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Dual Energy CT Impact on Determination of Chemical Composition for Urolithiasis

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ABSTRACT

Background: The urinary tract stone disease is a common problem. Dual energy CT with advanced post processing techniques gives anatomical information as size, site of the stone as well as its chemical composition which alter the clinical management.

Objective: This study was aimed at studying the role of dual energy computed tomography in characterization of renal stones.

Patients and methods: This study was carried out at the private radiology center throughout the period from January 2020 to January 2021 included 48 patients with renal stones. In this study, renal stones were more common in men (66.7 %) than in women (30.3%). The age of our selected patients ranged from 24 to 55 years with a mean of 42 years. The most affected age group was from 24-44 years (24 cases) represented 50% of the cases.

Results: The average age of the studied group was (42.1±7.6), the most common presentation symptoms was loin pain (75.0%) followed by hematuria (18.8 %) then nausea& vomiting (4.2%) and fever (2.0%).Dual energy CT had 88.9% ability to truly detect uric from non-uric acid stones with (97.9%) accuracy, (100.0%) ability to exclude non uric stones (specificity), (100.0%) predictive value positive and (97.5%) predictive value negative with (50.0%) prevalence and (35.0%) likelihood positive ratio.

Conclusion: It could be concluded that dual energy CT has been shown to be effective for characterizing chemical composition of the urinary stones, dual energy CT not well established enough to be used in clinical practice, but it will replace helical non contrast CT as the standard imaging modality for urinary calculi.

Keywords: Urolithiasis, Dual energy CT, Chemical Composition of stones

INTRODUCTION

The renal stone disease is a common clinical problem representing about 10–14% of the population. There are different chemical compounds forming renal stones; they are about sixteen in number, most of these are rare. The most common chemical composition that form stones are calcium oxalate (70%), calcium phosphate (20%), uric acid (8%) and cystine (2%) **(1).**

Unenhanced helical CT is the preferred method for evaluation patients with suspected urinary calculi, it provides information about the presence, size and location of stone, as well as the presence of associated complication **(2).**

Dual energy CT with advanced post processing technique improves characterization of renal stone chemical composition beyond that achieved with single energy CT (SECT) acquisition with basic attenuation assessment **(3).**

Because many patients harboring urinary calculi will ultimately require some form of intervention, here it is great importance in further developing the capability of CT to predict stone composition, a reliable determination of the type of the stone that is presence will allow the clinician to better satisfy treatment option for the patient, such as stones composed of uric acid, may be treated medically and may not require surgery **(4).**

Any given material will have different attenuation values when imaged at low and high peak kilo voltage (KVP) result in a predictable change in attenuation when imaged by two known x ray energy, two materials with similar attenuation values on SECT but different chemical composition can be distinguished from one another by analyzing their energy dependent changes in attenuation **(5)**.

Previously, most researches focused only on distinguishing uric acid from non-uric acid. recently, it was reported that in addition to reliably differentiation uric acid stones from calciferous stones , calcium oxalate and calcium phosphate stones could be marginally differentiated **(6).** Dual energy CT has been reported as having a near 100% sensitivity and specificity for characterizing renal stone composition when stone size is at least 3 mm **(7)**.

It is likely that dual energy CT will replace conventional SECT as the standard imaging method for urinary calculi, as it provides the same anatomical information as well as stone composition without increasing patient radiation exposure (8).

Therefore, this study was aimed at studying the role of dual energy computed tomography in characterization of renal stones.

PATIENTS AND METHODS

This study was carried out at the private radiology center throughout the period from January 2020 to January 2021. Our study included 48 patients (32 male and 16 female) with known renal stones. The patients aged from 24 to 55 years.

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Inclusion criteria: Patient previously diagnosed with renal stones more than 3 mm. Both sexes were included and no age predilection.

Exclusion criteria: There is absolute contraindication the only one was pregnancy.

All patients were subjected to full history taking, clinical examination and radiological examination including:

Ultrasonography: grey scale ultrasonography was done for all patients (n=48) for the assessment of presence of renal stones and back pressure changes of the kidney.

Computed tomography: all patients (n=48) underwent multi detector computed tomography: (CT machine) Aqilion one Toshiba 320, Japan.

Image acquisition: The patient was lying in a supine position with head fixation and arms above the head, then the asked him for holding breath at various times during the procedure.

In order to minimize radiation exposure, the patients were scanned first with a standard low dose renal stone CT, using a tube potential of 120 kvp and very low tube current 150-200 MAS, after assurance of the presence of renal stones by noncontrast study, dual energy CT examination were performed by using a single –source dual energy and single raw detectors with fast switching using 80 KVP and 140 KVP , DECT was performed focusing on the region of the stone only.

Post processing technique:

Images acquired with the dual energy modality were post processed using a dedicated remote workstation and dedicated software for the evaluation of the stone chemical composition. all the examination were visualized on the axial, coronal, and sagittal planes and urinary stone density was measured using region of interest smaller than 50% of the each stone diameter for each patient, we evaluated the number, location, maximal diameter and CT density expresented in HU. The software displaying the stones in red and blue color according to the color map [(9)].

Ethical approval:

The study was approved by the Ethical Committee of Zagazig Faculty of Medicine. An informed consent was obtained from all patients in this research. Every patient received an explanation for the purpose of the study. All given data were used for the current medical research only. This work has been carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki) for studies involving humans.

Statistical analysis

Data analyzed using Microsoft Excel software then imported into Statistical Package for the Social Sciences (SPSS version 20.0) software for analysis. According to the type of data qualitative represent as number and percentage , quantitative continues group represent by mean ± SD. Differences between quantitative independent multiple by ANOVA. Continuous variables were expressed as mean, whereas categorical variables were expressed as percentage, agreement between dual energy CT and crystallography was estimated using the Cohen kappa coefficient. P value was set at <0.05 for significant results &<0.001 for high significant result.

RESULTS

This study included 48 urolithiasis patients underwent non contrast CT study for evaluation, using dual energy CT at private radiology center. The average age of the studied group was (42.1±7.6) years ranged from 24 to 55 years, Half of the group (50.0%) had age ranged from 24 to 44 years and (50.0%) from 45 to 55 years **(Table 1).** The most common presentation symptoms were loin pain (75.0%) followed by hematuria (18.8 %) then nausea& vomiting (4.2%) and fever (2.0%) **(Table 2)**.

About half (56.3%) of the studied group were right sided affected, (43.7%) of them were left sided. About (87.5%) of patients had single stone, while (12.5%) of them had multiple stones. renal pelvic was the commonest affected site (58.3%) of the studied group followed by lower calyx kidney (31.3%) of them then upper calyx kidney (8.3%) and middle calyx (2.1%) **(Table 3)**.

The stone size of the studied group was (12.3±5.8) mm ranged from 4 to 28 mm, low energy attenuation value HU was (890.6±260.2) ranged from 173 to 1355, high energy attenuation value HU was (766.6±234.8) ranged from 258 to 1195 , attenuation ratio was (1.19±0.41) ranged from 0.7 to 2 **(Table 4)**.

Dual energy CT had 88.9% ability to truly detect uric from non-uric acid stones with (97.9%) accuracy, (100.0%) ability to exclude non uric stones (specificity), (100.0%) predictive value positive and (97.5%) predictive value negative with (50.0%) prevalence and (35.0%) likelihood positive ratio **(Table 5)**.

Table (1): Age distribution of the studied group:

Variable	The studied group(48)	
Age (years):		
Mean ± SD	42.1±7.6	
(Range)	(24-55)	
Median	44	
Variable	**NO(48)**	**%**
Age grouping		`
24-44 years	24	50.0%
45-55 years	24	50.0%

Table (2): The clinical presentation of the studied patients:

The clinical picture	No. (48)	%
Loin pain	36	75.0%
Hematuria	9	18.8%
Fever	1	2.0%
Nausea& vomiting	2	4.2%

Table (3): Laterality, number and types of renal stones among the studied group:

The affected side	No. (48)	%
Right	27	56.3%
Left	21	43.7%
Single	42	87.5%
Multiple	6	12.5%
Location of renal stones	**No. of patients**	**%**
Upper calyx kidney	4	8.3%
Middle calyx kidney	1	2.1 %
Lower calyx kidney	15	31.3 %
Renal pelvic	28	58.3 %
Total	(48)	100 %

Table (7): Characterization of calculi by DECT among the studied group:

Characterization	The studied group(48)
Size (mm): Mean ± SD Median	 12.3±5.8 11
Low energy attenuation value HU Mean ± SD Median	 890.6±260.2 888
High energy attenuation value HU Mean ± SD Median	 766.6±234.8 865.5
Attenuation ratio Mean ± SD Median	 1.19±0.41 1.1

Table (5): The diagnostic ability of DECT for detection of uric and non-uric acid stones:

Variable	Cut off	AUC	P	95% CI	
DECT	<1.14	0.99	**<0.001****	0.99-1	
Variable	**Sensitivity**	**Specificity**	**PVP**	**PVN**	**Accuracy**
DECT	88.9%	100.0%	100.0%	97.5%	97.9%

DISCUSSION

Technical difficulties only made it possible a few years ago to construct device capable of generation two X-ray beams of low and high energy with a short time distance. Single energy CT is performed using a single X-ray beam to create images for interpretation. Images obtained with conventional CT provide useful structure information, UT only limited material specific information because they represent of structure on these images depends solely on the linear attenuation coefficient of each of the constituent material and is independent of the material density and mass attenuation coefficient [4-6].

The current study included 48 patients, their age ranged from 24- 55 years with a mean of 42 years. The affected age group was about 24-44 years (24 cases) represent (50%) of the cases. the result of our study agreed with the series which was done by **Brisbane *et al.*** [10] found that the mean age of effection was from 20-40 years old.

The present study, renal stone were more common in men (66.7%) than women (33.3%). These result were agreed with **Manglaviti *et al.*** [9] who found that renal stone more common in male (70%), in contrast to series which was done by **Sellaturay and Fry** [12] who reported that renal stones were more in males (70%) than in female (30%).

In the selection of patient, 36 patients (75%) whose presented with loin pain, 9 patients (18.8%) whose presented with haematuria, 2 patients(4.2%) whose presented with nausea and vomiting, 1 patient (2.0%) whose presented with fever, most of the patient presented with loin pain. This result were in agreement with **Farris *et al.*** [13] who reported that loin pain was the most common symptoms in urolithiasis.

In this study, we accurately distinguished between uric stones (8 stones represent 20%) and non-uric stones (40 stones represent 80%) which agreed with **Stolzmann *et al.*** [14] who demonstrated that uric acid and non-uric acid containing stones can be accurately differentiated using a dual energy CT approach by dual source CT scanner. They compared stones on the basis of differences in attenuation at 80 and 140kv and found significantly higher attenuation among the stones that contained no uric acid.

In the our study according to dual energy CT, the most common type of renal stones was calcium oxalate 30 stones (62.5%), followed by cysteine about 10 stones (20.8%) then uric acid stones about 8 stones (16.7 %). The results of our study were agreed with the series which was done by **Basha *et al.*** [15] who found the most common type of renal stone was calcium oxalate about (55%) but cysteine stones second common type represent (25%), then uric acid stones (20%). Also our results were nearly agreed with that of **Manglaviti *et al.*** [9] who found that the most common type of renal stones was calcium oxalate (33 stones), then cysteine (7 stones), then uric acid (4 stones) and also agreed with **Ferrandino *et al.*** [16] who found calcium oxalate renal stones was about (56%) but uric acid stones second common represent (28%), then cysteine stones (16%).

The present study showed high accuracy in detection of stones composition of 47 stones represent 97.9%, these result agreed with **Bellin *et al.*** [17] who found that can identify an attenuation value characteristic of each kind of stone using the right window level to localize homogenous region inside the

stones even if this CT approach can be helpful , it is not well established enough to be used in clinical practice. Dual energy CT has been shown to be very effective for characterizing urinary stones.

CONCLUSION

It could be concluded that dual energy CT has been shown to be effective for characterizing chemical composition of the urinary stones, dual energy CT not well established enough to be used in clinical practice, but it will replace helical non contrast CT as the standard imaging modality for urinary calculi.

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Conflict of Interest: Nil.

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