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DIAGNOSTIC ACCURACY OF CT HOUNSFIELD UNIT FOR DETECTION OF CALCIUM STONES IN PATIENTS WITH RENAL STONE DISEASE

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ABSTRACT

Introduction: Different radiological investigations are used to evaluate renal stones and among all, non-contrast-enhanced computer tomography (CT) provides the highest level of diagnostic accuracy with low radiation exposure for urinary stones. Hounsfield unit is linear transformation of original linear attenuation coefficient measurement into one in which the radio-density of distilled water at standard pressure and temperature is defined as zero Hounsfield unit. Materials & Methods: A total of 201 patients of both genders (Male and Female) with age 15-60 years presenting with renal stones of any size undergoing percutaneous nephrolithotomy were included. Pregnant females, claustrophobia, young age and morbid obese were excluded. Non-contrast Computerized Tomographic scan (CT scan) was performed. Using GE-128 Slice and Hounsfield Unit was determined. Patient were undergone percutaneous nephrolithotomy and extracted stone was subjected to chemical analysis. Results: In CT positive cases, 95 were true positive and 08 were false positive. While in CT negative patients, 91 were true negative and 07 were false negative. Overall sensitivity, specificity, positive predictive value, negative predictive value and diagnostic accuracy of CT Hounsfield unit for detection of calcium stones in patients with renal stone disease taking stone chemical composition as gold standard is 93.14%, 91.92%, 92.23%, 92.86% and 92.54% respectively. Conclusion: This study concluded that the diagnostic accuracy of CT Hounsfield unit for detection of calcium stones in patients with renal stone disease is very high.

KEYWORDS: Urolithiasis, calcium oxalate, computed tomography.

INTRODUCTION

A urolithiasis is a solid concretion or crystal aggregation generated in the kidneys by dietary minerals in the urine. It is also referred to as a urinary tract calculus or nephrolithiasis.[1] Nephrolithiasis, ureterolithiasis, and cystolithiasis are three common classifications for urinary stones. Other classifications include chemical makeup (calcium-containing, struvite, uric acid, or other compounds). The majority of stones (68.0%) are calcium oxalate stones. Uric acid, struvite (magnesium ammonium phosphate), and other unrelated substances like cystine are included in different stone compositions.[3] Numerous hypotheses have been put out, despite the fact that the specific aetiology of urinary stone disease remains unknown.[4]

The supersaturation, crystallisation theory is the one that is most frequently accepted.[5] This hypothesis states that the solubility product, at which dissolved solutes can form the solid phase's nuclei, is achieved when the concentration of solutes in urine rises (the metastable zone). Both homogeneous and heterogeneous nuclei can arise. Pure solutions are necessary for homogeneous nucleation, which necessitates higher thermodynamic energy. It is thought that heterogeneous nucleation starts the crystal-forming process. Among all the radiological tests used to assess renal stones, non-contrast-enhanced computer tomography (CT) offers the best level of diagnostic precision with the least amount of radiation exposure.[7,8] The radio-density of distilled water at standard pressure and temperature is defined as zero Hounsfield unit, which is a linear translation of the original linear attenuation coefficient value. CT may be used to determine a stone's composition exactly.

Different compositions of renal stones, such as those that include calcium, oxalate, uric acid, matrix, struvite, cysteine, and many others, are widely described in the literature.[10]

SWL is the best method for 1-2 cm non-lower polar renal stones, while PCNL is recommended in the literature for lower polar stones.

Small to moderate-sized intrarenal calculi have historically responded well to SWL. SWL has become the accepted treatment for treating tiny stones up to a maximum diameter of 20 mm since it is noninvasive, has a low risk of problems, and doesn't need for anaesthesia.[11] Shock wave lithotripsy is less likely to dissolve stones with density > 1,000 HU on non-contrast-enhanced CT.[12] \sCT The Hounsfield unit is quite accurate in finding renal stones that contain calcium. 12 According to a prior research, the Hounsfield unit can clearly distinguish uric acid, struvite, calcium oxalate, and carbonate apatite stones (p0.001) and can distinguish them with a sensitivity of 80% and specificity of 84% when the cutoff value is 1.66. Overall, 82% of calcium stones were detected (112 out of 137). Uric acid (541.8858.69), Calcium oxalate Monohydrate+Calcium oxalate Dihydrate (960.44244.84), and Calcium oxalate Monohydrate COM (1016.82243.63) are the corresponding values for calculus composition vs. HU.[13]

In our country, there has never been a study that can demonstrate the diagnostic value of CT Hounsfield in identifying the renal stone composition of calcium-containing stones without stone analysis. Therefore, a research focusing on this evaluation will be very helpful for managing renal stones in our patient, avoiding unnecessary surgery and ESWL usage in patients with renal stones.

MATERIALS AND METHODS

The ethical review committee's blessing was obtained. Patients' informed consent was obtained. 201 participants in this cross-sectional validation research were male and female and ranged in age from 15 to 60. 80%13 sensitivity, 84%13 specificity, 80%13 prevalence, 10% precision for sensitivity, 10% precision for specificity, and 95% confidence level were used to compute sample size. Consecutive non-probability sampling was utilised. Patients receiving percutaneous nephrolithotomy for kidney stones of any size were included. From July 2021 to June 2022, the study was carried out in the Shahida Islam Teaching Hospital in Lodhran and the Bahawal Victoria Hospital in Bahawalpur. Patients who were severely obese (BMI >35 kg/m2), pregnant women, and claustrophobics were not included in the research.

All patients who were enrolled had a history check, physical exam, and many tests, including an abdominal ultrasound, full blood count, coagulation profile, and anaesthetic fitness tests. Non-contrast Radiology departments at Bahawal Victoria Hospital in Bahawalpur and Shahida Islam Teaching Hospital in Lodhran both performed computerised tomography scans (CT scans). Calcium stones were identified using the GE-128 Slice and Hounsfield Unit and reported as present or absent. In the department of urology, shahida islam teaching hospital lodhran and bahawal Victoria hospital, bahawalpur, patients underwent percutaneous nephrolithotomy and the stone that was removed was chemically analysed.

SPSS V-20 was used to enter and evaluate all of the data. All quantitative data, such as age and stone size, were given a mean and standard deviation. All qualitative variables, including gender and geography, were computed using frequency and percentage. By building the following 2x2 table, the sensitivity and specificity were computed.

Calcium stone on Stone Chemical Composition

Calcium Stone on C.T Hounsfield Unit	Yes	No
Yes	TP	FP
No	FN	TN

Sensitivity: TP / (TP+FN) x 100
Specificity: TN / (TN + FP) x 100
Predictive value of a positive test: TP / (TP+FP) x 100
Predictive value of a negative test: TN / (TN+FN) x 100
Pretest Probability: (TP+FN) / (TP+FP+TN+FN) x 100

RESULTS

Age range in this study was from 15-65 years with mean age of 33.73 ± 10.61 years. Majority of the patients 150 (74.63%) were between 15 to 40 years of age. Out of these 201 patients, 118 (58.71%) were female and 83 (41.29%) were males with female to male ratio of 1.4:1. Mean size of stone is 28.52 ± 8.93 mm. Distribution of patients according to location of stone is shown in Figure I. All the patients were subjected to first computed tomography and then PCNL was done. CT supported the diagnosis of calcium stones in 103 patients. Chemical analysis confirmed calcium stones in 98 cases. In CT positive cases, 95 were true positive and 08 were false positive. While in CT negative patients, 91 were true negative and 07 were false negative (Table I). Overall sensitivity, specificity, positive predictive value, negative predictive value and diagnostic accuracy of CT Hounsfield unit for detection of calcium stones in patients with renal stone disease taking stone chemical composition as gold standard is 93.14%, 91.92%, 92.23%, 92.86% and 92.54% respectively. ROC curve is shown in Figure II.

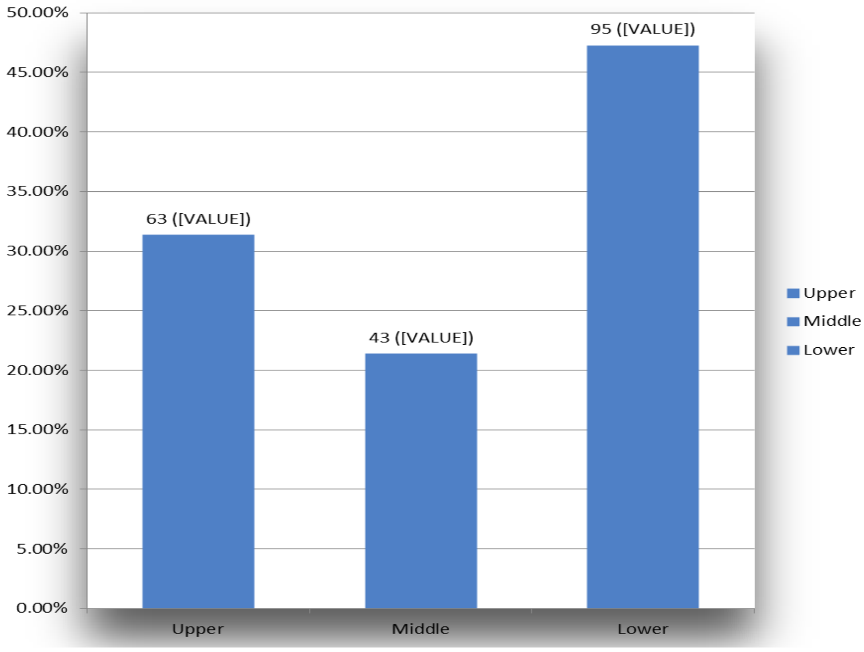

Figure I: Distribution of patients according to location of stone (n=201).

Table I: Diagnostic accuracy of CT Hounsfield unit for detection of calcium stones in patients with renal stone disease taking stone chemical composition as gold standard.

	Positive result on chemical composition	Negative result on chemical composition	P-value
Positive on CT	95 (TP)*	08 (FP)***	
Negative on CT	07 (FN)**	91 (TN)****	0.0001

*-TP=True positive **-FP=False positive ***-FN=False negative ****-TN=True negative

Sensitivity: 93.14%
Specificity: 91.92%
Positive Predictive Value (PPV): 92.23%
Negative Predictive Value (NPV): 92.86%
Liklihood ratio for positive test result: 11.53
Liklihood ratio for negative test result: 0.076
Diagnostic Accuracy: 92.54%

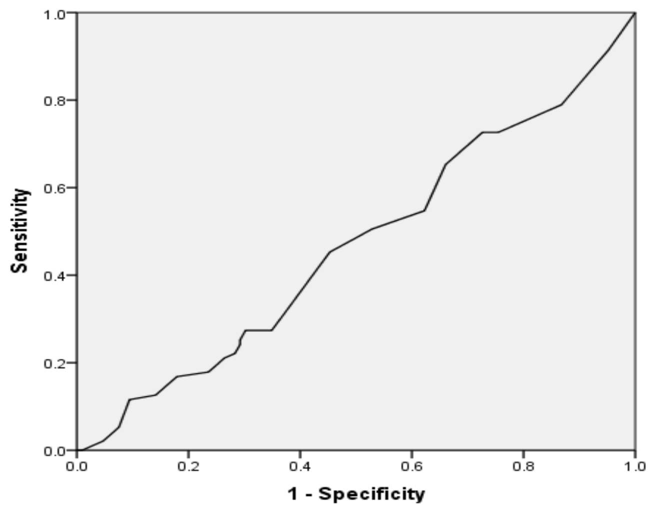

Figure II: ROC Curve.

DISCUSSION

In individuals with urinary system stones, the use of helical non-contrast computed tomography (CT) has grown recently. The density of the stone or structure of interest is connected to Hounsfield units (HU), a measure produced from conventional CT. The radiodensity scale was created by Sir Godfrey Newbold Hounsfield, who also invented the idea of measuring how much X-ray energy penetrates or is absorbed by tissues. Each of the pixels that make up a CT picture has a grey scale value ranging from 1 (black) to 256. (white). The amount of X-rays that travel through the structure is represented by this value, which may be measured and given in Hounsfield units (HU). Since then, HU have been used to assess and measure tissues and fluids. Fat has a negative HU when the radiodensity of water is set to 0, but blood and other tissues have a positive HU. This approach makes it feasible to identify 256 shades of grey that are invisible to the unaided eye. The CT density of urinary system stones may also be evaluated using the 11 HU technique. This has grown in importance as a diagnostic tool in recent years, serving as both a stone type predictor and a treatment mode choicer. By using the chemical composition of the stones as the gold standard, I have done this study to evaluate the diagnostic efficacy of the CT Hounsfield unit for calcium stone identification in patients with renal stone disease. There were 95 genuine positive CT cases and 8 false positive instances. 91 CT negative patients had real negative results, while 7 had fake negative results. When using the chemical composition of the stone as the gold standard, the overall sensitivity, specificity, positive predictive value, negative predictive value, and diagnostic accuracy of the CT Hounsfield unit for the detection of calcium stones in patients with renal stone disease are 93.14%, 91.92%, 92.23%, 92.86%, and 92.54%, respectively. According to a prior research, the Hounsfield unit can clearly distinguish uric acid, struvite, calcium oxalate, and carbonate apatite stones (p0.001) and can distinguish them with a sensitivity of 80% and specificity of 84% when the cutoff value is 1.66.[13]

According to Bellin et al., stone density and helical CT attenuation may both be used to predict stone composition in vitro with 64%–81% accuracy. On the basis of attenuation measures, in vitro calculi of uric acid, cystine, calcium oxalate monohydrate, and brushite have been detected with an accuracy of more than 85%.[14,15] Despite the fact that studies' estimates of the attenuation values of various types of stones (especially struvite stones) varied, CT is a reliable tool for predicting stone composition in vitro.[14,16] Urinary calculi often have attenuation values between 200 and 450 HU for uric acid, 600 to 900 HU for struvite, 600 to 1100 HU for cystine, 1200 to 1600 HU for calcium phosphate, and 1700 to 2800 HU for calcium oxalate monohydrate and brushite.[14,16]

To choose the best course of treatment, it is essential to comprehend the makeup of urinary system stones. The composition of stones has long been predicted by urine pH, the presence of crystals, the presence of urease-positive bacteria in the urine, plain radiography, and a history of urinary stones; more recently, HU has also been employed for this purpose.[17] In an in vitro research, Mostafavi et al.[18] found that HU could accurately predict the composition of stones. By dividing HU by the largest transverse diameter of the stone (in mm), Motley et al[19] sought to identify the composition of the stone and indicated that HU density was more accurate than HU alone. The scientists did note, however, that neither the HU value nor the density were enough for figuring out the composition of stones in vivo.[19]

The HU values were shown to be particularly helpful for identifying calcium oxalate monohydrate and dihydrate stones by Patel et al[20], who looked at whether they could be used to distinguish between different subtypes of calcium stones. In a related study, the researchers found that calcium stones could be distinguished from cystine and uric acid stones with good accuracy using HU values, but that it was challenging to distinguish between these two forms of stones due to the overlap in HU values. As our investigation showed (1123 254 and 844 346), the cacium phosphate stones (brushite and apatite) had the highest densities based on their HU values. Urine pH and HU were used in an in vivo investigation by Spettel et al[22] to predict the presence of uric acid stones. They claimed that utilising both measures together was more successful than using each one separately. In particular, a HU 500 and pH 5.5 exhibited a positive prediction value of 90% for uric acid composition for stones larger than 4 mm. Marchini et al.[23] observed that the HU values of pure and mixed struvite stones overlapped in order to clarify whether the composition of struvite stones could be anticipated using HU values. They came to the conclusion that struvite stone composition could not be reliably predicted by HU.

When Mostafavi et al.[24] were able to analyse the chemical makeup of pure stones, they discovered that uric acid attenuations ranged from 409 HU to 1703 HU for brushite. They found that the three most common stone types—uric acid, struvite, and calcium oxalate—could be accurately distinguished using single-energy scanning at 120 kV; however, dual-energy scanning was required to distinguish between stones with similar densities, such as struvite and cystine and calcium oxalate and brushite stones. At 1 mm, 3 mm, and 10 mm collimation, 127 urinary calculi were scanned by Saw et al.[25] With the exception of brushite and hydroxyapatite, all stone types could be distinguished by the spiral CT scan at 1 mm collimation. NCHCT was investigated by Nakada et al.[26] for predicting in vivo stone composition. They discovered a significant difference between calcium oxalate stones and uric acid in the Hounsfield measurement.

Urologists can choose the best course of therapy and imaging modality to utilise during follow-up by using information on the radio-opacity of urinary system stones. However, nothing is known about the connection between radio-opacity and the range/threshold of the HU values of stones evaluated by CT. The benefits of utilising CT to detect radiolucent stones include avoiding needless follow-up radiographies, limiting radiation exposure, easing patient worry, and saving money. The radio-opacity of stones detected using plain radiographs and HU values was also evaluated by Chua et al. With 89.3% sensitivity and 87.3% specificity, they determined that 498.5 HU was the proper cut-off value for detecting whether a stone > 4 mm was radio-opaque or radiolucent after looking at 184 instances.[27] In a research that included included ureteral stones, Huang et al.[28] found that stones with a density of > 800 HU were apparent on simple radiography pictures, whereas stones with a density of 200 HU were not. When considered as a whole, the results examining the association between HU values and radio-opacity revealed that some patient groups might be properly followed up with plain radiographs rather than repeated CT scans, saving time, money, and ionising radiation exposure.

According to tests done by Motley et al. on 100 patients, 87 patients had calcium stones, 7 had uric acid stones, 4 had struvite stones, and 2 had cystine stones. Their relative HU values were discovered to be 440 262, 270 134, 401 198, and 248 0. The average HU values for various stone kinds did not show any clear differences.[29] Demirel et al. found that 54 patients had calcium oxalate stones, 19 had struvite stones, and 14 had uric acid stones. The HU values for these stones were 812 135, 614 121, and 413 143, respectively.[30] Based on their average HU values, these three different types of stones could be distinguished (P = 0.001).

CONCLUSION

This study concluded that the diagnostic accuracy of CT Hounsfield unit for detection of calcium stones in patients with renal stone disease is very high. So, we recommend that CT Hounsfield unit for detection of calcium stones should be applied routinely in our general practice for diagnosing calcium oxalate stones pre-operatively which will help the clinicians to take proper managements protocols accordingly.

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