International Journal
of
Radiology and Diagnostic Imaging

E-ISSN: 2664-4444
P-ISSN: 2664-4436
www.radiologypaper.com
IJRDI 2025; 8(1): 32-38
Received: 21-12-2024
Accepted: 23-01-2025

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Low dose CT for evaluation of suspected urolithiasis

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DOI: https://doi.org/10.33545/26644436.2025.v8.i1a.433

Abstract
Background: The urolithiasis is a common public health problem in Iraq with high recurrence rate. The computerized tomography (CT) scan is highly valuable in diagnosis of urolithiasis. Aim of study: To evaluate the validity of low dose CT scan in alternative diagnosis for patients with urolithiasis.
Patients and methods: A cross sectional study carried out in the Computerized Tomography unit of Radiology department in Al-Shaheed Ghazi Teaching Hospital at Medical Complex in Baghdad city-Iraq through the period of one year from 1st of March, 2022 to 28th of February, 2023 on sample of 75 patients with urolithiasis. The selected patients were referred by Urologists to Computerized Tomography unit of Radiology department in Al-Shaheed Ghazi Teaching Hospital for suspicion of urolithiasis.
Results: No significant differences were observed between standard protocol and low CT-scan protocol regarding KVP, renal length, renal width, parenchymal thickness, number of stones, diameter of stones, findings and site of stones. Mean mAS of standard CT-scan protocol was significantly higher than mean mAS of low CT-scan protocol (p<0.001). Mean fat density of standard CT-scan protocol was significantly lower than mean fat density of low CT-scan protocol (p=0.03). There was a significant association between detection of inguinal hernia and use of low CT-scan protocol, while standard CT-scan protocol detected simple renal cyst and inguinal hernia (p=0.04).
Conclusions: Low dose computerized tomography scan protocol is effective and safe method in diagnosis of urolithiasis.

Keywords: Urolithiasis, computerized tomography, standard, low dose

Introduction

Urolithiasis is a prevalent condition affecting diverse populations worldwide, irrespective of race, culture, or geographic boundaries. In recent decades, its incidence has risen significantly in both developed and developing countries, largely attributed to lifestyle changes and increasing obesity rates [1, 2]. Notably, there has been a shift in the composition of urinary stones and an increased prevalence among females and younger patients in the last decade. Managing urolithiasis effectively is vital due to its potential complications, including infections, chronic kidney disease, and high recurrence rates [1, 3].

Imaging plays a crucial role in the diagnosis, treatment planning, and follow-up of urolithiasis. Unenhanced computed tomography (CT), introduced in the 1990s, has become the gold standard for evaluating kidney stones, offering superior sensitivity and specificity (>95% and >96%, respectively) compared to alternatives like plain radiography and ultrasound [4]. Multi-detector CT (MDCT) and advanced technologies, such as dual-energy CT (DECT), have further expanded the scope of CT imaging. MDCT allows detailed assessment of stone size, location, and composition, aiding in treatment planning and outcome prediction [5].

Unenhanced helical CT is highly sensitive (up to 98%) and specific (96-100%) for diagnosing urolithiasis, making it the imaging modality of choice [4]. Besides detecting urinary stones, CT also identifies extra-urinary pathologies, such as appendicitis or ovarian torsion, which may mimic renal colic. CT facilitates alternative diagnoses in approximately 10-14% of emergency cases [6]. MDCT enhances the evaluation of stone burden through three-dimensional reconstructions and volumetric analysis, critical for treatment planning. Furthermore, stone composition can be estimated using Hounsfield Units (HU), aiding in the choice of appropriate interventions [7].

CT stone protocols differ from routine abdominopelvic scans, with tailored acquisition parameters like thinner slices (1-3 mm) and optimized tube potentials (100-120 kVp). Iterative reconstruction techniques reduce radiation doses while maintaining image quality [8, 9]. Coronal and sagittal reformations are integral to the protocol, improving the detection of small stones and differentiation of calcifications [6, 10].

MDCT also aids in assessing stone fragility and composition. Stones with heterogeneous internal structures are more fragile and respond better to treatments like shock wave lithotripsy (SWL), whereas homogeneous stones are more resistant and often require multiple sessions [11]. DECT provides additional capabilities, distinguishing between uric acid and non-uric acid stones by analyzing their attenuation profiles at varying energy levels [12]. This technology improves diagnostic accuracy and aids in selecting effective treatment strategies for different stone types [13].

Concerns over CT radiation doses have led to the development of low-dose (LD) and ultra-low-dose (ULD) protocols, which significantly reduce exposure while maintaining diagnostic accuracy [14]. Techniques such as iterative reconstruction and limiting scan coverage have been instrumental in minimizing radiation while ensuring adequate image quality [15]. These advancements underscore the evolving role of CT in safely and effectively managing urolithiasis. Aim of study to evaluate the validity of low dose CT scan in alternative diagnosis for patients with urolithiasis.

Method

This cross-sectional study was conducted in the Computerized Tomography (CT) unit of the Radiology Department at Al-Shaheed Ghazi Teaching Hospital in Baghdad, Iraq, over one year from March 1, 2022, to February 28, 2023. The study population included all patients presenting to the CT unit with suspected urolithiasis. A convenient sample of 75 eligible patients was selected based on inclusion criteria (adult patients with suspected urinary stones) and exclusion criteria (younger age, recurrent urolithiasis, debilitating conditions, renal tumors, radiotherapy, or refusal to participate). Data collection involved a structured questionnaire designed by the supervisor. It gathered demographic data (age, gender), anthropometric measurements (weight, height, BMI), and findings from standard and low-dose CT protocols. BMI was calculated using the formula: BMI = weight (kg) / height (m^2) and classified as normal (18-24.9 kg/m^2), overweight (25-29.9 kg/m^2), or obese (≥30 kg/m^2). CT imaging was conducted using a Siemens 64-Slice CT scanner (SOMATOM, Germany) with automated tube current modulation. Standard CT protocol used 120 kV and 350 mAs, while the low-dose protocol employed 60 mAs, adjusted for BMI. Imaging parameters recorded included renal dimensions, parenchymal thickness, hydronephrosis, stone characteristics (number, diameter, density, site), and other findings. Ethical approvals were obtained from the Arab Board of Health Specializations and hospital authorities. Oral informed consent was taken from participants. Data were analyzed using SPSS version 22. Descriptive statistics were reported as mean ± standard deviation and frequencies (%). Chi-square and Fisher's exact tests were applied for categorical variables, and independent sample t-tests were used to compare two independent means. A p-value ≤0.05 was considered statistically significant.

Results

This study included 75 patients with urolithiasis presented with mean age of 44.4±11.3 years and range of (23-70 years); 8% of patients were in age group 20-29 years, 820% of patients were in age group 30-39 years, 32%% of them were in age group 40-49 years, 32% of them were in age group 50-59 years and 8% of patients were 60 years age and more. Male patients with urolithiasis were more than females with male to female ratio as 2.1:1. (Table 1)

Table 1: Demographic characteristics of patients with urolithiasis.

Variable	No.	%
Age mean ± SD (44.4±11.3 years)		
20-29 years	6	8.0
30-39 years	15	20.0
40-49 years	24	32.0
50-59 years	24	32.0
≥60 years	6	8.0
Total	75	100.0
Gender		
Male	51	68.0
Female	24	32.0
Total	75	100.0

Mean weight of patients with urolithiasis was (87.3 Kg) and mean height of them was (168.6 cm). Mean body mass index of patients with urolithisis was 30.5±6 Kg/m^2; 16% of patients had normal BMI, 32% of patients were overweight and 52% of them were obese. (Table 2)

Table 2: Anthropometric characteristics of patients with urolithiasis.

Variable	No. %	
Weight	Mean ±SD (87.3±19.9 Kg)	
Height	Mean ±SD (168.6±9.5 cm)	
Body mass index	Mean ±SD (30.5±6 Kg/m^2)	
Normal	12	16.0
Overweight	24	32.0
Obese	39	52.0
Total	75	100.0

Mean standard KVP was (120), while mean mAS was (362). Mean renal length of patients with urolithiasis checked by standard CT-scan protocol was (10 cm), while mean renal width (4 cm) and mean parenchymal thickness was (16 mm). The standard CT-scan protocol finding was hydronephrosis in 48% of patients. Mean number of stones was (1.8), while mean diameter was (20 mm) and mean density was (750.6 HU). The stone site detected by standard CT-scan protocol was commonly kidney (60%), followed by; ureter (16%), urinary bladder (16%) and kidney and ureter (8%). Other findings detected by standard CT-scan protocol were simple renal cyst (8%) and inguinal hernia (8%). (Table 3)

Table 3: Standard CT-scan protocol findings of patients with urolithiasis.

Variable	No. %	
Standard CT-scan protocol KVP (120)		
Standard CT-scan protocol mAS mean ±SD (362±99.2)		
Standard CT-scan protocol renal length mean ±SD (10±2.3 cm)		
Standard CT-scan protocol renal width mean ±SD (4±0.8 cm)		
Standard CT-scan protocol parenchymal thickness mean ±SD (16±1.3		
Standard CT-scan protocol findings		
Hydronephrosis	36	48.0
No hydronephrosis	39	52.0
Total	75	100.0
Standard CT-scan protocol	Number of stones	Mean ±SD (1.8±1.4)
Standard CT-scan protocol	Diameter of stones mean ±SD (20±10.3 mm)	
Standard CT-scan protocol	Density of stones mean ±SD (750.6±334.8	
Standard CT-scan protocol	Site of stones	
Kidney	45	60.0
Ureter	12	16.0
Urinary bladder	12	16.0
Kidney & ureter	6	8.0
Total	75	100.0
Standard CT-scan protocol other findings		
None	63	84.0
Simple renal cyst	6	8.0
Inguinal hernia	6	8.0
Total	75	100.0

Mean low KVP was (120), while mean mAS was (58.8).

Mean renal length of patients with urolithiasis checked by low CT-scan protocol was (10.1 cm), while mean renal width (4.2 cm) and mean parenchymal thickness was (16 mm). The low CT-scan protocol finding was hydronephrosis in 48% of patients. Mean number of stones was (1.8), while mean diameter was (20.6 mm) and mean density was (861 HU). The stone site detected by low CT-scan protocol was commonly kidney (60%), followed by; ureter (16%), urinary bladder (16%) and kidney and ureter (8%). Other findings detected by standard CT-scan protocol were only inguinal hernia (8%). (Table 4).

Table 4: Low CT-scan protocol findings of patients with urolithiasis.

Variable	No.	%
Low CT-Scan protocol KVP (120)		
Low CT-scan protocol mAS mean±SD (58.8±10.7)		
Low CT-scan protocol renal length mean±SD (10.1±1.1 cm)		
Low CT-scan protocol renal width mean±SD (4.2±0.8 cm)		
Low CT-scan protocol parenchymal thickness mean±SD (16±1.1 mm)		
Low CT-scan protocol findings		
Hydronephrosis	36	48.0
No hydronephrosis	39	52.0
Total	75	100.0
Low CT-scan protocol number of stones mean±SD (1.8±1.4)		
Low CT-scan protocol diameter of stones mean±SD (20.6±10.9 mm) Low CT-scan protocol density of stones mean±SD (861±311.7 HU) Low CT-scan protocol site of stones		
Low CT-scan protocol number of stones mean±SD (1.8±1.4)		
Low CT-scan protocol diameter of stones mean±SD (20.6±10.9 mm) Low CT-scan protocol density of stones mean±SD (861±311.7 HU) Low CT-scan protocol site of stones		
Low CT-scan protocol number of stones mean±SD (1.8±1.4)		
Low CT-scan protocol diameter of stones mean±SD (20.6±10.9 mm) Low CT-scan protocol density of stones mean±SD (861±311.7 HU) Low CT-scan protocol site of stones		
Kidney	55	60.0
Ureter	12	16.0
Urinary bladder	12	16.0
Kidney & ureter	6	8.0
Total	75	100.0
Low CT-scan protocol other findings		
None	69	92.0
Inguinal hernia	6	8.0
Total	75	100.0

No significant differences were observed between standard protocol and low CT-scan protocol regarding KVP, renal length (p=0.8), renal width (p=0.38), parenchymal thickness (p=0.79), number of stones (p=1.0) and diameter of stones (p=0.85). Mean mAS of standard CT-scan protocol was significantly higher than mean mAS of low CT-scan protocol (p<0.001). Mean fat density of standard CT-scan protocol was significantly lower than mean fat density of low CT-scan protocol (p=0.03). (Table 5).

Table 5: Distribution of CT-scan measures according to standard and low protocols.

Variable	CT-scan protocol		P
	Standard	Low	
	Mean ±SD	Mean ±SD	
KVP	120±0.0	120±0.0	1.0* NS
mAS	362±99.2	58.8±10.7	<0.001* S
Renal length (cm)	10±2.3	10.1±1.1	0.8* NS
Renal width (cm)	4±0.8	4.2±0.8	0.38* NS
Parenchymal thickness (mm)	16±1.3	16±1.1	0.79* NS
Number of stones	1.8±1.4	1.8±1.4	1.0* NS
Diameter of stones (mm)	20±10.3	20.6±10.9	0.85* NS
Density of stones (HU)	750.6±330.2	860.9±307.5	0.03* S

* Independent sample t-test, S=Significant, NS=Not significant.

No significant differences were observed between standard protocol and low CT-scan protocol regarding findings (p=1.0) and site of stones (p=1.0). There was a significant association between detection of inguinal hernia and use of low CT-scan protocol, while standard CT-scan protocol detected simple renal cyst and inguinal hernia (p=0.04). (Table 6).

Table 6: Distribution of CT-scan findings according to standard and low protocols.

Variable	CT-scan				P
	Standard		Low		
	No.	%	No.	%	
Findings					
Hydronephrosis	36	48.0	36	48.0	1.0* NS
No hydronephrosis	39	52.0	39	52.0	
Site of stone					
Kidney	45	60.0	45	60.0	1.0* NS
Ureter	12	16.0	12	16.0	
Urinary bladder	12	16.0	12	16.0	
Kidney & ureter	6	8.0	6	8.0	
Other findings					
None	63	84.0	69	92.0	0.04*S
Simple renal cyst	6	8.0	0	-	
Inguinal hernia	6	8.0	6	8.0	

*Fishers exact test, S=Significant, NS=Not significant.

Fig 1: Multiple left sided renal calyceal stones: Left=Low dose CT- scan, Right=Standard CT-scan.

Fig 2: Left Renal Staghorn stone: Left=Low dose CT-scan, Right=Standard CT-scan.

Discussion

Urolithiasis remains a significant public health concern worldwide, with recurrence rates exceeding 50% [16]. Imaging plays a vital role in its diagnosis, management, and follow-up, emphasizing the importance of reducing radiation exposure while maintaining diagnostic quality [16].

The present study revealed that the mean age of patients was 44.4 years, with a predominance of males (68%). This aligns with findings from Kadhum and Kandel in Iraq, reporting a mean age of 41.58 years and male predominance [17]. However, a systematic review by Gillams *et al.* in Europe noted an increasing prevalence of urolithiasis among females, particularly adolescents [18].

The study showed a mean BMI of 30.5 kg/m², with 52% of patients being obese. This finding supports Baatiah *et al.*'s study in Saudi Arabia, which highlighted a higher prevalence of urolithiasis among obese individuals [19]. Asplin's study in the United States further explained that obesity contributes to stone formation through increased dietary intake of lithogenic substances and metabolic syndrome, which lowers urine pH and increases the risk of uric acid stones [20]. The mean standard CT-scan protocol parameters were 120 kVp and 362 mAs. These findings align with Shamir *et al.*'s study in the United States, which applied similar kVp values for renal stone imaging, though with varying mAs levels [21]. The study reported a mean renal length of 10 cm, consistent with Glodny *et al.*'s study in Austria (10.8 cm), which also highlighted renal length variations based on demographic and anatomical factors [22]. The mean renal width of 4 cm agreed with Park *et al.*'s findings in South Korea [23]. The mean renal parenchymal thickness of 16 mm was higher than the 2.25 cm reported by Kaplon *et al.* in the United States in cases of obstructed renal units, where thickness predicted renal function [24]. Hydronephrosis was detected in 48% of patients, lower than the 83% reported by Patatas *et al.* in the United Kingdom [25]. The mean number of renal stones (1.8), mean diameter (20 mm), and mean density (750.6 HU) were consistent with Mahmood *et al.* and Muter *et al.*'s studies in Iraq [26, 27]. The kidney was the most common site (60%), followed by the ureter and urinary bladder (16% each), similar to Qaader *et al.*'s findings in Iraq [28]. Other findings included renal cysts (8%) and inguinal hernia (8%), aligning with Savin *et al.*'s study in Palestine [29]. There were no significant differences between standard and low-dose CT protocols regarding parameters such as renal dimensions, stone characteristics, and hydronephrosis detection ($p>0.05$), consistent with Weinrich *et al.*'s findings in Germany [30]. Anas *et al.* in Egypt also emphasized the effectiveness of low-dose CT in measuring renal dimensions and stone parameters compared to ultrasound [31]. However, the mean mAs of the standard protocol was significantly higher than the low-dose protocol ($p<0.001$), supporting Marsoul *et al.*'s findings in Iraq [32]. Low-dose CT showed higher fat density (p=0.03), as reported by Murphy *et al.* in Ireland [33]. Low-dose CT remains effective for urolithiasis diagnosis while significantly reducing radiation exposure [16, 34]. However, it may fail to detect small stones in obese patients or simple renal cysts, as noted by Sahni *et al.* in the United States [35]. These findings underscore the importance of protocol optimization for accurate diagnosis while minimizing radiation risks.

Conclusion

Low-dose CT scan protocol is an effective and safe method for diagnosing urolithiasis, with comparable accuracy to standard protocols in detecting stone number, size, diameter, and site. It utilizes a lower tube current but shows higher fat density compared to standard protocols. However, it may fail to detect simple renal cysts. These findings highlight its potential for reducing radiation exposure without compromising diagnostic quality.

Acknowledgement

Not available

Author's Contribution

Not available

Conflict of Interest

Not available

Financial Support

Not available

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How to Cite This Article
Ahmed RY, Kareem AH, Tajer AM. Low dose CT for evaluation of suspected urolithiasis. International Journal of Radiology and Diagnostic Imaging. 2025;8(1):32-38.