EVALUATION OF RENAL STONES BY COMPUTED TOMOGRAPHY AND ITS CORRELATION WITH URINE pH AND BIOCHEMICAL ANALYSIS

Bonigala Pratap Kumar[1], S Ahmed Varusai[2]

[1]Associate Professor, [2]Assistant Professor, Department of Radiology, Karpaga Vinyaga Institute of Medical Sciences and Research Center, Madhurantagam, Kanchipuram District, Tamilnadu, India.

ABSTRACT

Introduction: The aim of the study is to assess the composition of renal stones by non chemical analysis that is by use of computed tomography (CT) values in Hounsfield Units (HU) and to compare the results of biochemical stone analysis collected post surgically done in biochemistry lab. **Methodology:** This is a prospective study, included patients in age group of 25 – 60yrs. Patients who were referred to radiology department from Urology and also patients referred from surgery with complaints of loin pain, groin pain, hematuria, crystalluria were recruited for the study. About 100 patients were screened with first line modality of ultrasound evaluation for identifying the presence of stone in kidney, later on positive confirmation from ultrasound evaluation they were further subjected to CT scan evaluation. "Urine was collected from all the patients with renal stones and urine pH was measured. Stones collected post surgically were used for the biochemical analysis to know the chemical composition of the stones **RESULTS:** The stone removed from the patients of this group contain high calcium content. Most of the stones removed from bladder comprises two categories 1.uric acid (mainly) 2.large stones more than 20 mm size were proved to be calcium stones possibly related to greater sunlight exposure, resulting in increase in insensible fluid losses and increase in vitamin D production. We obtained a reference from hounsfield units value from stones collected post surgically from the urological department. The stones are categorized into three types - Pure highly reflective crystalline white stones, Stones which appears most mostly black, Complex mild yellow stones. **Conclusion:** CT may enable accurate in vivo characterization of kidney stone composition.

Keywords: Hounsfield unit (HU); Renal stone; Computed Tomography.

INTRODUCTION

A kidney stone is a solid piece of material that forms in the kidney from substances in the urine. It may be as small as a grain of sand or as large as a pearl. Most kidney stones pass out of the body without help from a doctor. But sometimes a stone will not go away. It may get stuck in the urinary tract, block the flow of urine and cause great pain. In addition to causing severe pain (renal colic) resulting in emergency room visits and sometimes hospitalization, stone formation is associated with increased rates of chronic kidney disease and hypertension. The composition of a kidney stone can be determined by laboratory analysis after passage or surgical removal of the stone [1].

Composition of renal system stone is important for determining the optimal mode of treatment, and dietary and medical measures to reduce the risk of recurrence [1]. For example stones composed of cystine or calcium oxalate monohydrate have a firm composition and can be treated effectively with PCNL.

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Common techniques for in vitro stone analysis include: X-ray diffraction, infrared spectroscopy, polarization microscopy but it has no role in pre operative assessment. CT scan of the abdomen and pelvis can be used for diagnosis and evaluation of renal stone by using Hounsfield Units (HU) and found that it has high sensitivity [2]. The size and location of the stone and the overall health of the kidney can be assessed by CT scan and also by density of the stone in HU value by which the chemical composition of the stone can be predicted [1-2]. HUs have been used to predict the type and opacity of stones during diagnosis, and the efficacy has been assessed using methods including extracorporeal shock wave lithotripsy (ESWL), percutaneous Nephrolithotomy (PCNL), ureterorenoscopicureterolithotripsy (URSL), and medical expulsive treatment (MET) [3]. Previous studies have focused on the success rate of HU for predicting the type of stone and of ESWL treatment. The most recent reports have suggested that the HU value

Correspondence: Dr. Bonigala Pratap Kumar, Associate Professor, Department of Radiology, Karpaga Vinayaga Institute of Medical Sciences, Madhurantagam, Kanchipuram, Tamilnadu, India.
Email: dr.nagineniraobhaskar@gmail.com

and its variants facilitate prediction of stone composition [2, 3]. In this study we tried to correlate the type of stone and its composition by using CT, HU density and urine pH of the patients.

Radiographic features: These depend on stone composition, and vary according to modality. The much greater sensitivity of CT to tissue attenuation means that some stones radiolucent on plain radiography are nonetheless radiopaque on CT [4].

Abdominal radiography: Calcium-containing stones are radiopaque

struvite (triple phosphate) - usually opaque but variable Lucent stones include: uric acid, cystine

Indinavir stones: pure matrix stones (although may have radiodense rim or centre) [5, 6]

Fluoroscopy: This exam has been largely replaced by noncontrast CT.

Ultrasound: Ultrasound is frequently the first investigation of the urinary tract, and although by no means as sensitive as CT, it is often able to identify calculi. Small stones and those close to the corticomedullary junction can be difficult to reliably identify [5, 6].

DECT is a technique allowing determination of calculus composition, by assessing stone attenuation at two different kVp levels. Each CT vendor has its own algorithms for the use of dual energy CT for assessing stone composition [7].

Differential diagnosis: The differential of renal calculi is essentially that of abdominal calcifications. On CT there is usually little confusion as not only is CT exquisitely sensitive in detecting stones, but their location can also be precisely noted [8].

Thus the differential diagnosis is predominantly on plain radiograph, and to a lesser degree ultrasound:

cholelithiasis overlying right kidney, pancreatic calcification, phleboliths, calcified mesenteric lymph nodes, renal artery calcification [9], intrarenal gas (only a differential for ultrasound) acoustic shadow is usually 'dirtier', gas typically more mobile than stones, pure/protein matrix stones may mimic an upper tract soft tissue mass [10].

The aim of the study is to assess the composition of renal stones by non chemical analysis that is by use of CT values in Hounsfield Units, correlate HU value with urine pH and also to compare the results with stone analysis done in biochemistry lab.

MATERIALS AND METHODS

Study design: It was an Observational study

Ethics approval: The study was approved by institutional ethical committee. After explaining the purpose of the study, informed consent was obtained from all the participants.

Study period: Study was conducted in a span of 8 months

Inclusion criteria: Patients age range of 25 to 67 years, who were referred to radiology department from Urology and Surgery departments with complaints of loin pain, groin pain, hematuria, crystalluria were recruited for the study. Only stones with a diameter of more than 20 mm were included in the study.

Exclusion criteria: Patients had received treatment for previous stones.

Sample size: A total of 172 patients with complaints of loin pain, groin pain, hematuria, crystalluria were screened with first line modality of ultrasound evaluation for identifying the presence of stone in kidney. Out of 172 screened patients, 100 patients were diagnosed with renal stones.

Methodology: Later on positive confirmation from ultrasound evaluation they were further subjected to CT scan evaluation. All patients underwent a single-energy computed tomography (SECT) scan (Siemens, Germany) as per our hospital protocol for renal stones(0.55 mm thickness, 2.5-mm increments, 120 kVp, and 240 mA, pixel width 0.7mm). In order to assess the HU values, we used the Siemens software Agfa, (Beljium & Germany) to view and evaluate the scans digitally. The highest attenuation value in a pixel for each stone was accessed by adjusting the window view with the width made equal to 1 HU (maximum contrast) and the level progressively heightened (Figure 1).The highest HU value in a stone (PixHU); the mean HU value (mPixHU), defined as the sum of the highest HU values of a pixel in each cut divided by the total number of cuts; and the standard deviation of the mPixHU (sdmPixHU) were considered the representative SECT values of each-stone.

CT images are made up of pixels each of which has a gray scale value from 1 (black) to 256 (white). This value corresponds to the amount of X rays that pass through the structure and it is measured and expressed in HOUNSFIELD UNITS.HU range from -1000(black) to +1000(white) [5 -7]

Table 1. Demographic features of the study

	Age	HU	Urine PH
N	100	100	100
Mean	45.28	897.65	5.88
Median	46	875	6
Std. Deviation	10.423	420.172	0.787
Minimum	25	134	4
Maximum	67	1800	7

HU – Hounsefield unit

Table 2. Frequency of the males and females included for the study

Sex	Frequency
Male	67
Female	33
Total	100

Table 3. Frequency of type of crystal

TYPE OF CRYSTAL	Frequency
CALCIUM OXALATE	54
CALCIUM PHOSPHATE	9
CYSTINE	21
URIC ACID	16
Total	100

Table 4. Pearson correlation study among patients with renal stone

	Correlations	Age	HU
HU	Pearson Correlation	0.069	
	Sig. (2-tailed)	0.497	
	N	100	
Urine pH	Pearson Correlation	-0.082	**.259****
	Sig. (2-tailed)	0.418	**0.009**
	N	100	100

there is 25.9% positive correlation b/w HU & Urine pH

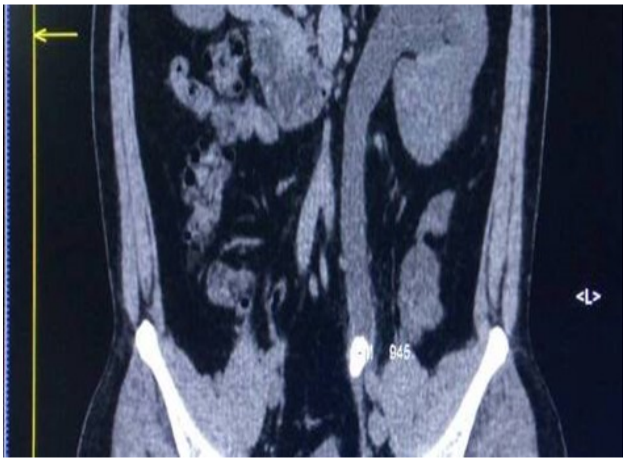

Figure 1. Arrow shows the renal stone with 945 HU

Water = 0 HU, fat = --100HU, blood and other tissues have +HU.

After obtaining CT values in HOUNSFIELD UNITS the stone were analysed for chemical composition in our chemistry lab by adopting suitable qualitative stone analysis methods.

RESULTS

Total 100 patients were included in the study. Out of 100 patients 67 patients were males and 33 patients were females. Mean age of patients was 45.2 ± 10.4 with minimum age of 25 years and maximum of 67 years. (Table 1 & 2)

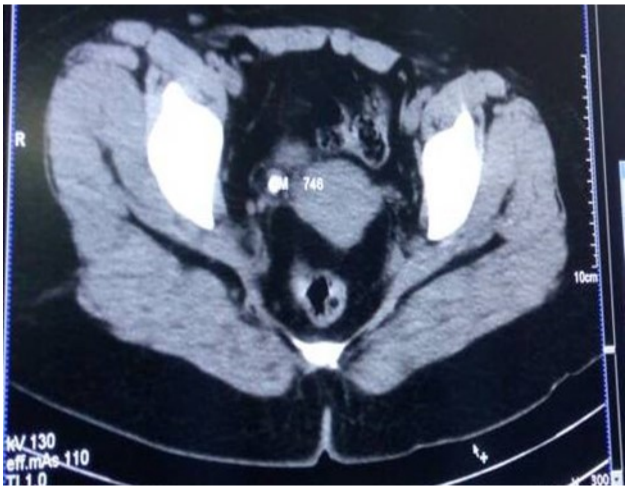

Figure 2. CT image showing renal stone with HU 746

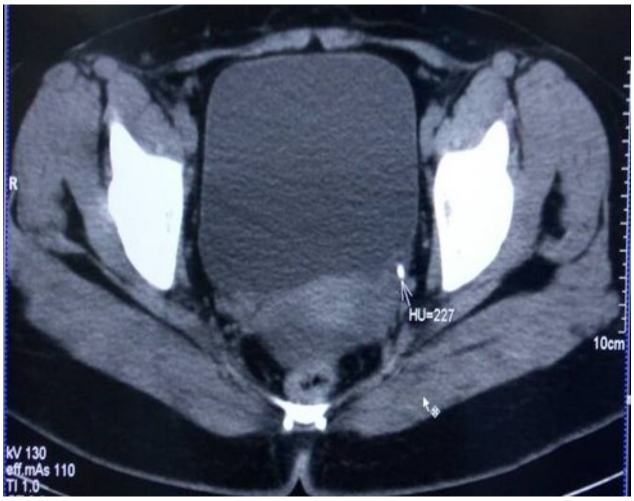

Figure 3. A CT image showing renal calculi with HU 227

Based on the HU of the CT scan, type of crystal was assessed. Simultaneously urine sample of the patient was collected and sent to biochemistry lab to measure PH of urine. Renal stones were collected from all the recruited patients after PCNL surgery and sent to biochemistry lab for chemical analysis of the stone composition.

The HU values ranging 750 to 1800 HU (Figure 1) were determined as calcium oxalate crystals. Out of 100 patients, 63 patients were identified as calcium crystals. Their mean HU value is 1157 and standard deviation is 285.04. Mean urine PH of patients with calcium oxalate crystals was 5.95.

Out of 100 patients, 21 patients were found to have HU values in the range of 368 to 684 HU (Figure 2) were determined as cystine crystals. The mean and SD value HU of cystine crystals was found to be 578.6 ± 95.8. Mean urine PH of patients with cystine crystals was 6.65.

Remaining 16 patients were found to have HU values in the range of 134 to 350 HU (Figure 3) were determined as uric acid crystals. The mean and SD value of HU of uric acid crystals was 294.56 ± 62.4. Mean urine PH of patients with uric acid crystals was 4.68.

Description of the renal stones

Of the 100 patients identified with renal calculi, 54% of the crystals were found to be calcium oxalate, 9% of the stones were found to be of calcium phosphate crystals, 21% were found to be cystine crystals, 16% were found to be Uric acid crystals. Most of the stones were of pure crystals. (Table 3)

Pearson correlation was used to find the correlation of between urine pH and HU. There was a positive correlation between urine pH and HU (25.9%) (Table 4).

From the least to the most dense the stone types were uric acid, struvite, cystine, calcium oxalate dihydrate, calcium oxalate monohydrate and brushite. Each type of calculus was easily differentiated from one another (p <0.03) using the 2 parameters measured. The best single CT parameter for this purpose was the absolute CT value regon of interests at 120 kv. Derived The chemical composition of uric acid, struvite and calcium oxalate stones was accurately identified based on the absolute CT value measured at 120 kV. Uric acid calculi were theonly stones that could be distinguished from all other stones using the absolute CT value measured at 120 kV. The mean HU at 120 kV for uric acid stone was 409 -118, which was considerably lower than that of other stones. Struvite calculi could be distinguished from uric acid, calcium oxalate dihydrate, calcium oxalate monohydrate and brushite stones by the absolute CT value. The use of dual energy CT value permitted distinction of struvite from cystine calculi with statistical significance (p <0.0001). Calcium oxalate stones (dihydrate and monohydrate) were easily distinguished from all stones using the absolute CT value except when compared to brushite calculi.

Among the study the pure white stones which gave a high HOUNSFIELD UNITS value were proved as calcium stones, and second category of stones were proved as uric acid stones, third category appeared to be cysteine stones. There is some promise in applying this information to an in vivo setting to assist the urologist with the appropriate selection of treatment to optimize success. While there is some overlap in the absolute CT values of calculi, the ability of CT to differentiate the most common types of calculi of uric acid, struvite and calcium oxalate remains accurate and dependable.

The use of dual energy CT value permitted this distinction with statistical significance (p <0.03). Finally, calcium oxalate dihydrate and monohydrate calculi were distinguished from each other using the dual energy CT value.

People who live nearby and peripheral part of lignite belt (Neyveli) are more susceptible for stone formation. Though no study could prove this hypothesis so far the content of portable water in these areas is causing stone formation. Whether this could be taken as high incidence for prevalence of kidney stones could be evolved by hypothesis.

DISCUSSION

CT has long been used to evaluate radiolucent masses of the upper collecting system [4-6]. In 1978 Segal et a1 [7] used CT to 0 f 41 -29 distinguish calculus from tumor or clots. They found that CT could define a calculus as small as 5 mm. with greater density discrimination that conventional radiography or tomography [7]. The HU measured for a calculus was significantly higher than that for tumor or clots. In their series 2 pure uric acid calculi had CT values measured at 140 and 160 HU. A third calculus that was a mixture of uric acid predominantly and calcium oxalate had a higher CT value at 240 HU. Miller al examined 9 patients with nonopaque calculi in the upper urinary tract by CT analysis [8]. In vivo and in vitro CT studies of calculi were performed. In vivo CT studies demonstrated uric acid stone attenuation values of 346 to 400 HU, while cystine stone measured at 586 HU and calcium oxalate at 510 HU. They also studied these calculi in vitro in a water bath and found similar CT values [9 - 12].

Using absolute CT values can distinguish calculi from tumor and clot with a high degree of accuracy [13]. *As* such, the same concept has been applied to determine the composition of different calculi using the absolute CT values. There have been 3 previous reports of CT analysis of urinary calculi in an in vitro model. Table 3 illustrates the comparison of this study data using GE HiSpeed scanner versus other published studies. Previous studies showed that the differentiation of stone chemical composition can be made on the basis of the 3 parameters of absolute CT value at a single x-ray energy, the difference between CT values measured at 2 different x-ray energies, and CT value frequency histograms (pixel patterns) of the stone [12 -14]. Uric acid stones were differentiated from all other stones at a significant level by the absolute CT value at 125 kV. and also by the change in CT value when scanned at 77 and 125 kV. Similarly, calcium oxalate and brushite stones were differentiated from other stones using these 2 parameters. It was not possible to differentiate between struvite and cystine stones [15].

Many authors in their studies demonstrated that in an in vitro setting CT is accurate in differentiating the 3 most common types of renal calculi of uric acid, calcium oxalate and struvite [11, 13-15]. A multivariate analysis showed that the mean and standard deviation of stone pixel values were the best CT parameters for differentiating types of renal calculi and the results of scanning calculi in vitro including few mixed stones [14, 16]. The CT images of the individual stones displayed great in homogeneity of density throughout the scanned plane, a finding also observed by Silva et al. However, when arranged according to CT density, they also showed a similar trend from the least to the densest calculi reported by the others (Table 4).

Our results are in agreement with the previous authors in that in an in vitro setting the chemical composition of urinary calculi can be accurately predicted by CT. To our knowledge our report is the first in vitro study in which all types of calculi could be differentiated from each other with statistical significance using the 2 CT parameters of absolute CT value at 120 kV and the dual kilovolt CT value. In our series we used 1 mm. section thickness through the stones to minimize the partial volume effects that can contribute to CT number measurement error [17]. The best single CT parameter for differentiating the stones was the absolute CT value at 120 kV. We demonstrated that from the least to the most dense the stone types were uric acid, struvite, cystine, calcium oxalate dihydrate, calcium oxalate monohydrate and brushite. This finding corroborates other previous reports [6, 9 12, 13 -16]. The slight variations in the absolute CT numbers may be attributed to the different scanners as well as the energy settings used. There are some overlaps between the CT numbers, especially when differentiating struvite from cystine and calcium oxalate from brushite calculi. CT is quite accurate in differentiating the 3 most common types of renal calculi of uric acid, calcium oxalate and struvite [17, 18]. The average absolute CT value for uric acid ranges from 409 to 540 HU, while for struvite it ranges from 651 to 943 HU and for calcium oxalate calculi from 948 to 1,620 HU between the different series (table 4. Levi et al reported considerable variability in the CT numbers obtained from scanning the same phantom with different equipment [19].They found this to be true not only among scanners manufactured by different companies, but even among different scanners of the same manufacturer and model, which may explain the slight variations seen in CT numbers among different reports. It has been reported that CT of bone obtained at various energies demonstrates decreasing Hounsfield units with increasing x-ray energy levels. This property has been exploited to determine the composition of trabecular bone and differentiating fatty infiltrate of the liver from low density tumors [18 - 20]. This concept has been applied to differentiate chemical composition of stones using 2 energy levels. Wolf JS measured the dual kilovolt CT values at 77 and 125 kV and found that single energy scanning provided almost the same information as the dual energy scanning of calculi [6, 19-20].

We used 80 and **120 kV.** Energy levels to measure the dual kilovolt CT value. We also observed that in the majority of cases when single energy scanning was able to differentiate the chemical composition of stones, the dual energy scanning provided no additional information. However, dual energy scanning was extremely valuable in differentiating stones when single energy scanning could not do so.

CONCLUSION

To conclude our study we are able to analyse our observation in vivo study and in vitro study comparatively resulting in 85% accuracy. Though the chemical composition of stones has no relevance to surgical exploration by PCNL or open surgeries.

Suggestion: Though our study we were able to give metabolic, dietary advice to the patients to reduce future recurrence .

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