have been reported in previous studies. LDCT sensitivity of 95% at 70 mAs has been reported previously (Sharma et al., 2018). Similarly, sensitivity of 88-93% at the ureterovesical junction with LDCT at 50 mAs was reported earlier (Kim et al., 2005), while another study reported 93% sensitivity for ureteral calculi (Poletti et al., 2007). Sensitivity of 93.8% for ureteral calculi has also been documented previously (Tack et al., 2003). Therefore, the sensitivity of LDCT for localization of calculi in the present study is in agreement with earlier literature.

For ureteral segments, LDCT sensitivity ranged 92.31 to 100% (proximal), 94.44 to 100% (middle), and 87.50–100% (distal), with no significant difference from SDCT (all $p>0.05$).

Similar observations have been reported previously for proximal, middle, and distal ureteric calculi (Kim et al., 2005). LDCT and SDCT were comparable for detecting hydronephrosis (91.01%-93.25%) and the tissue rim sign (90.69%-93.02%). However, perinephric stranding was less conspicuous on LDCT (47.19%-50.56%) than on SDCT (73.03%). Comparable findings regarding hydronephrosis, tissue rim sign, and perinephric stranding have also been documented previously (Kim et al., 2005; Poletti et al., 2007). Hydronephrosis has been shown to possess strong positive predictive value for obstruction (Fielding et al., 1997), and the present study similarly found no significant difference between LDCT and SDCT in its detection.

In the present study, CT performed with a reduced tube current of 25 mAs and a pitch of 0.8 resulted in 80.81% reduction in dose when compared with the dose of standard protocol using a current of 130 mAs and a pitch of 0.8. The mean effective dose with LDCT was 1.48 mSv (men) and 1.76 mSv (women), comparable to the dose associated with the acquisition of three-film excretory urography (1.5 mSv) and is lower than that of six-film excretory urography (2.5 mSv). Similar reductions in radiation dose have also been reported previously (Kim et al., 2005; Poletti et al., 2007). Therefore, the substantial radiation dose reduction achieved in the present study without compromising diagnostic sensitivity is consistent with earlier studies.

This study has several limitations. Fixed tube current (mAs) was used without automated tube current modulation, which may have introduced image noise variation by patient body habitus. Patients with BMI >30 kg/m² were excluded, limiting generalizability to the obese population. The small number of alternative diagnoses ($n = 11$) precluded a statistically meaningful comparison of protocol performance for non-stone pathology.

CONCLUSION

Low-dose unenhanced helical CT at 25 mAs is a clinically viable alternative to standard-dose CT (130 mAs) for evaluating suspected urolithiasis in patients with BMI <30 kg/m². LDCT achieves comparable sensitivity, specificity, and accuracy for clinically significant calculi >2 mm, with no statistically significant difference from SDCT, while reducing radiation exposure by approximately 81%. Although low-dose CT was limited in its ability to depict small-sized calculi ≤ 2 mm, it is still comparable to standard-dose CT for the diagnosis of both ureter stones and alternative disease. A low-dose CT protocol can be used as the first-line imaging tool in the workup of patients with suspected urolithiasis and a BMI < 30, providing that clinicians and patients are aware of the limitations and advantages of this technique with regard to standard-dose CT. Future prospective studies will be needed to address whether the diagnostic accuracy or alternative diagnosis varies depending on BMI in LDCT.

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