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Ultra-Low Dose Multi-Detector CT-KUB for Identification of Urinary Tract Stones

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Abstract

Background: Urinary stone disease is common and poses a significant health care burden in a working-age population.

With recurrence rates of 50-70% at 10 years patients are likely to be subjected to repeated imaging. Computed tomography (CT) is the reference tool for the diagnosis of renal colic, This is because CT is fast, does not require intravenous administration of iodinated contrast material, has high diagnostic capabilities, provides direct information relative to the size and attenuation value of urinary stones.Its main limitation, however, is the high radiation dose given to the patient, especially because urinary stone disease has a high recurrence rate.

Aim of Study: The aim of this work is to investigate the diagnostic accuracy of ultra-low dose CT scans (ULDCT) for stone detection in patients with renal colic and hematuria.

Patients and Methods: This Descriptive study was conducted on 201 patients exposed to ULD CT of the kidney, ureters, and bladder (KUB) scan with urinary stones attended Urology & Nephrology Center, Mansoura, Egypt from September 2022 to September 2023, with colic pain and hematuria. Pregnant females were excluded from the study.

Results: The study found that ULD CT has a high accuracy in detecting urinary tract stones that measures 1mm or larger. kidney stones have been found more common than the ureteral or urinary bladder stones. Also, ULD CT could detect the density of different urinary stones giving information about their composition.

Conclusion: Our study suggests that ULD CT with reduced effective radiation dose has been excellent detector of stones 1mm or larger with accurate detection of size, site, density of that stones & presence of hydroureteronephrosis.

Recommendations: Performing further multicenter studies with larger sample size. Performing further prospective studies to assess the prognostic value of ULD CT in prediction of renal stones complications.

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Key Words: *Urinary stones – ULD CT – Radiation dose – Hydroureteronephrosis.*

Introduction

URINARY stone disease is common and poses a significant health care burden in a working-age population **[1]**. Most patients tend to present between 30-60 years of age **[2]**. Urolithiasis is also associated with recurrence rates of 50-70% at 10 years **[3]**. Stone recurrence depends on geographic, climatic, ethnic, dietary, and genetic factors **[1]**. Therefore, patients are likely to be subjected to repeated imaging.

Renal colic is particularly appropriate for low-dose CT because of the excellent spontaneous contrast between most urinary stones that are spontaneously hyperattenuating (between 200 and 2800 HU) **[4]**, and the soft tissues that surround them. Thus, even if the dose reduction is substantial, the naturally high contrast between urinary stones and the surrounding soft tissues prevents too Much deterioration of the contrast-to-noise ratio while preserving good diagnostic performance **[5]**.

We defined an ultra-low-dose CT (ULD CT) as a study with dose equivalent of <1.9mSv, which is lower than the mean effective dose used to perform abdominal film KUBs (~2.15mSv), which require multiple views to capture the abdomen and pelvis **[6]**.

In general, the earlier studies of LD scanning employed techniques that reduce kVp and/or mAs where image reconstruction from raw data is performed using traditional filtered back projection (FBP) **[7]**. The step change to allow ULD scanning has largely been engendered by the move to the use of various iterative reconstruction (IR) methods which are much more computationally intensive and have only more recently become available clinically.

Patients and Methods

This Descriptive study was conducted on 201 patients with urinary stones who underwent imaging by (ULDCT) at Urology & Nephrology Center, Mansoura, Egypt.

Ethical consideration:

The whole study design was approved by the Institutional review board (IRB), Faculty of Medicine, Mansoura University. Confidentiality and personal privacy were respected in all levels of the study. A written informed consent was obtained from all participants before inclusion in the study, explaining the value of the study, plus the procedures that were conducted.

Inclusion criteria:

Patients with loin pain, patients with lower urinary tract symptoms and patients with hematuria.

Exclusion criteria:

Patients who are pregnant.

Methods:

Complete physical examination was performed including the following: Vital signs (Temperature, Blood pressure, Pulse, Respiratory rate). Examination of general state, weight, height and BMI of the cases.Laboratory Investigations: Complete Blood Count, Erythrocyte Sedimentation Rate and C-Reactive Protein.Ultrasound (US): Renal and urinary bladder US for all patients were performed with the patient in supine position and additional scans in the lateral decubitus and prone were useful in some situations. Ultra-low dose CT: We performed all ULD CT scans without contrast on a 128-section CT scanner by using automated tube current modulation, 0.5-seconds rotation time, and a pitch of 1.375. We set the range of the tube current for low-BMI protocol to 45–150 mA, the tube voltage to 80 -100kV, and noise index to 25. Examinations were reconstructed with a standard kernel for filter back projection and with adaptive statistical iterative reconstruction (ASIR; GE Healthcare) using a ratio of 70%.

Statistical analysis:

The collected data were coded, processed and analyzed using the SPSS (Statistical Package for Social Sciences) version 27 for Windows® (IBM SPSS Inc, Chicago, IL, USA). Qualitative data were expressed as number (Percent) while quantitative data were expressed as mean ± SD / median (Range).

Results

The mean age of the cases was 42.43±15.47 years with range between 10 months and 80 years. There were 153 males (76.1%) and 48 females (23.9%). The mean weight was 77.20±17.04kg with range between 9 and 110kg. The mean effective dose was 1.31±0.33 mSv with range between 0.29 and 1.9 mSv (Table 1). The mean size of the stones was 204.02±400.38 with range between 1mm^3 and 5400mm^3. The mean density was 639.31±399.02 with range between 106 and 1881 HU (Table 2).Regarding the Side of stones, there were 122 stones (37%) in the right kidney, 129 stones (39.1%) in the left kidney, 39 stones (11.8%) in the right ureter, 39 stones (11.8%) in the left ureter and one stone in the UB (0.3%). According to the site of the stones, the lower calyces was the most common affected site by 127 stones (38.5%) followed by middle calyceal (26.4%), pelvic ureter (9.7%), lumbar ureter (7.9%), upper calyceal (7.6%), iliac ureter (4.8%), PUJ (1.8%), UVJ (1.8%), renal pelvis (1.2%) and UB (0.3%) (Table 3). Hydronephrosis was reported in 47.3% of the cases (Table 4).

Table (1): Clinical characteristics of the cases of single limp.

Variables	Study cases N = 201	
	N	%
Gender:	153	76.1
Males	48	23.9
Females		
Age (years):		
Mean ± SD	42.43±15.47	
Median (Range)	42 (0.83-80)	
Weight (Kg):		
Mean ± SD	77.20±17.04	
Median (Range)	80 (9-110)	
Effective Dose (mSv):		
Mean ± SD	1.31±0.33	
Median (Range)	1.3 (0.29-1.9)	

SD: Standard deviation.

Table (2): Stone criteria of the cases.

Variables	Number of stones N=330
Length (mm):	
Mean ± SD	4.94±3.18
Median (Range)	4.15 (1-22)
Width (mm):	
Mean ± SD	4.54±2.74
Median (Range)	4 (1-24)
Height (mm):	
Mean ± SD	5.30±2.24
Median (Range)	5 (1-15)
Size (mm^3):	
Mean ± SD	204.02±400.38
Median (Range)	100 (1-5400)
Density (HU):	
Mean ± SD	639.31±399.02
Median (Range)	145 (106-1881)

Table (3): Site of stones in the cases of the study.

Side and Site of stones	Number of stones N = 330	
	N	%
Side of stones:		
Right kidney	122	37.0
Lef kidney	129	39.1
Right ureter	39	11.8
Left ureter	39	11.8
Urinary bladder	1	.3
Site of stones:		
Lower calyceal	127	38.5
Middle calyceal	87	26.4
Pelvic ureter	32	9.7
Lumbar ureter	26	7.9
Upper calyceal	25	7.6
Iliac ureter	16	4.8
PUJ	6	1.8
UVJ	6	1.8
Renal pelvis	4	1.2
UB	1	0.3

Table (4): Hydronephrosis in the cases of the study.

Hydronephrosis	Number of stones N = 330	
	N	%
No	174	52.7
Yes	156	47.3

A 27-years-old male patient weighted 65 Kg presented with recurrent bilateral loin pain. He underwent Ultra Low Dose Spiral CT scan “100Kv -32mA”. A. Non contrast Axial ULD CT “Effective dose = 1.09mSv” showing Right middle calyceal stone measuring 2x2x3mm with density about 305 HU with no hyronephrosis. B. Non contrast Axial ULD CT “Effective dose = 1.09mSv” showing Left middle calyceal stone measuring 2x3x5mm with density about 264 HU with no hydronephrosis (Fig. 1).

A 61-years-old male patient weighted 100 Kg presented with left loin pain. He underwent Ultra Low Dose Spiral CT scan “100Kv-47mA”. A. Non contrast Axial ULD CT “Effective dose = 1.8mSv” showing left lower calyceal stone measuring 7x6x7 mm with density about 1120, with no hydronephrosis (Fig. 2).

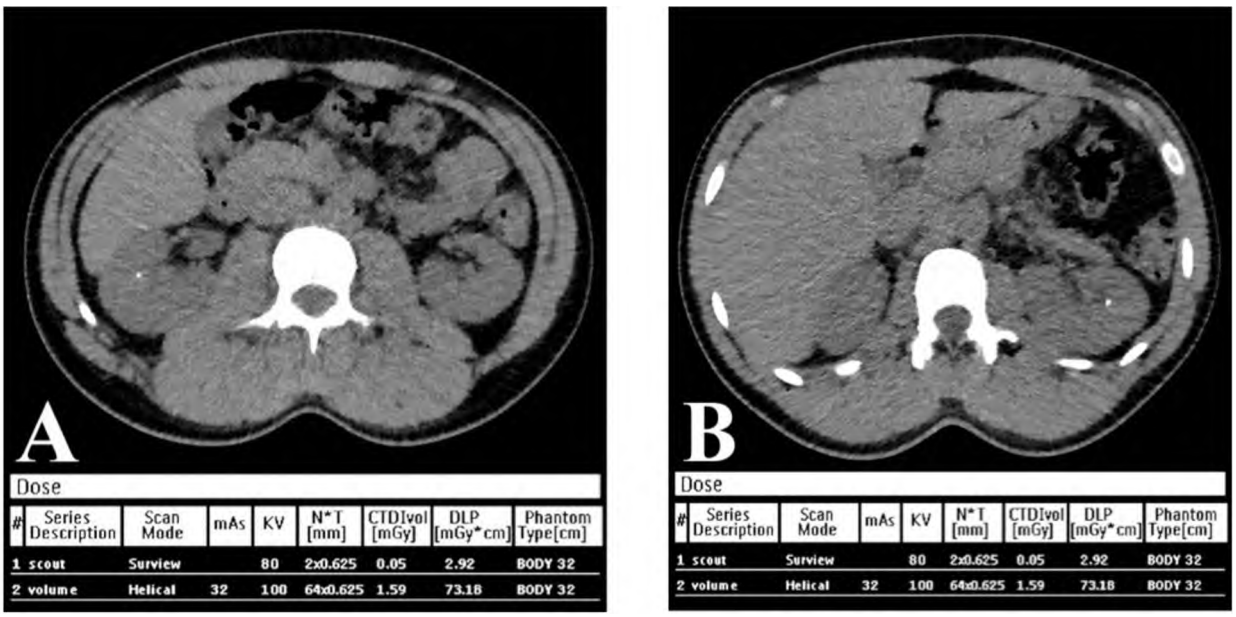

Fig. (1): A 27-years-old male patient showing 2 stones.

Fig. (2): A 61-years-old male patient showing A left lower calyceal stone.

Discussion

Urolithiasis is highly prevalent among the middle age population worldwide .In our study, the mean age of the included patients was 42.43±15.47. The age range was similar to the study that was conducted by Khaled et al. **[12]** on fifty patients with commonest affected age group was 41 to 60 years old as 20 patients were between 41 and 60 years old with 40%.

In our study, most of the included participants were men, as they formed 76.1% while the remaining participants were women. This is accordance with multiple previous studies that showed an association between male gender and ureteric stones. In developing countries, the male-to-female ratio range from 1.15:1 in Iran **[13]** and 1.6:1 in Thailand **[14]**. In the current study, the highest distribution of the stones were located in the kidneys forming about 76.1% while the remaining stones were ureteral and bladder stones. This was in accordance with William Sohn who detected that ureteral stones were demonstrated in 38 (36%) of 106 patients **[15]**.

However, this disagreed with Solian and Sakr who showed that 45.5% of stones were located in the kidney, while 54.5% of stones were presented in the ureter **[16]**. In the current study, ULD CT can detect urinary tract stones with size range (1-5400) mm^3 that even small graviles could be detected along the urinary tract system.

This was similar to two studies, one by Roberts et al. **[17]** involving 21 patients and another by McLaughlin et al. **[18]** involving 33 patients, that reported no significant differences in renal-calculus detection rate or size limit between ULDCT and LDCT when the radiation dose was decreased to sub-millisievert levels. However, these results disagreed with Roberts et al. **[17]** who showed that four renal calculi were missed by ULDCT in four of the eight patients (median calculus size 2mm, all calculi <3mm). One patient had two calculi, with the 6-mm calculus being concordant between SDCT and ULDCT, but ULDCT missed a 2.5mm calculus. The ULDCT detected three calculi (two of 2.5mm, one of 5mm) incorrectly, due to vascular calcification misclassification. They also showed that for ureteric calculus detection, two of the eight patients showed discordant findings on ULDCT due to failure to detect calculi of <3mm on ULDCT (median size 2.25mm).

Conclusion: Our study suggests that Ultra-Low Dose multi detector CT with reduced effective radiation dose by less than 1.9mSv has been excellent detector of stones 1mm or larger with a very high accuracy for detection of its characters as size, site & density. Also can detect hydroureteronephrosis for clinical purpose.

Recommendations: Performing further multicenter studies with larger sample size. Performing further prospective studies to assess the prognostic value of ULD CT in prediction of renal stones complications.

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دور الجرعة المنخفضة للغاية للأشعة المقطعية متعددة الكواشف للكشف عن حصوات المسالك البولية

مرض حصوات المسالك البولية شائع ويشكل عبئًا كبيرًا على الرعاية الصحية لدى السكان فى سن العمل. يميل معظم المرضى إلى ظهور الأعراض بين ٣٠–٦٠ سنة. وترتبط حصوات المسالك البولية بمعدلات تكرار تصل إلى ٥٠–٧٠٪ بعد ١٠ سنوات. يعتمد تكرار الحصوات على العوامل الجغرافية، والمناخية، والعرقية، والغذائية، والوراثية، لذلك من المرجح أن يتعرض المرضى للتصوير المتكرر.

الهدف من الدراسة هو التحقق من الدقة التشخيصية للأشعة المقطعية بجرعة منخفضة للغاية للكشف عن الحصوات لدى المرضى الذين يعانون من المغص الكلوى .

تم إجراء هذه الدراسة على مئتان وواحد من المرضى الذين يعانون من مغص كلوى ولقد استخدمنا فى دراستنا التصوير المقطعى المحوسب متعدد الكواشف منخفض الجرعة للغاية على كل المرضى لتقييم قدرة التصوير المقطعى المحوسب بالجرعة المنخفضة للغاية على اكتشاف عدد الحصوات وحجمها وموقعها وتكوينها. الحالات المشاركة فى الدراسة تم اختيارها من مستشفى الكلى والمسالك البولية من سبتمبر ٢٠٢٢ إلى سبتمبر٢٠٢٣ بعد موافقة اللجنة الأخلاقية بكلية الطب جامعة المنصورة وبعد الحصول على الموافقة المكتوبة من المرضى على إجراء خطوات الدراسة.

تشير النتائج التى حصلنا عليها من هذه الدراسة إلى أن أجهزة الكشف المتعددة ذات الجرعات المنخفضة للغاية بالأشعة المقطعية مع جرعة إشعاع فعالة منخفضة أقل من ١,٩ كانت كاشفًا ممتازًا لحصوات المسالك البولية التى يبلغ حجمها ١مم أو أكبر.