Role of Dual Energy CT in Determination of Urolithiasis Chemical Composition

Maamar Ahmed Hasan, Khaled Ahmed Lakouz, Mohamed Zakaria Alazzazy and Nesma Adel Hamed

Radiodiagnosis Department, Faculty of Medicine, Zagazig University, Egypt.

Corresponding author: **Maamar Ahmed Hasan**, Email: moamerahmadhasan@gmail.com

ABSTRACT

Background: Factors that place a patient at risk for renal calculus formation are overall poorly understood. The concept of super saturation is essential to theories on calculus formation.The current study aimed to evaluate the role of dual energy computed tomography in determination of renal stone chemical composition which will effect there treatment strategy. Patients and methods: This study included 48 patients with nephrolithiasis who underwent non contrast CT study for evaluation using dual energy CT at private radiology center. Results: There was statistically significant difference between patients with different stone composition regarding location where (50.0%, 20.0% & 50.0%) of uric, Ca oxalate and cysteine stones respectively were in renal pelvic while all of upper calyceal kidney were cysteine stones. Also, there was statistically significant difference between patients with different stone compositionre garding clinical picture. Regarding age, sex and laterality, there was no statistically significant association with the different stones types. Patients underwent to extracorporeal shock wave lithotripsy were 54% and patients underwent to percutaneous nephrolithotomy were 21%. There was excellent agreement between DECT and crystallography on detection of stone types with (97.9%) success and (2.1%) failure rate of detection when using crystallography as a confirmatory test to DECT with identical results. Conclusion: Dual energy CT provides the anatomical information as number, location,maximal diameter, CT density and also characterize the stone chemical composition which use of this technique could help doctor and patient select appropriate treatment and avoid more invasive & high impact procedures.

Keywords: Dual energy CT; Nephrolithiasis; Uric acid stones

INTRODUCTION

Renal colic accounts for about 1% of hospital admissions worldwide and the initial episode is normally dealt with by urologists, but physicians are increasingly encountering patients with nephrolithiasis because of its association with hypertension, obesity, diabetes and osteoporosis **(1)**.

All stones share similar presenting symptoms, and urine supersaturation with respect to the mineral phase of the stone is essential for stone formation. The presence of hydroxyapatite crystals in either the interstitial or tubule compartment (and sometimes both) of the renal medulla in stone formers is the rule and has implications for the initial steps of stone formation and the potential for renal injury **(2)**.

Risk factors of recurrent disease include younger age at onset, family history of stones, associated UTI, and systemic disease that promotes the stone formation, such as hyperparathyroidism **(3)**.

In general, smaller stones are most hazardous, because they may pass into the ureters, producing colic as well as ureteral obstruction. Larger stones cannot enter the ureters and remain silent within the renal pelvis. Commonly, these larger stones first manifest themselves by hematuria **(4)**.

Computed tomography and magnetic resonance imaging have demonstrated renal injury in 63-85% of patient treated with shock wave lithotripsy **(5)**.

With dual energy CT, two images data sets are acquired in the same anatomic location with two different x-ray spectra to allow the analysis of energy dependent changes in the attenuation of different material to allows a more nuanced characterization of the feature depicted **(6)**.

This study aimed to evaluate the role of dual energy computed tomography in determination of renal stone chemical composition which will effect there treatment strategy.

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.

Inclusion and exclusion criteria:

Patient previously diagnosed with renal stones more than 3 mm. Both sexes were included and no age predilection. There is absolute contraindication the only one was pregnancy.

All patients were subjected to full history taking, clinical examination and radiological examination including ultrasonography and computed tomography.

Radiological investigation:

Dual-source CT scanner by use of dual-energy modes adaptively selected on the basis of phantom size. CT number ratio, which is distinct for different materials, was calculated for each pixel of the stones. Each pixel was then classified as uric acid and non–uric acid by comparison of the CT number ratio with preset thresholds ranging from 1.10 to 1.70 **(7).**

Statistical analysis:

Data analyzed using 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 patients with nephrolithiasis who 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, most of the studied group (66.7%) were males and (33.3%) of them were females **(Figure 1)**. The most common presentation symptoms was loin pain (75.0%) followed by hematuria (18.8 %) then nausea& vomiting (4.2%) and fever(2.0%) **(Figure 2)**.

Rrgarding stone location, renal pelvic was the commonest affected site (58.3%) of the studied group followed by lower calyx kidney (31.3%) of them then upper calyxkidney (8.3%) and middle calyx (2.1%) **(Figure 3)**. More than half of the studied group (62.5%) had Ca oxalate, (20.8%) of them had cysteine stones and (16.7%) had uric acid stones **(Table 1)**.

There was statistically significant difference between patients with different stone composition regarding location where (50.0%, 20.0% & 50.0%) of uric, Ca oxalate and cysteine stones respectively were in renal pelvic while all of upper calyceal kidney were cysteine stones. Also, there was statistically significant difference between patients with different stone compositionre garding clinical picture. Regarding age, sex and laterality, there was no statistically significant association with the different stones types **(Table 2)**. There was statistically highly significant higher attenuation ratio among Ca oxalate than cysteine than uric acid stones also high and low energy attenuation value HU were statistically significant higher among Ca oxalate than cysteine than uric acid stones. Regarding number of stones, there was no statistically significant association with the different stones types **(Table 3)**.

The best cut-off value for the prediction of uric acid at the 80/Sn140 kV ratio was <1.14, resulting in 88.9% sensitivity and 100% specificity **(Figure 4)**. Potential treatment based on size and chemical composition is summerzied in **Table (4)** Patients underwent to extracorporeal shock wave lithotripsy were 54% and patients underwent to percutaneous nephrolithotomy were 21% **(Table 5)**.

There was excellent agreement between DECT and crystallography on detection of stone types with (97.9%) success and (2.1%) failure rate of detection when using crystallography as a confirmatory test to DECT with identical results **(Table 6)**.

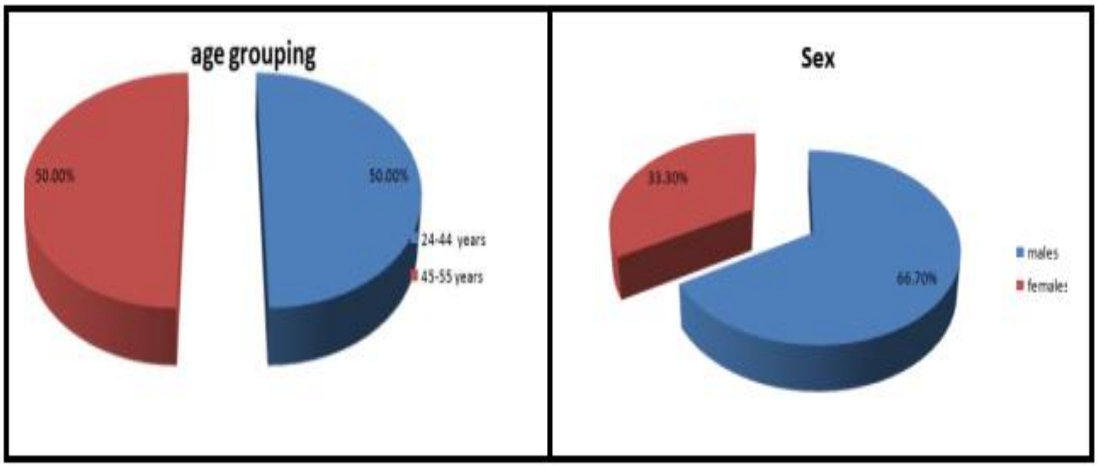

Figure (1): Pie chart for age and sex distrubution among the studied group

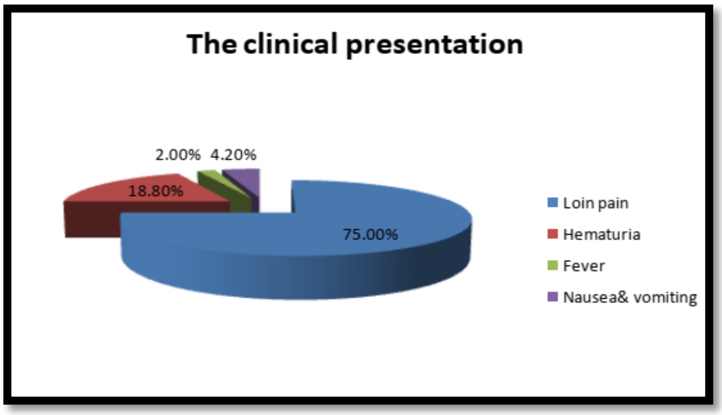

Figure (2):Pie chart for the clinical presentation of the studied patients.

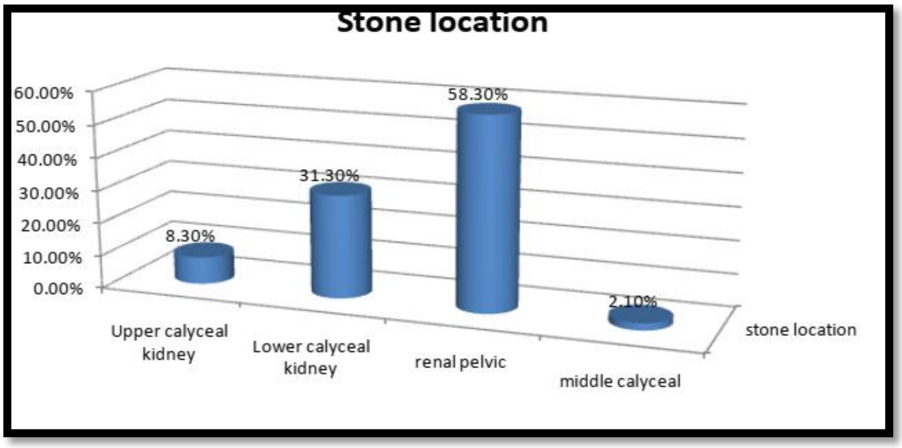

Figure (3):Bar chart for the affected site among the studied group

Table (1): Type of stone predicated by DECT :

Stone type	Numbar	%
Ca oxalate	30	%62.5
Cysteine	10	%20.8
Uric acid	8	%16.7
Total	**(48)**	%100

Table (2): Comparison between patients with different stone types regarding patients characteristics among the studied group:

Variable	Uric acid		Ca oxalate		Cysteine		χ^2	p
	No. (8)	%	No. (30)	%	No. (10)	%		
Age group								
24-44 years (24)	5	62.5	12	40.0	7	70.0	3.3	0.2
45-55 years (24)	3	37.5	18	60.0	3	30.0		
Sex								
Male (32)	1	12.5	18	60.0	7	70.0	2.2	0.3
Female(16)	7	87.5	12	40.0	3	30.0		
Laterality								
Left (21)	4	50.0	12	40.0	5	50.0	5.4	0.2
Right (27)	4	50.0	18	60.0	5	50.0		
Location								
lower calyx (15)	4	50.0	6	20.0	5	50.0	30.5	**0.001****
Upper calyx (4)	0.0	0.0	0.0	0.0	4	40.0		
Renal Pelvic (28)	3	37.5	24	80.0	1	10.0		
Middle calyx (1)	1	12.5	0.0	0.0	0.0	0.0		
Clinical picture								
Loin pain (36)	4	50.0	25	83.3	7	70.0	16.9	**0.01***
Haematuria (9)	1	12.5	5	16.7	3	30.0		
Fever (1)	1	12.5	0	0.0	0	0.0		
Nausea &vomiting(2)	2	25.0	0	0.0	0	0.0		

* Statistically significant difference ($P \le 0.05$)

Table (3): Comparison between patients with different stone types regarding stone characterization by DECT among the studied group:

Variable	Uric acid		Ca oxalate		Cysteine		Uric acid	Ca oxalate
	No. (8)	%	No. (30)	%	No. (10)	%		
Number Single (42) Multiple (6)	6 2	75.0 25.0	26 4	86.7 13.3	10 0	100.0 0.0	2.5	0.3
Size (mm) Mean ± SD (Range)	14.4 ± 6.7 (6-28)		11.3 ± 4.3 (4-19)		7.75 ± 0.9 (7-9)		K.W 4.9	**0.01***
Low energy attenuation value HU Mean ± SD (Range)	767.5±226.1 (258-959)		1050.7±293.9 (538-1195)		939.5±201.3 (376-1000)		F= 7.5	**0.002***
High energy attenuation value HU Mean ± SD (Range)	703±210.9 (248-940)		830 ± 253.3 (425-1000)		787.9±259.6 (300-950)		F=3.8	**0.04***
Attenuation ratio Mean ± SD (Range)	0.93± 0.09 (0.7-1.13)		1.59 ± 0.5 (1.25-2.4)		1.21 ± 0.05 (1.14-1.24)		K.W 23.9	**0.001****

* Statistically significant difference (P ≤ 0.05)

** Statistically highly significant difference (P ≤ 0.001)

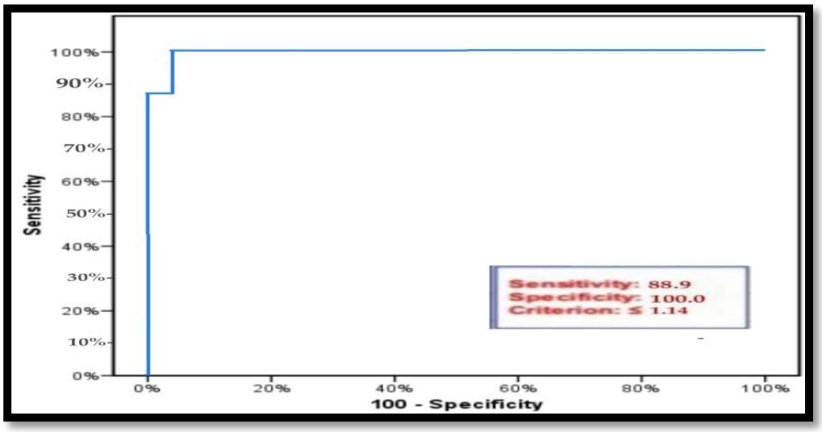

Figure (4):The ROC curve for the 80/Sn140 kV ratio, adjusted for the presence of uric acid based on chemical analysis.

Table (4): Potential treatment based on size and chemical composition:

Stone size (mm),	Stone composition	Treatment	Percentage
< 5,All	All , N=6	medical treatment	12.5%
5-15	N=22		46%
Uric acid	N=3	Medical treatment	6.5%
Non uric acid	N=19	extracorporeal shock wave lithotripsy	39.5%
16 - 20	N=12		25%
Uric	N=3	Medical treatment and ESWL	6.5%
Cysteine	N=2	Percutaneous nephrolithotomy	4%
Calcium oxalate	N=7	extracorporeal shock wave lithotripsy	14.5%
> 20, All	All , N=8	Percutaneousnephrolithotomy	16.5%

Table (5): Number of patients underwent to different types of treatments:

Treatment	no of patient	Percentage %
Medical treatment	12	25%
Extracorporeal shock wave lithotripsy	26	54%
Percutaneous nephrolithotomy	10	21%
Total	48	100%

Table (6): The agreement between DECT and crystallography in stones type detection:

Variable		DECT		Crystallography		Kappa agreement	p-value
		No (48)	%	No. (48)	%		
stones diagnosis	Success (47)	47	97.9%	48	100.0%	0.9	**0.001****
	Failed (1)	1	2.1%	0.0	00.0%		

DISCUSSION

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

In the present study, we found 42 patients(87.5%) had single stone and 6 patients (12.5%) had multiple stones, the mean stone size was 12.3±5.8 mm (range 4-28mm), and showed that about half of stones (56.3%) were right sided, (43.7%) of them were left sided and shows that renal pelvis was the commonest affected site (58.3%) followed by lower calyx kidney (31.3%) of them then upper calyx kidney (8.3%) and middle calyx (2.1%). the assessment of renal stones attenuation profiles depended on low and high energy,In current study, 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, found that uric acidstones ranged from (258-959) HU for low-energy CT,(248–940) HU for high-energy CT, cystine calculi ranged from(376–1000) HU for low-energy CT, (300–950) HU for high-energy CT and calcium oxalate calculi attenuation values ranged from (538–1195) HU for low-energy CT, (425–1000) HU for high-energy CT.

The result of our study agreed with series which were done by **Boll et al., (9)** found thaturic acidstones (453–629) HU for low-energy CT, (443–615) HU for high-energy CT, cystine calculi (725–832) HU for low-energy CT, (513–747) HU for high-energy CT and calcium oxalate (425–2697) HU for low-energy CT, (346–1939) HU for high-energy CT.

In the our study attenuation ratios of < 1.14 was characteristic of uric acid stones, ratio of 1.14 – 1.24 were characteristic of cysteine stones and ratios of>1.24 indicated calcium stones, these result agreed with the study done by **Hidas et al., (10)** found the attenuation ratio of less than 1.1 was characteristic of uric acid stones, ratio of1.1– 1.24 were characteristic of cysteine stones, and ratios greater than 1.24 indicated calcified stone.

The present study failed to distinguish Ca oxalate from Ca phosphate stone, but almost there was excellent agreement between DECT and crystallography with no

(0.0%) false positive cases and one (11.1%) false negative uric stone when using crystallography as a confirmatory test to DECT with identical results.

In the last 20 years, there were great changes in the therapy choice due to the better knowledge of the etiopathogenesis of urolithiasis and the development of more elaborate tools. In particular, endoscopic surgery and extracorporeal lithotripsy have supplanted open surgery in most cases. Unfortunately, at present there is no clear standardization of indication, and the therapeutic decision often falls to the specialist's preferences, surgical ability and technical means. Most commonly the urologist chooses to use the least invasive method, however,it is known that this is not always the most useful approach to obtain the optimal result, which is the complete stone removal without damage to the urinary tract and to renal function.

The clinical management of urinary tract stones depends on the location, size and number of calculi, as well as their chemical composition. The chemical composition of stones affect the type of fragmentation and as a consequence, its elimination with extracorporeal treatment for example cysteine and monohydrate calcium oxalate stones tend to yield large residual fragmentation that are difficult to eliminate **(11)**.

A correlation between stone CT density as measured in Hounsfield units and response to lithotripsy treatment is already known, calcium oxalate stones with a smooth surface, diameter greater than 1cm, and a CT density greater than 1200 HU rarely get fragmented by extracorporeal shock wave lithotripsy, where's calcium oxalate stone with CT density less than 1000 Hu can be treated successfully. in contrast, cysteine stones with CT density greater than 1000 Hu are not treated with extracorporeal shockwave lithotripsy but percutaneous nephrolithotomy **(12)**.

In the present study, the treatment strategies were based on stones size and composition, renal stone <5mm represent (6 patients 12.5%) underwent medical treatment, 5-15 mm represent (22 patients 46%), uric stones (3 patients 6.5%) underwent medical treatment, and non uric(19 patients 39.5%) underwent extracorporeal shock wave lithotripsy, 16-20 mm represent (12 patients 25%), uric acid (3 patients 6.5%) underwent medical treatment, cystine (2 patients 4%) underwent percutaneous nephrolithotomy, Ca oxalate (7patients 14.5%) underwent extracorporeal shock wave lithotripsy, >20mm (8 patients represent 16.5%) not suitable for extracorporeal shock wave lithotripsy, and underwent percutaneous nephrolithotomy. so (12 patients 25%) underwent medical treatment, (26 patients

54%) underwent ESWL and (10 patients 21%) underwent percutaneous nephrolithotomy. the result of our study agreed with **Miller and KANE (13)** found that stones <20 mm, extracorporeal shock wave lithotripsy was used and for stones >20 mm, percutaneous nephrolithotomy was used .

There is some limitation in our study :First, the sample size is still limited due to the large number of patients who spontaneously expelled their calculi and did not bring them to the laboratory for chemical analysis. Second, some patients had poor-quality images due to motion artefacts and obesity. Third, chemical analysis was used to determine the calculus composition, although this analysis is no longer the reference standard for urinary calculi because its accuracy is inferior to more sophisticated techniques (e.g., infrared spectroscopy or X-ray diffraction) (Basha et al., 2018) , Fourth, we classified the calculi based on only their dominant composition and excluded mixed calculi from our study; this point needs additional research. Finally, we classified calculi composition using attenuation ratio based on the manufacturer's recommendations. Thus, radiologists should work closely with the manufacturer of their particular scanner to perform calculus analyses using DECT .

CONCLUSION:

Dual energy CT provides the anatomical information as number, location,maximal diameter, CT density and also characterize the stone chemical composition which use of this technique could help doctor and patient select appropriate treatment and avoid more invasive & high impact procedures.

No Conflict of interest.

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