“EVALUATION OF RENAL STONE HOUNSFIELD UNIT (HU) VALUE WITH MULTIDETECTOR COMPUTED TOMOGRAPHY (32 SLICE THICKNESS) AND COMPARISION WITH RENAL STONE BIOCHEMISTRY AND URINARY Ph”

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ABBREVIATIONS

No.	ABBREVIATION	EXPANSION
1	HU	Hounsfield Unit
2	CT	Computed tomography
3	ESWL	Extracorporeal shock wave lithotripsy
4	ANOVA	Analysis of variance
5	KUB	Kidneys, Ureters and Urinary bladder
6	HD	Hounsfield density
7	M	Mean
8	SD	Standard deviation
9	ROC	Receiver operator curve
10	AUC	Area under the curve

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INTRODUCTION

The Hounsfield unit (HU) is a unit of radio density used universally to interpret computed tomography (CT) images. Nephrolithiasis is an extremely common and very often painful urological disorder, with the lifetime risk estimated to be as high as 10–15%. Extracorporeal shock wave lithotripsy (ESWL) is the most commonly employed technique that is used in the management of renal stones; however, the success of this technique depends heavily on the chemical composition of the calculus and its fragility. Hence, the pre-treatment identification of the composition of calculi becomes extremely important. Even though there is currently insufficient data available regarding the usefulness of knowing the chemical composition pre-operatively for assessing the efficacy of percutaneous nephrolithotomy, ureterorenoscopic ureterolithotripsy and medical expulsive treatment, it might assist urologists to decide which of these treatments should be used to treat a patient.

Given the lack of a standard non-invasive investigative modality to achieve this composition identification pre-operatively and given that various reports in the past that have had varying success when using CT and HU values to determine the composition of urinary calculi, the aim of our study was to determine HU values and the chemical composition of renal stones in a cohort of our patients and to then correlate HU value with urine pH and also to compare the results with stone analysis done in biochemistry lab.

AIMS & OBJECTIVES OF THE STUDY:

1. To determine the HU value of different types of urinary calculi in a cohort of patients.
2. To evaluate whether CT HU value can be used as an effective technique to identify the renal calculus composition pre-operatively by comparing and correlating HU value of urinary stones with their biochemical composition and urinary pH

SOURCE OF DATA AND METHODS

This was a prospective observational study conducted among patients with urolithiasis in a tertiary care hospital in Karnataka, India. Patients aged more than 18 years with confirmed urolithiasis who underwent non contrast CT, urinary pH estimation, and biochemical analysis of stone after passing the stone or after ESWL were included in the study. The CT HU value of different types of calculi were compared. Continuous variables were expressed as Mean ± Standard Deviation and compared if required, using unpaired t test/One Way ANOVA if the data followed normal distribution and Mann-Whitney U test/Kruskal Wallis Test if the data did not follow normal distribution. A Pearsons’s correlation coefficient was used to measure the strength of a linear association between HU value and urinary pH. A Receiver operator curve analysis was performed to assess the utility of CT HU in distinguishing the type of stone.

RESULTS

113 patients were enrolled in the study. 70 (62%) were males while 43 (38%) were females. The ages in the study ranged between 18 to 84 years with the mean (M)± standard deviation (SD), median, and mode ages in the study were 40.7±16, 36, and 28 years respectively. The types of stones identified in this study included calcium oxalate, calcium phosphate, uric acid, and struvite stones. There were 57 (50.5%) calcium oxalate stones, 31 (27.5%) calcium phosphate stones, 12 (10.6%) uric acid stones, and 13 (11.4%) struvite stones. The total CT HU values identified in this study ranged between 300 to 1600 with a M± SD, median, and mode of 907±357, 900, and 900 respectively. The CT HU values in calcium oxalate stones identified in this study ranged between 869 to 1600 with a M± SD, median, and mode of 1206±201, 1191, and 1300 respectively. The M± SD HU of non-calcium oxalate stones was 602±179. There was a statistically significant difference identified between HU of calcium oxalate and non-calcium oxalate stones with calcium oxalate stones having a significantly higher HU value ($t=16.702$, $p<0.00001$). The CT HU values in calcium phosphate stones identified in this study ranged between 450 to 946 with a M± SD, median, and mode of 699±136, 700, and 900 respectively. The M± SD HU of non-calcium phosphate stones was 986±382. There was a statistically significant difference identified between HU of calcium phosphate and non-calcium phosphate stones with calcium phosphate stones having a significantly lower HU value ($t=4.046$, $p=0.000048$). The CT HU values in uric acid stones identified in this study ranged between 320 to 800 with a M± SD, median, and mode of 437±115, 445, and 450 respectively. The M± SD HU of non-uric acid stones was 961±336. There was a statistically significant difference identified between HU of uric acid and non-uric acid stones with uric acid stones having a significantly lower HU value ($t=5.214$, $p<0.00001$). The CT HU values in struvite stones identified in this study ranged between 300 to 800 with a M± SD, median, and mode of 515±172, 451, and 350

respectively. The M± SD HU of non-struvite stones was 958±343. There was a statistically significant difference identified between HU of struvite and non-struvite stones with struvite stones have a significantly lower HU value ($t=4.539$, $p<0.00001$). Analysis of variance between the CT HU values of the different types of stones showed a significant difference in HU values between the stones with calcium oxalate stones showing the highest HU value, followed by calcium phosphate, struvite, and uric acid stones respectively ($f=116.47$, $p<0.00001$). The urinary pH in the study ranged from 5 to 7.6 with a M± SD, median, and mode of 6±0.5, 5.9, and 5.8 respectively. The urinary pH in patients with calcium oxalate stones ranged between 5.2 to 7 with a M± SD, median, and mode of 6.1±0.4, 6, and 6.2 respectively. The urinary pH in patients with calcium phosphate stones ranged between 5 to 6.2 with a M± SD, median, and mode of 5.7±0.2, 5.8, and 5.8 respectively. The urinary pH in patients with uric acid stones ranged between 5 to 5.9 with a M± SD, median, and mode of 5.6±0.3, 5.7, and 5.7 respectively. The urinary pH in patients with struvite stones ranged between 6.8 to 7.6 with a M± SD, median, and mode of 7.1±0.2, 7.2, and 7.2 respectively. ANOVA between the pH values of the different types of stones showed a significant difference in pH values between the stones with struvite stones showing the highest pH value, followed by calcium oxalate, calcium phosphate, and uric acid stones respectively ($f=52.362$, $p<0.00001$). On comparison of the CT HU values and urinary pH in this study, Pearson's correlation coefficient analysis failed to demonstrate a significant association between these two parameters ($R=-0.022$, $p=0.817$). An ROC analysis of CT HU for the identification of calcium oxalate stones which were of the highest frequency in the present study showed an area under the curve (AUC) of 0.995.

CONCLUSION:

From the results of this study, CT HU is a reasonable non-invasive investigative technique in pre-determining chemical composition of renal calculi which helps in deciding the mode of treatment. Renal calculi with higher CT HU values are likely to be calcium oxalate stones. Urinary pH, although useful in predicting the chemical composition of certain type of stones, does not correlate well with CT HU values and may be less useful in the pre-procedure determination of stone composition

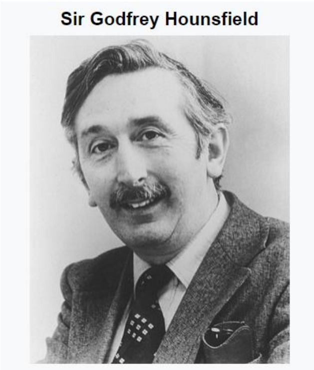
INTRODUCTION

INTRODUCTION

The Hounsfield unit (HU) is a universally used unit of radio density to interpret computed tomography (CT) images. The absorption or attenuation coefficient of the amount of radiation in a particular tissue is used during the reconstruction of CT in order to produce a grayscale image. The density of the tissue is directly proportional to the absorption of the X-ray. Hounsfield unit (HU), which is also known as the CT unit, can then be calculated based on a linear transformation of the baseline linear attenuation coefficient of the X-ray. Distilled water at standard temperature and pressure is defined to have 0 HU while air have -1000 HU [1][2].

The upper limit of HU can be around 1000 HU for bones, 2000 HU for dense bones such as the cochlea, and higher than 3000 for metals and implants. The linear transformation tends to produce a Hounsfield scale which are displayed as gray tones. This results in denser tissue showing positive HU values because of greater X-ray beam absorption and appear brighter. Lower density tissue appears darker with negative HU values because of lesser X-ray absorption. Hounsfield unit (HU) was named after Sir Godfrey Hounsfield, a 1979 Nobel laureate in Physiology and Medicine, for the invention of Computed tomography which led to a revolution in medical diagnostics and subsequent increase in quality of medical care [2][3] (Figure-1).

HU is a relative scale rather than an absolute scale. This is because of the linear transformation of the original linear attenuation. Different X-ray energies tend to result in varying tissue absorption and subsequently varying HUs. Thus, HU tends to be dependent on the various CT parameters [4]. The nature of the CT reconstructing algorithm, its design and the kilovoltage of the X-ray beams, all tend to influence the HU value. The standardization of these parameters makes HU a reliable diagnostic measurement tool [5].



28 August 1919 -12 August 2004

Fig 1- Sir Godfrey Hounsfield

Nephrolithiasis is an extremely common and very often painful urological disorder, with the lifetime risk estimated to be as high as 10–15% in a large-scale study [6]. In a large longitudinal report by the National Health and Nutritional Examination Survey, the prevalence of nephrolithiasis had increased from 3.8% in the 1970s to 8.4% in 2010, highlighting the importance of this condition [7]. The current guidelines for workup in nephrolithiasis include a medical history to identify risk factors with subsequent laboratory investigations to determine the stone composition [8].

A non-contrast helical CT with 5 mm cuts is the current gold standard investigative modality for the diagnosis of renal stones, with following urinalysis, and blood work providing additional information regarding the stone composition [9][10][11]. However, currently there exist no non-invasive techniques that can accurately determine the stone composition. More than two 24-hour urine samples that are tested for metabolic abnormalities including hypercalciuria, hyperuricosuria, hyperoxaluria, and hypocitraturia, may provide some information about the underlying calculus type, however, these are not always accurate and may even be misleading in many cases [12].

The non-contrast helical CTs are highly sensitive and specific for identifying the presence and location of renal calculi, but can only rarely provide definitive information on its composition [13]. The need for a non-invasive technique for identifying the composition of renal calculi has led to physicians turning to the HU as a reasonable means of doing so.

Since the 1990s, unenhanced CT has gained widespread acceptance in the investigation of nephrolithiasis. The precise determination of the stone localization, size, and composition of the stones is key to diagnosis and the choice of treatment [14]. Extracorporeal shock wave lithotripsy (ESWL) is the most commonly employed technique that is used in the management of renal stones; however, the success of this technique depends heavily on the chemical composition of the calculus and its fragility [15][16][17][18]. Brushite, cystine, and calcium stones tend to be more resistant to ESWL than are the other types of stones [19]. Failure of ESWL can increase costs, necessitate alternative treatment, and hence results in undesirable exposure of the kidneys to shock waves. Hence, the pre-treatment identification of the composition of calculi becomes extremely important in deciding whether to perform ESWL or opt for other procedures like percutaneous nephrolithotomy and medical expulsive treatment.

Given the lack of a standard non-invasive investigative modality to achieve this composition identification, and given that various reports in the past have had differing outcomes when using non contrast CT and HU values to determine the composition of urinary calculi, the aim of our study was to determine the HU values and the chemical composition of renal stones in a cohort of our patients and to then correlate HU value with urine pH and also to compare the results with stone analysis done in biochemistry lab.

OBJECTIVES

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1. To determine the HU value of different types of urinary calculi in a cohort of patients.

2. To evaluate whether CT HU value can be used as an effective technique to identify the renal calculus composition pre-operatively by comparing and correlating HU value of urinary stones with their biochemical composition and urinary pH

REVIEW OF THE LITERATURE

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The chemical composition of renal stones depends on the change in the urine composition of different metabolites. Stones can differ in their size, shape, and chemical compositions [20]. Based on the variations in their mineral composition and their pathogenesis, renal stones are commonly classified into 5 types [21]:

Calcium Stones:

Calcium stones are the predominant renal stones that comprise about 80% of all calculi [22]. Calcium stones include calcium oxalate stones (50%), calcium phosphate stones (5%), or a mixture of both (45%) [23]. Many factors contribute to calcium oxalate stone formation including hypercalciuria, hyperuricosuria, hyperoxaluria, and hypercystinuria [24]. A urinary pH between 5.0 to 6.5 promotes Calcium oxalate stone formation [25], whereas calcium phosphate stones generally tend to occur when the pH is greater than 7.5 [26].

Struvite stones

Struvite stones consist of about 10–15% of all renal stones and are also called infection stones or triple phosphate stones. They are frequently seen in patients with chronic urinary tract infections which leads to the production of urease, the most common organism implicated being *Proteus mirabilis* and less commonly implicated pathogens including *Pseudomonas aeruginosa, Klebsiella pneumonia, and Enterobacter* [21][22][27].

Uric Acid Stones

These stones account for about 3–10% of all renal stone types [22][27]. Purines rich diet including high protein diets such as meat and fish, can result in hyperuricosuria, a low urine volume, and a low urinary pH (< 5.05) which can increase the likelihood of uric acid stone formation [22][26][28]. Patients with gout may form renal calculi as well.

Cystine Stones

These comprise less than 2% of all renal stones. Cystine stones are formed because of a genetic disorder of the transport of an amino acid called cystine which results in an excess of cystinuria [22][27] and a deranged renal tubular absorption of cystine or leaking cystine into urine leading to cystine stone formation [26].

Drug-Induced Stones

These account for about 1% of all renal stone types [27]. Drugs such as triamterene, atazanavir, sulfa drugs, and guaifenesin induce calculi. Patients on protease inhibitors are at increased risk of developing renal stones [21]. These lithogenic drugs and its metabolites can induce the formation of stones by interfering with calcium oxalate or purine metabolisms [29].

HOUNSFIELD UNITS:

The normal HU values for various tissues are summarised in table 1 [30].

Table 1: Normal HU values for various tissues

Substance or Organ	Typical HU Value
Air	−1000
Normal lung	−700 to −900
Fat	−100
Water	0
Acute blood	50 to 80
Muscle	50
Intravenous contrast	300
Bone (cortex)	>1000

HOUNSFIELD UNITS IN NEPHROLITHIASIS:

Understanding the composition of renal calculi is critical in determining the optimal mode of treatment. The commonly employed modalities including urinary pH, microscopy to look for presence of crystals, the identification of urease-positive bacteria in urine and a clinical history suggestive of particular diet or previous history of renal calculi are the current methods to predict the composition of renal stones pre-operatively. However, increasing number of reports have been recently published which takes into account the utility of CT HU for this purpose [31].

Mostafavi et al [32] performed a study to determine the precision of spiral CT in the identification of the chemical composition of six types of urinary calculi. Their study included 102 chemically pure stones which were divided into 6 groups. The chemical composition determination was performed using the absolute HU value. They found that although HU was not precise in differentiating calcium oxalate calculi from brushite stone and struvite calculi from cystine stones, CT was able to differentiate the latter stones from the former and uric acid stones from all other stones with statistical significance ($p < 0.03$) based purely on the HU values. They concluded that the chemical composition of renal calculi could be accurately determined by CT using HU values.

Motley et al [33] conducted a study to determine the composition of renal stones using non contrast CT. In their study of 100 pure stones, no significant difference was seen between HU values of calcium oxalate vs calcium phosphate stones. The mean HU values were not significantly different for different kinds of stones analysed either. An ANOVA showed statistically significant differences between the mean HU density of calcium and uric acid stones ($p = 0.006$). When comparing calcium and struvite stones, a trend toward significance was found ($p = 0.073$). They did not find any significant differences among the other stones. They concluded that HU density rather than absolute HU values was more useful in the characterization of urinary stone composition. Their main conclusion was about the usefulness of CT HU values for differentiation of calcium stones from uric acid stones.

Patel et al [34] conducted an in vivo study on 100 patients who had undergone non contrast CT as well as chemical composition analysis of urinary calculus very similar to the present study. They investigated whether HU values were useful in differentiating among subtypes of the calcium calculi. They found that The Calcium oxalate monohydrate had a significantly higher HU when compared to the Calcium oxalate dihydrate group ($p < 0.05$). They also found that Calcium oxalate monohydrate had a significantly lower HU than the brushite calculi ($p < 0.05$). They concluded that CT HU values were particularly useful in the identification of calcium oxalate monohydrate and dihydrate stones, with this being significant in clinical decision making as well as deciding on mode of therapy.

Torricelli et al [35] studied several measurements from a non-contrast CT to try to distinguish between calcium oxalate, uric acid, and cystine calculi. Their study involved a total of 113 patients with pure urinary stones who also had a corresponding non contrast CT. They found that the HU values and HU density were significantly different among the 3 types of calculi ($p<.001$). They concluded that non contrast CT is useful in identifying calcium oxalate stones with a high degree of accuracy.

Spettel et al [36] conducted an in vivo study to identify uric acid stones by using HU along with urine parameters. They found that in 235 cases of renal calculi, there was a significant difference between the HU values as well as urine pH of calcium stones. Using a receiver operating characteristic curve, they found that HU $\leq$494 and pH of $\leq$5.5 tends to predict uric acid stones. They further found that the combination of urinary pH and HU had a sensitivity of 86%, specificity of 98%, and a positive predictive value of 80%. Their conclusion was that CT HU value is a useful tool in differentiating uric acid stones from other kinds of stones.

Shahnani et al [37] conducted a study on 180 subjects to evaluate the efficacy of HU units and non-contrast CT in determining the composition of urinary calculi. They found that calcium stones had a definite range of HU without any significant overlap with other types of renal stones. However, they failed to demonstrate distinct HU values between the other type of stones, namely, between cystine, uric acid, and struvite stones. They concluded that non contrast CT and HU values were only useful in differentiating calcium stones from non-calcium stones, similar to the findings of Motley et al [33]. The different HU values and Hounsfield density (HD) in the different stone types reported by Shanani et al [37] are summarised in table 2.

Table 2: Ranges and means of HU and HD values reported by shanani et al [37]:

Stone groups	95% confidence interval for mean		Minimum	Maximum
	Lower bound	Upper bound		
HU				
Calcium oxalate	448.2	760.8	495	1250
Uric acid	260.3	348.7	274	401
Calcium phosphate	435	631	290	945
Struvite	282.5	373.6	225	396
Cystine	108.9	191.6	112	215
HD				
Calcium oxalate	49.94	68.19	53	179.8
Uric acid	23.63	41.2	15.8	43
Calcium phosphate	37.97	52.6	29.22	98
Struvite	20.29	38.2	14.87	39.9
Cystine	11.52	16.09	11.97	14.95

Silva et al [38] looked at whether the HU value can predict calcium oxalate monohydrate stones in patients who had undergone percutaneous nephrolithotomy. They found that out of 119 patients who had undergone percutaneous nephrolithotomy, by performing a receiver operating characteristics analysis, the optimal cutoff value was 1548 HU to determine the likelihood of a calculus being calcium oxalate monohydrate. They concluded that a higher HU value and increase in age of the patient favored calcium oxalate monohydrate calculi over other type of stones.

Córdova – Chávez et al [39] conducted an observational, descriptive, cross-sectional and retrospective study on 45 patients who underwent both non contrast CT and crystallography for renal calculi. They found that CT HU could be used to distinguish between calcium oxalate and uric acid calculi but it could not distinguish between other components.

Gadelmoula et al [40] evaluated 100 cases with urinary tract stones to look at if the stone composition could be predicted using X-Ray KUB and/or non-contrast CT. They concluded that calculi radio-opacity determination by X-ray KUB followed by estimation of its attenuation value by non-contrast CT could successfully identify calcium oxalate calcium monohydrate, struvite, and urate stones. However, chemical analysis was still required in addition as most stones were mixed. The various studies that looked at the usefulness of HU values in determining composition of renal calculi are summarised in table 3.

Table 3: Summary of studies that looked at the usefulness of HU values in determining composition of renal calculi.

Sl no	Author	Country	Year	Conclusions
1	Mostafavi et al [32]	USA	1998	Chemical composition of renal calculi could be accurately determined by CT using HU values.
2	Motley et al [33]	USA	2001	HU density rather than absolute HU values was more useful in the characterization of urinary stone composition. Their main conclusion was about the usefulness of CT HU values for differentiation of calcium stones from uric acid stones.
3	Patel et al [34]	USA	2009	CT HU values were particularly useful in the identification of calcium oxalate monohydrate and dihydrate stones, with this being significant in clinical decision making as well as deciding on mode of therapy.
4	Spettel et al [36]	USA	2013	CT HU value was a useful tool in differentiating uric acid stones from other kinds of stones.
5	Torricelli et al [35]	Brazil	2014	Non contrast CT is useful in identifying calcium oxalate

				stones with a high degree of accuracy.
6	Shahnani et al [37]	Iran	2014	Non contrast CT and HU values were only useful in differentiating calcium stones from non-calcium stones.
7	Córdova – Chávez et al [39]	Mexico	2014	They found that CT HU could be used to distinguish between calcium oxalate and uric acid calculi but it could not distinguish between other components.
8	Silva et al [38]	Brazil	2016	A higher HU value and increase in age of the patient favoured calcium oxalate monohydrate calculi over other type of stones
9	Gadelmoula et al [40]	Egypt	2020	Calculi radio-opacity determination by X-ray KUB followed by estimation of its attenuation value by non-contrast CT could successfully identify calcium oxalate calcium monohydrate, struvite, and urate stones. However, chemical analysis was still required in addition as most stones were mixed.

MATERIALS AND METHODS

MATERIALS AND METHODS

STUDY SETTING:

This study was conducted over a two-year period from November 2019 to June 2021 at a tertiary care centre - Department of Radio-diagnosis, Shri B.M. Patil Medical college hospital and research centre, Vijayapura, Karnataka, India.

STUDY DESIGN:

Prospective observational Study

PATIENT SELECTION:

A set of patients with confirmed urinary system calculi, who satisfied the inclusion criteria were selected from the departments of Urology, Nephrology, and Radiodiagnosis. In total, 113 patients were selected to be part of the study.

INCLUSION CRITERIA:

- Patients aged more than 18 years who were confirmed to have urinary calculi by CT abdomen and pelvis
- Calculi more than 6mm in diameter

- Patients in who chemical analysis of stone composition and urinary pH measurement could be carried out
- Pure or near pure stones (>80% of one major component)

EXCLUSION CRITERIA:

Patients were excluded from the study if they met any of the following criteria:

- Patients who refused to undergo treatment or stone extraction at the study centre.
- Patients aged less than 18 years
- Calculi less than 6mm in diameter
- Patients who did not want to take part in the study
- Impure stones (<80% of one major component)

METHODS OF DATA COLLECTION:

Imaging protocols:

(i) Non enhanced helical CT of Kidneys-Ureters- bladder performed on a Siemen's SOMATOM Scope- 32 slice Multidetector CT scanner with distended urinary bladder at the time of imaging

(ii) Patient position- Supine with arms above the head.

(iii) Respiratory phase – Inspiratory breath hold

(iv) Scout image was taken from above the diaphragm to below pubic symphysis with a topogram length of 512

(v) Scan extent- Above kidneys to below pubic symphysis.

(vi) In an average sized patient 110 to 130 mAs (milliampere-seconds) and 120 to 140 kV (Kilovolts) were used with a slice thickness of 1.5 mm and Field of view (FoV) of 320 mm

(vii) A collimation of 2.5mm with reconstruction at 2.5mm and a pitch of 0.8 to 1.2 with a study time of 10 to 15 seconds.

Each CT scan was interpreted by a radiologist who was blinded to the clinical details. The stone size was measured in its greatest transverse diameter and HU of the stone calculated using the mean HU between two and five-pixel points of the calculus surface area (Figures 2 to 11). With a Field of view (FoV) of 320 mm, the theoretical size of one pixel in an image matrix is 0.625 mm for 512 x 512 matrix size. As HU could possibly be influenced by the size of the calculus and smaller stones of less than 6 mm are easily expelled without any intervention, only stones with a diameter more than 6 mm were included in the study.

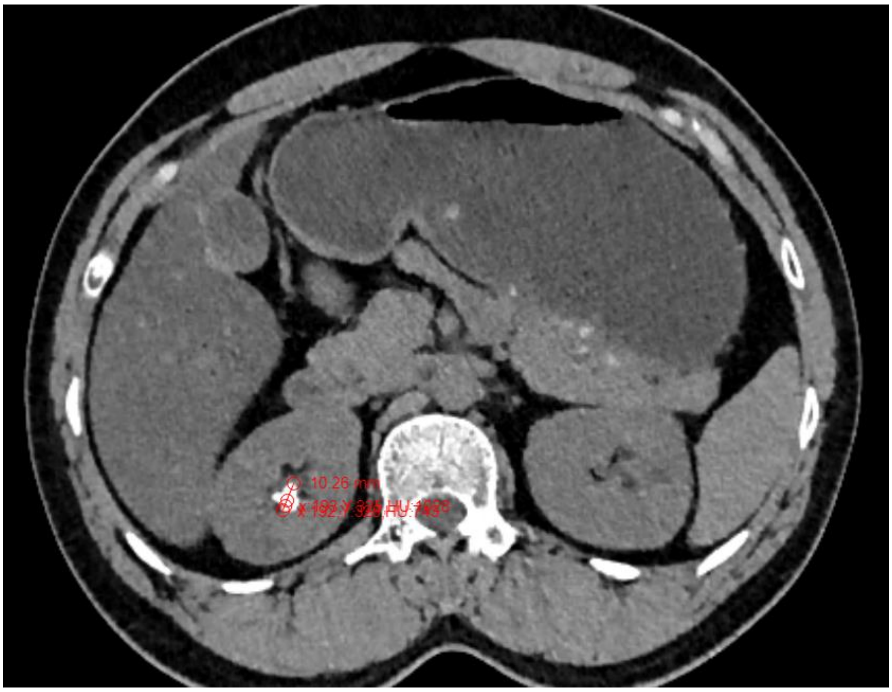

Figure-2: CT-KUB in axial section shows a 10.3 mm sized calculus in mid-pole of right kidney with a mean HU of 885

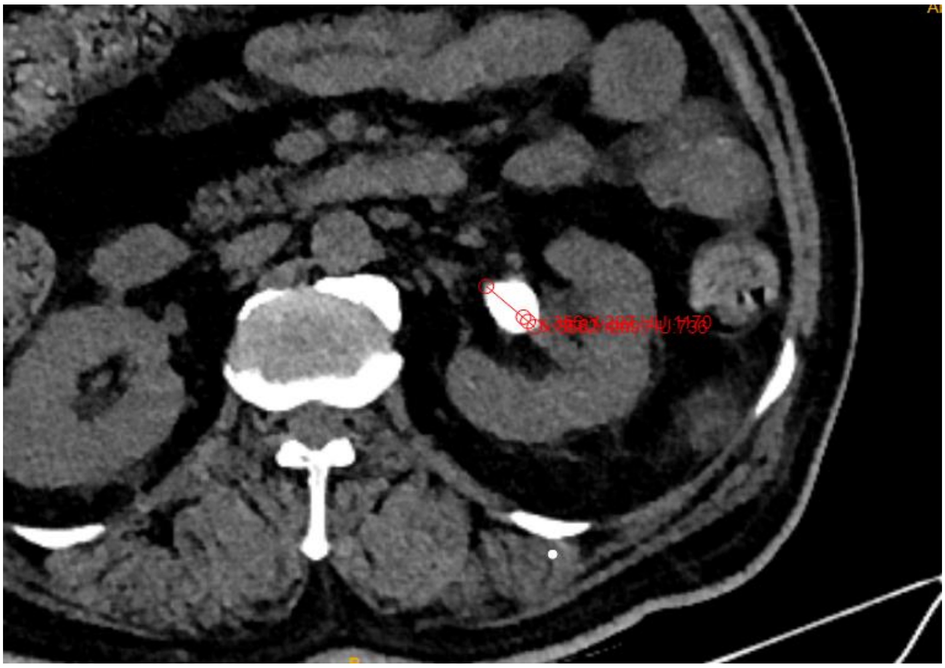

Figure-3: CT-KUB in axial section shows a 19.5 mm sized calculus (at its greatest transverse diameter) in left renal pelvis causing mild focal caliectasis with a mean HU of 953

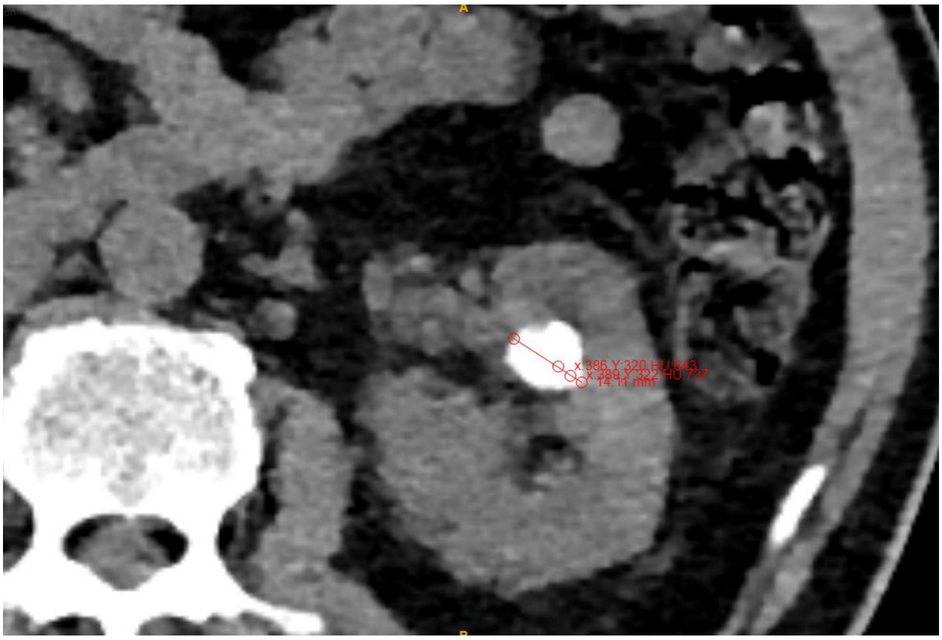

Figure-4: CT-KUB in axial section shows a 14 mm sized calculus (at its greatest transverse diameter) in mid-pole of left kidney with a mean HU of 690

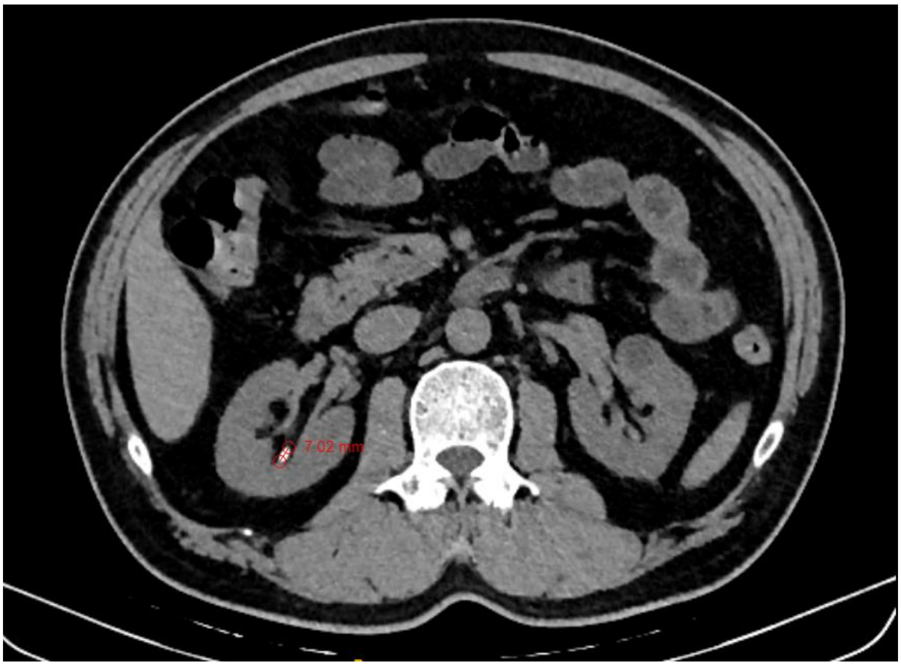

Figure-5: CT-KUB in axial section shows a 7 mm sized calculus (at its greatest transverse diameter) in upper-pole of right kidney with a mean HU of 423

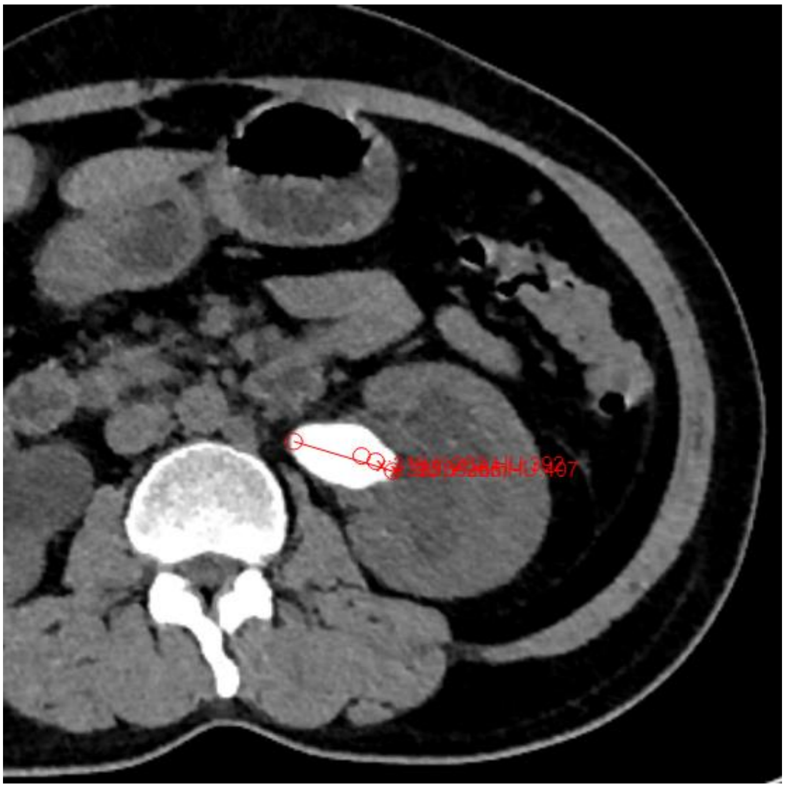

Figure-6: CT-KUB in axial section shows a 30 mm sized calculus (at its greatest transverse diameter) in left renal pelvis causing caliectasis with a mean HU of 399

Figure-7: CT-KUB in axial section shows a 10 mm sized calculus (at its greatest transverse diameter) in lower pole calyx of left kidney with a mean HU of 470

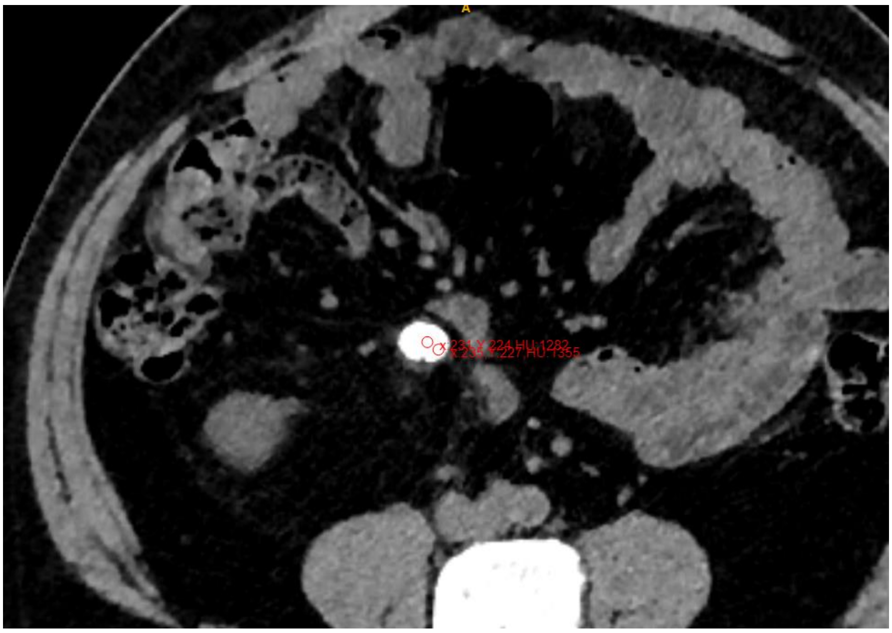

Figure-8: CT-KUB in axial section shows a 14.5 mm sized calculus (at its greatest transverse diameter) in right upper 1/3rd ureter with a mean HU of 1318

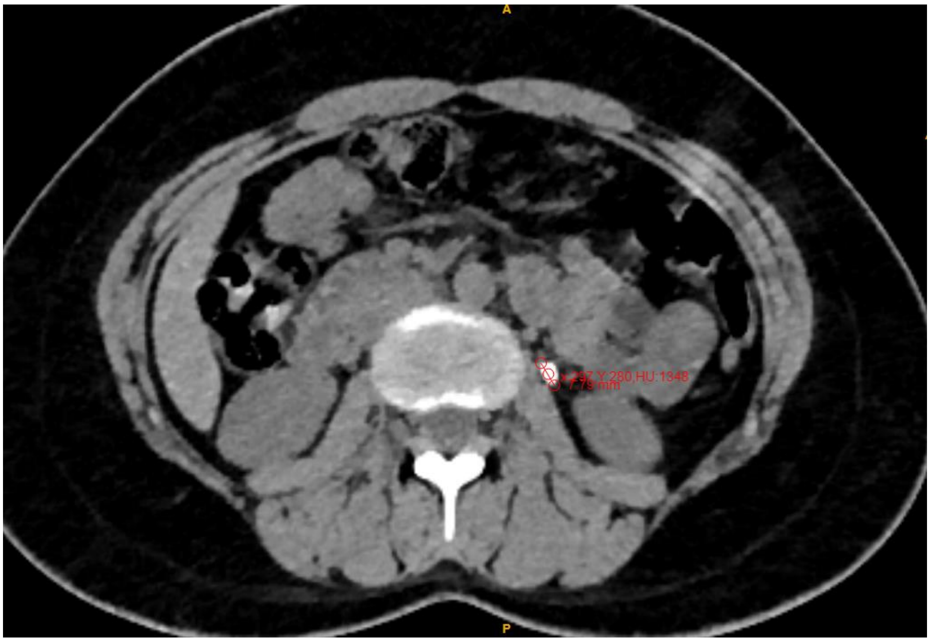

Figure-9: CT-KUB in axial section shows a 7.4mm sized calculus (at its greatest transverse diameter) in left upper 1/3rd ureter with a HU of 1348 at centre of the calculus and a mean HU of 1278

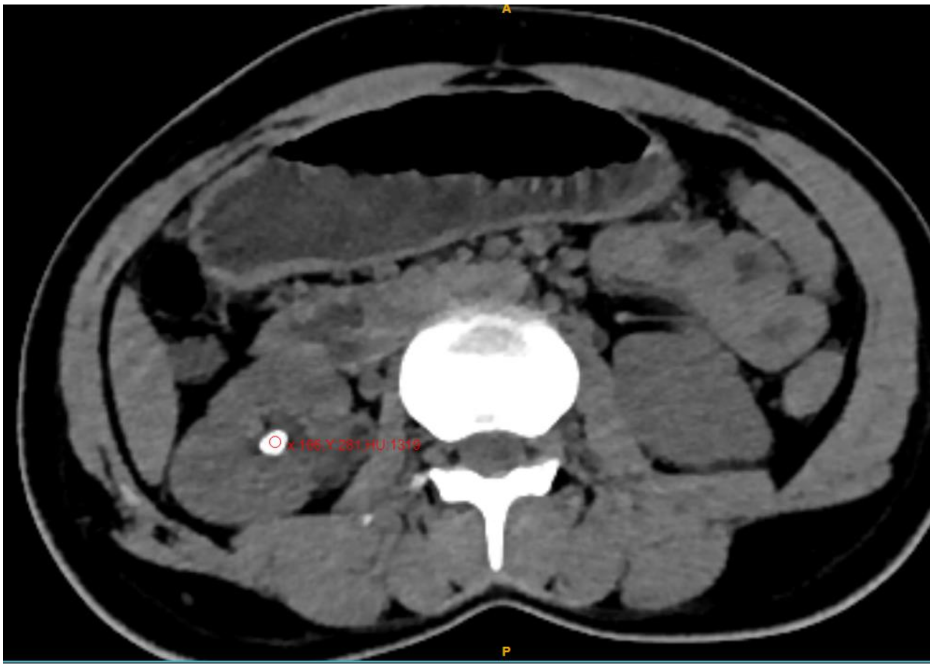

Figure-10: CT-KUB in axial section shows a 7.8 mm sized calculus (at its greatest transverse diameter) in lower pole calyx of right kidney with HU of 1319 at centre of the calculus and a mean HU of 1035

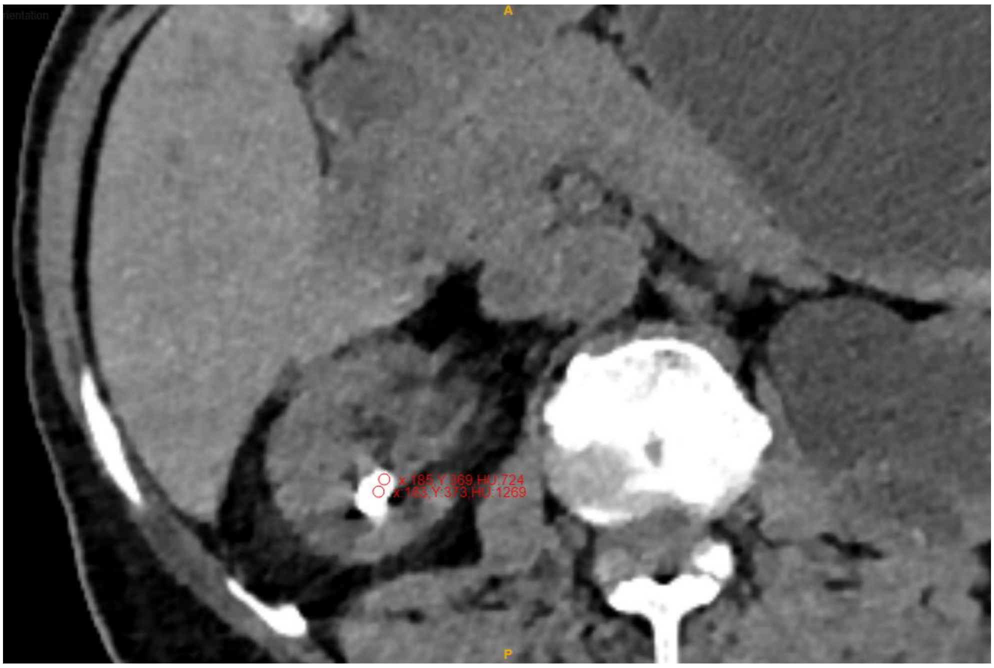

Figure-11: CT-KUB in axial section shows a 9.2 mm sized calculus (at its greatest transverse diameter) in mid pole calyx of right kidney with a mean HU of 996

Biochemical analysis protocols:

All stones were analyzed by a stone analysis kit and the percentage of composition of the calculi was determined. Calculi were received in sterile containers from the Urology department, and these were cleaned, dried, and stored in an air-conditioned environment until chemical analysis. Large stones measuring more than 12 mm were fractured using a sharp needle in order to get to the nucleus/core. In larger stones, the core and the surface samples were each analyzed separately using the stone analysis kit. The calculi were then powdered into a homogeneous fine powder using a pestle and mortar.

Stone analysis and reporting:

Solutions of finely powdered stones were analyzed using colorimetry by using a stone Analysis Kit. The presence of calcium was determined using titration by calconcarboxylic acid as the indicator. Reagents were added drop-wise as per manufacturer's instructions with the appearance of certain colors indicating the presence of calcium, oxalate, phosphate, ammonia, uric acid, and magnesium. The percentages of each of these components were assessed by visual comparison with the semi-quantitative kit color scale.

Only those stones which were considered as pure stones, i.e., containing 100% of a single component and near pure stones, i.e., containing two mixed components but with at least 80% of one of the major components were included in the study. Stones with more than 2 components and stones which were not found to be pure or near pure were excluded from the study. Calculi were hence evaluated as four groups including calcium phosphate, calcium oxalate, uric acid, and struvite.

METHODS IN THE STUDY:

Once a patient was identified to fit into the pre-determined criteria for urinary calculus, the patient’s demographic details, clinical details, imaging findings, HU value of the calculus, chemical stone composition, and urinary pH were collected and entered as per the proforma. The data is collected by the lead investigator and periodically entered into a Microsoft Excel 2016 master chart.

STATISTICAL METHODS:

SAMPLE SIZE:

The sample size was determined by the formula:

$$n = (z)^2 p (1 - p) / d^2$$

Where n = sample size

z = level of confidence according to the standard normal distribution (z = for a level of confidence of 95%, z = 1.96)

p = estimated proportion of the population that presents the characteristic (p = 0.012)

d = tolerated margin of error (10%)

Based on the prevalence of 12% urolithiasis from a systematic review by Alelign et al [41], and with a 95 % confidence level and 10% allowable error the minimum sample size came to 113 patients with urolithiasis. Finally, a sample size of 113 patients were included.

STATISTICAL ANALYSIS:

Continuous variables were expressed as Mean ± Standard Deviation and compared if required, using unpaired t test/One Way ANOVA if the data followed normal distribution and Mann-Whitney U test/Kruskal Wallis Test if the data did not follow normal distribution. A Pearson's correlation coefficient was used to measure the strength of a linear association between HU value and urinary pH. A Receiver operator curve analysis was performed to assess the utility of CT HU in distinguishing the type of stone. An alpha level of 5% has been taken, i.e., if any p value is less than 0.05 was considered as significant. The statistical software SPSS version 20 was used for the analysis.

RESULTS

RESULTS

A total of 113 patients who met the pre-determined criteria who presented with nephrolithiasis and who underwent non contrast CT and subsequent chemical analysis of stone composition were included in the study.

Analysis was done under following headings:

- Descriptive Statistics
- Clinical details of the patient
- CT findings
- Hounsfield unit values
- Chemical composition of the stone based on chemical analysis
- Urinary pH of the patient
- ANOVA to compare the difference in mean HU between different types of stones
- Pearson's correlation coefficient to determine the linear association between CT HU values and urinary pH

GENDER:

Out of the 113 patients enrolled in the study, 70 (62%) were males while 43 (38%) were females [Table 4] [Fig 12].

Table 4: Gender distribution in the study

Gender	n (113)	Percentage (%)
Male	70	62
Female	43	38

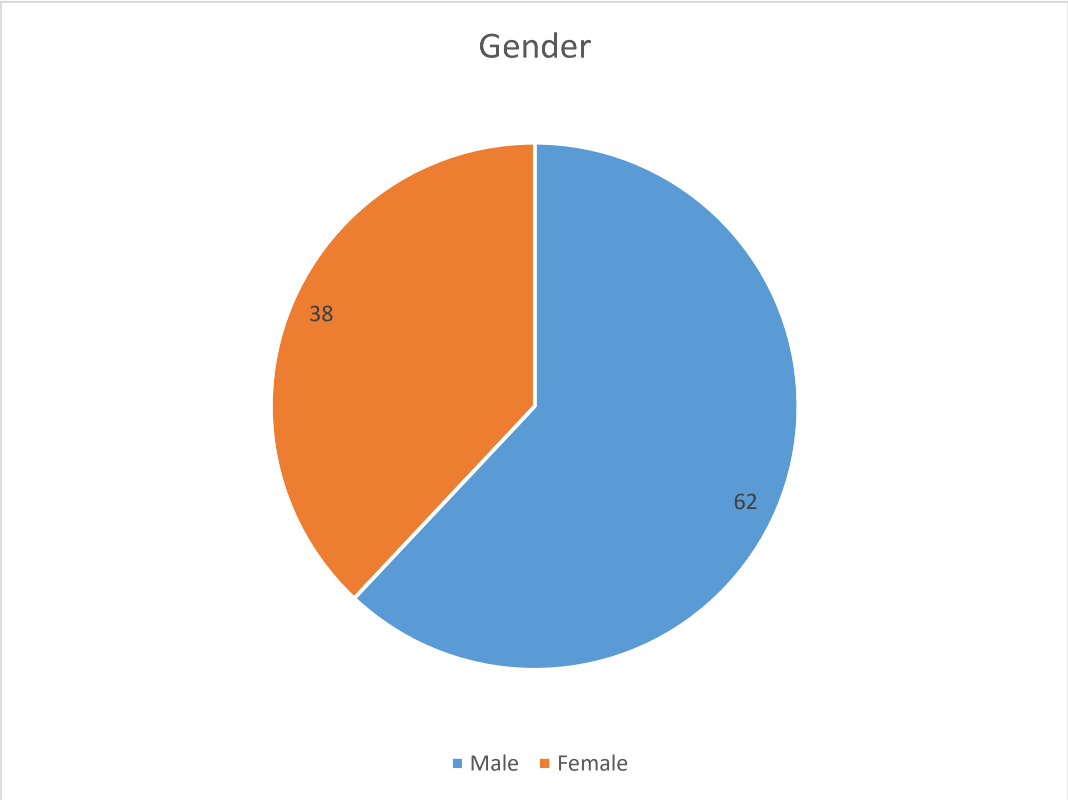

Fig 12: Pie chart showing the Gender distribution in the study

AGE:

The ages in the study ranged between 18 to 84 years with the mean (M)± standard deviation (SD), median, and mode ages in the study were 40.7±16, 36, and 28 years respectively. The ages in the males ranged between 18 to 84 years with the M± SD, median, and mode ages being 40.2±16.4, 35, and 28 years respectively. The ages in the females ranged between 19 to 75 years with the M± SD, median, and mode ages among the females were 41.4±15.5, 40, and 35 years respectively. There was no statistically significant difference identified in the ages between males and females in the study (t=0.38, p=0.35) [Table 5] [Fig 13].

Table 5: Association between age and gender in the study

Gender	M± SD age (years)	P value
Male	40.2±16.4	0.35
Female	41.4±15.5	
Total	40.7±16	

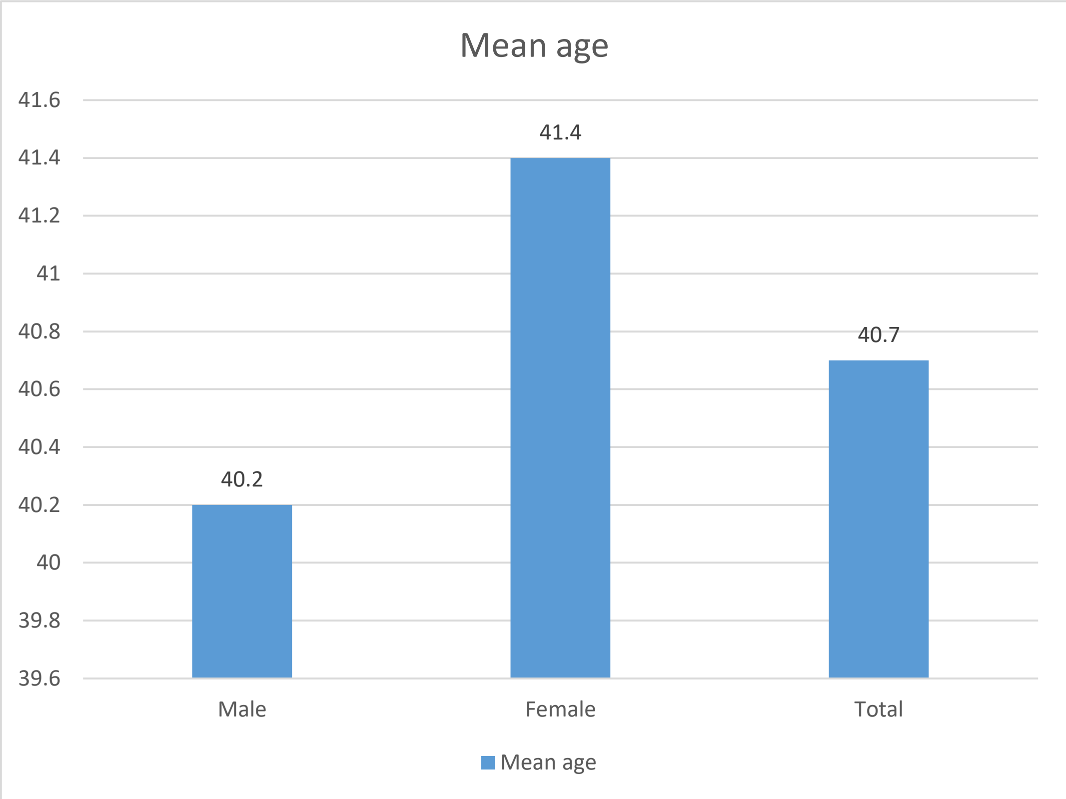

Fig 13: Bar diagram showing the comparison of ages between genders in the study

Types of stones by biochemical analysis:

The types of stones identified in this study included calcium oxalate, calcium phosphate, uric acid, and struvite stones. There were 57 (50.5%) calcium oxalate stones, 31 (27.5%) calcium phosphate stones, 12 (10.6%) uric acid stones, and 13 (11.4%) struvite stones [Table 6] [Fig 14].

Table 6: The distribution of the biochemical composition of the stones identified in this study

Biochemical composition	n (113)	Percentage (%)
Calcium oxalate	57	50.5
Calcium phosphate	31	27.5
Uric acid	12	10.6

Struvite	13	11.4

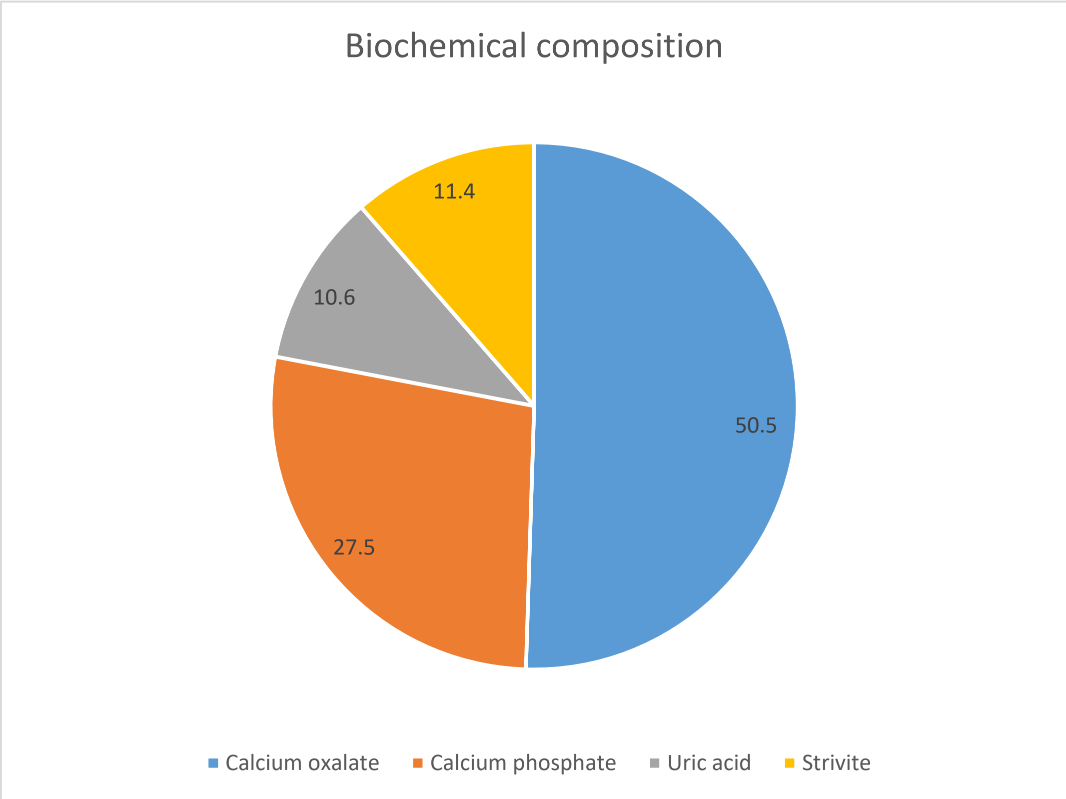

Fig 14: Pie chart showing the distribution of the biochemical composition of the stones identified in this study

CT Hounsfield Unit values:

The total CT HU values identified in this study ranged between 300 to 1600 with a M± SD, median, and mode of 907±357, 900, and 900 respectively.

CT HU in calcium oxalate stones:

The CT HU values in calcium oxalate stones identified in this study ranged between 869 to 1600 with a M± SD, median, and mode of 1206±201, 1191, and 1300 respectively. The M± SD HU of non-calcium oxalate stones was 602±179. There was a statistically significant difference identified between HU of calcium oxalate and non-calcium oxalate stones with calcium oxalate stones having a significantly higher HU value ($t=16.702$, $p<0.00001$) [Table 7] [Fig 15].

Table 7: Comparison of Hounsfield unit values between calcium oxalate stones and non-calcium oxalate stones in the study

Stone composition	CT HU value	p value
Calcium oxalate	1206±201	<0.00001
Non-calcium oxalate	602±179	

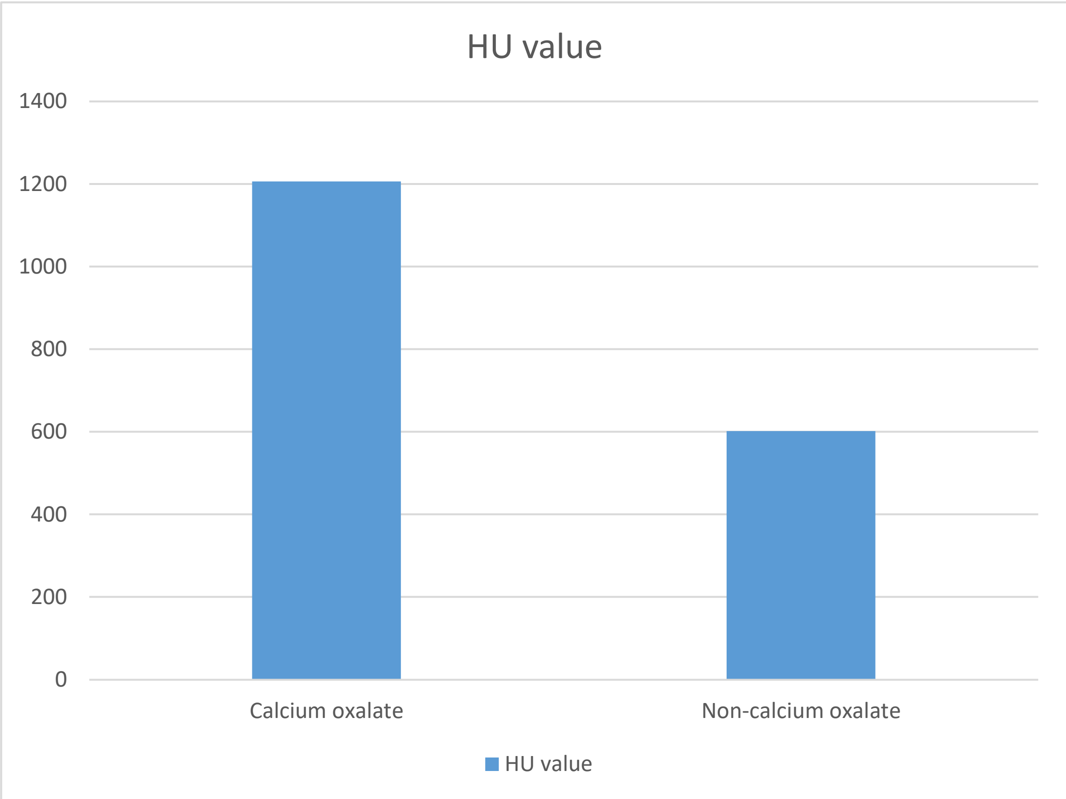

Fig 15: Bar diagram showing the comparison of Hounsfield unit values between calcium oxalate stones and non-calcium oxalate stones in the study

CT HU in calcium phosphate stones:

The CT HU values in calcium phosphate stones identified in this study ranged between 450 to 946 with a M± SD, median, and mode of 699±136, 700, and 900 respectively. The M± SD HU of non-calcium phosphate stones was 986±382. There was a statistically significant difference identified between HU of calcium phosphate and non-calcium phosphate stones with calcium phosphate stones having a significantly lower HU value ($t=4.046$, $p=0.000048$) [Table 8] [Fig 16].

Table 8: Comparison of Hounsfield unit values between calcium phosphate stones and non-calcium phosphate stones in the study

Stone composition	CT HU value	p value
Calcium phosphate	699±136	0.000048
Non-calcium phosphate	986±382	

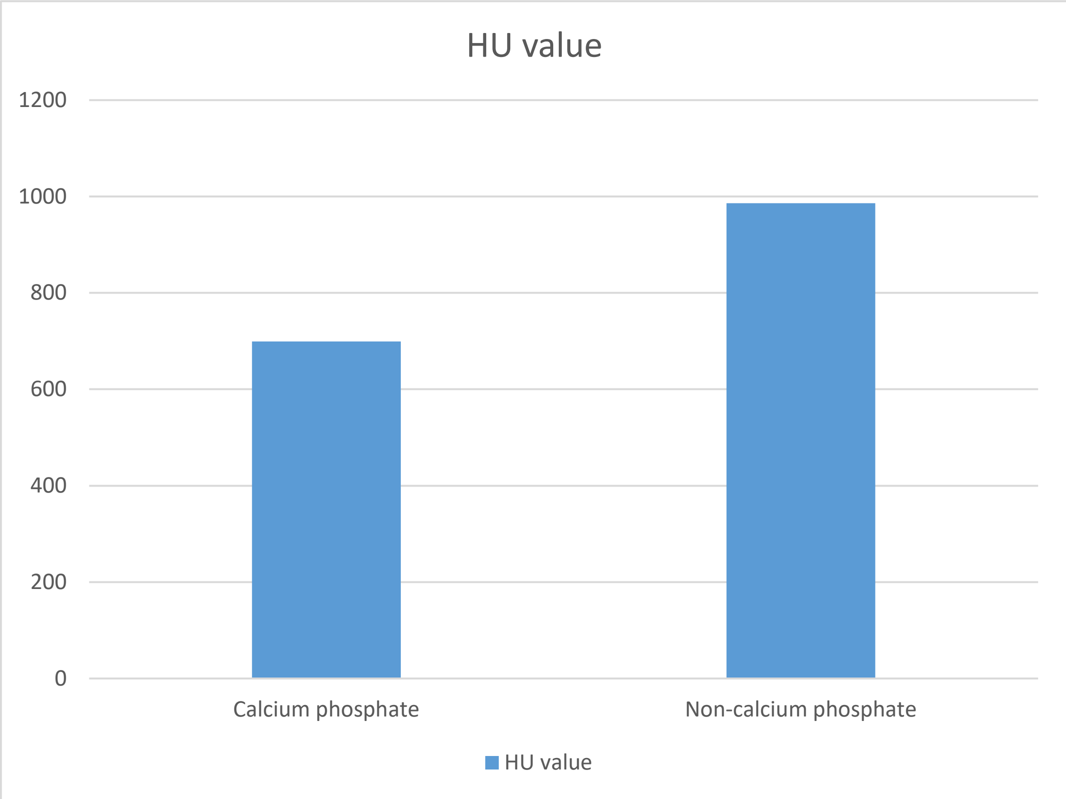

Fig 16: Bar diagram showing the comparison of Hounsfield unit values between calcium phosphate stones and non-calcium phosphate stones in the study

CT HU in uric acid stones:

The CT HU values in uric acid stones identified in this study ranged between 320 to 800 with a M± SD, median, and mode of 437±115, 445, and 450 respectively. The M± SD HU of non-uric acid stones was 961±336. There was a statistically significant difference identified between HU of uric acid and non-uric acid stones with uric acid stones having a significantly lower HU value (t=5.214, p<0.00001) [Table 9] [Fig 17].

Table 9: Comparison of Hounsfield unit values between uric acid stones and non-uric acid stones in the study

Stone composition	CT HU value	p value
Uric acid	437±115	<0.00001
Non-uric acid	961±336	

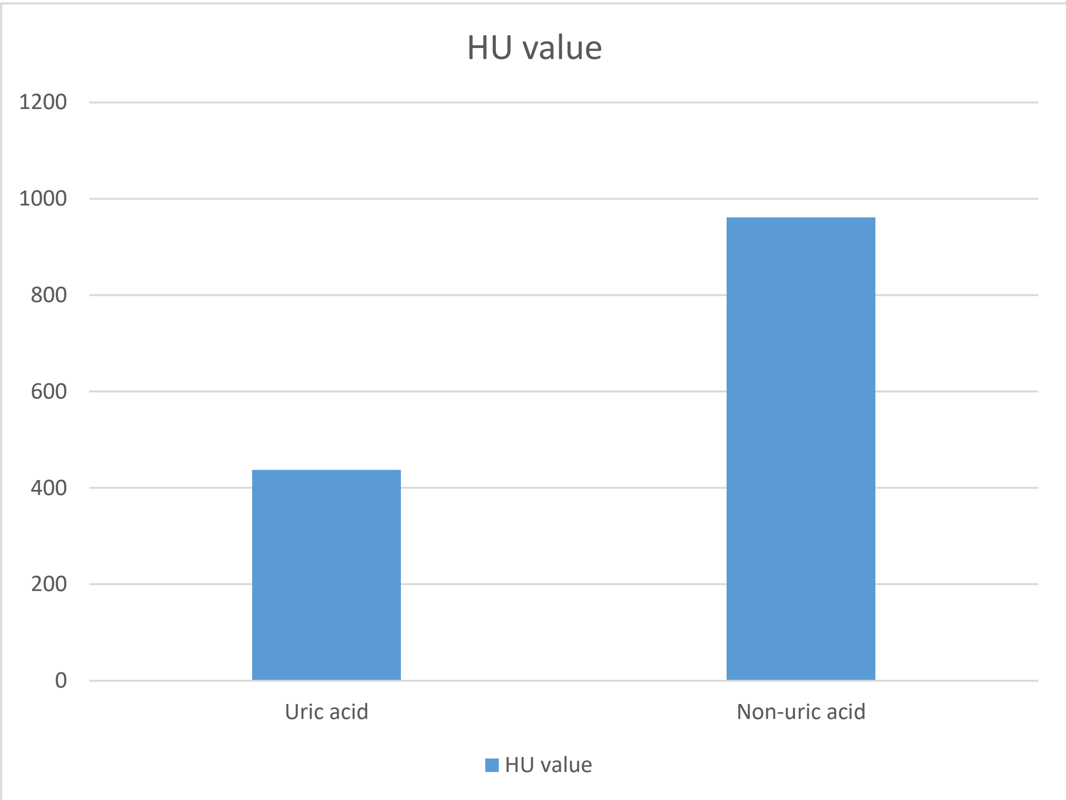

Fig 17: Bar diagram showing the comparison of Hounsfield unit values between uric acid stones and non-uric acid stones in the study

CT HU in struvite stones:

The CT HU values in struvite stones identified in this study ranged between 300 to 800 with a M± SD, median, and mode of 515±172, 451, and 350 respectively. The M± SD HU of non-struvite stones was 958±343. There was a statistically significant difference identified between HU of struvite and non-struvite stones with struvite stones have a significantly lower HU value (t=4.539, p<0.00001) [Table 10] [Fig 18].

Table 10: Comparison of Hounsfield unit values between struvite stones and non-struvite stones in the study

Stone composition	CT HU value	p value
Struvite	515±172	<0.00001
Non-struvite	958±343	

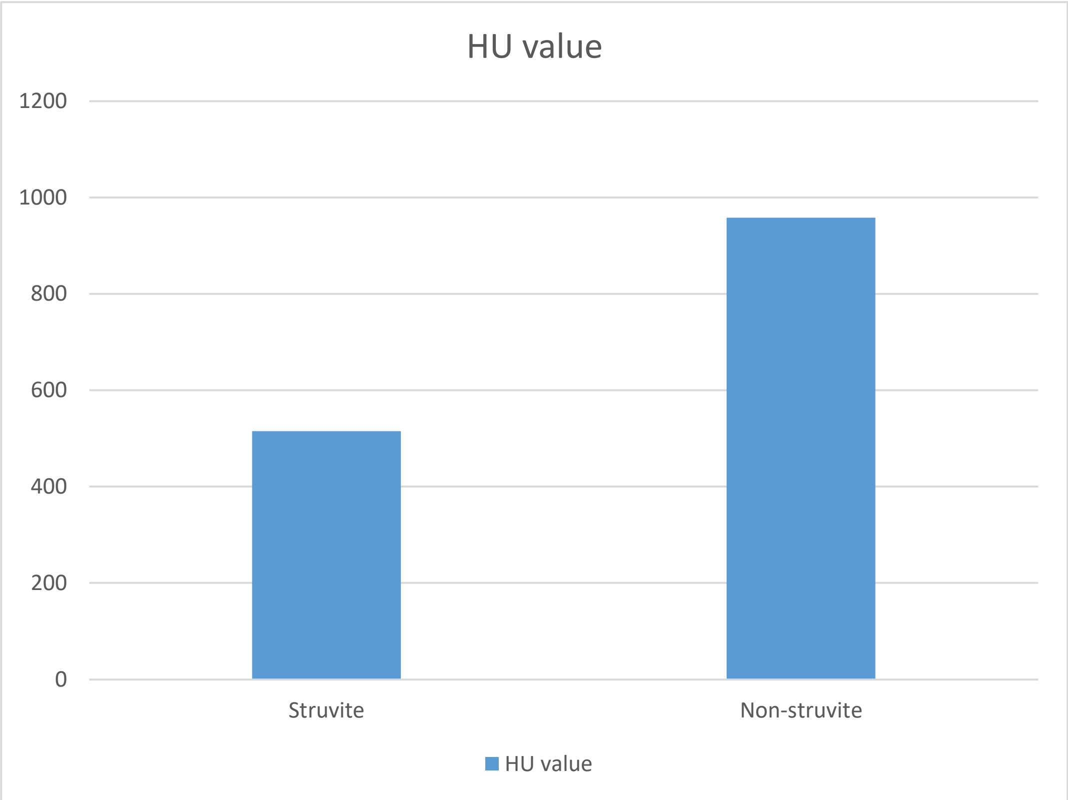

Fig 18: Bar diagram showing the comparison of Hounsfield unit values between struvite stones and non-struvite stones in the study

ANOVA of CT HU among different stones:

Analysis of variance between the CT HU values of the different types of stones showed a significant difference in HU values between the stones with calcium oxalate stones having the highest HU value, followed by calcium phosphate stones, struvite, and uric acid stones respectively ($f=116.47$, $p<0.00001$) [Table 11] [Fig 19].

Table 11: Analysis of variance of HU values of different stones in the study

Stone composition	CT HU value	p value
Calcium oxalate	1206±201	0.00001
Calcium phosphate	699±136	
Uric acid	437±115	
Struvite	515±172	

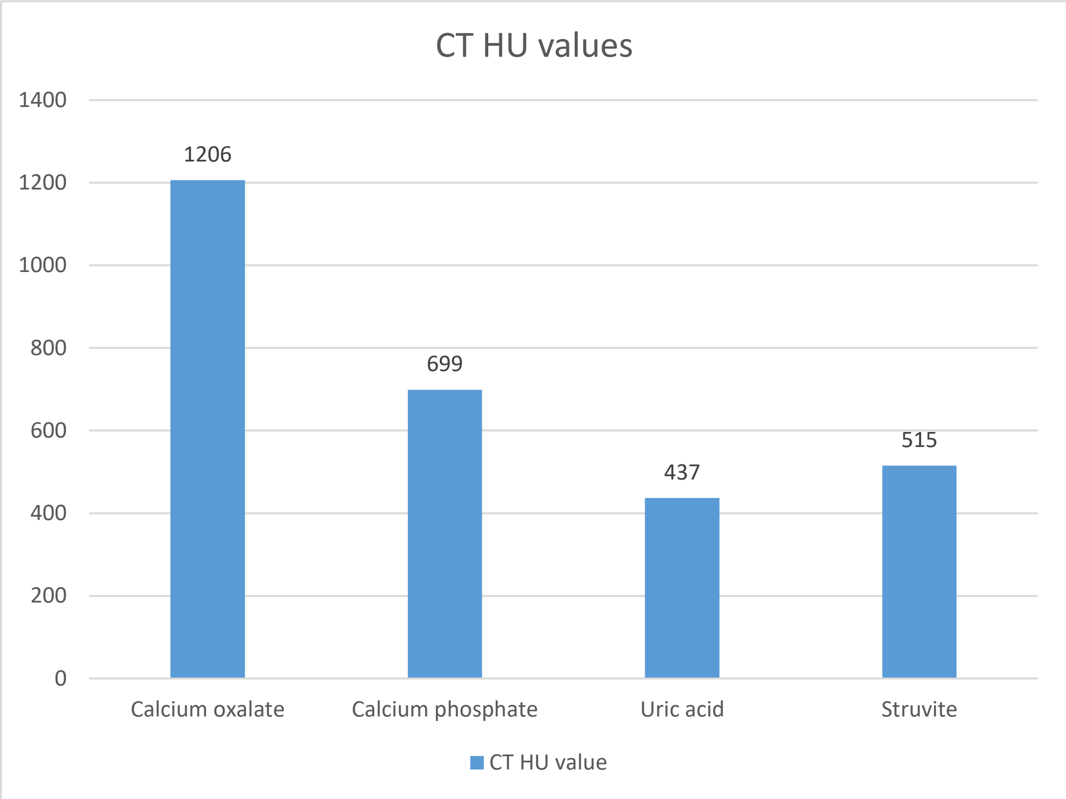

Fig 19: Bar diagram showing the comparison of CT HU values between different types of stones in the study

ANOVA of Urinary pH in the study:

The urinary pH in the study ranged from 5 to 7.6 with a M± SD, median, and mode of 6±0.5, 5.9, and 5.8 respectively. The urinary pH in patients with calcium oxalate stones ranged between 5.2 to 7 with a M± SD, median, and mode of 6.1±0.4, 6, and 6.2 respectively. The urinary pH in patients with calcium phosphate stones ranged between 5 to 6.2 with a M± SD, median, and mode of 5.7±0.2, 5.8, and 5.8 respectively. The urinary pH in patients with uric acid stones ranged between 5 to 5.9 with a M± SD, median, and mode of 5.6±0.3, 5.7, and 5.7 respectively. The urinary pH in patients with struvite stones ranged between 6.8 to 7.6 with a M± SD, median, and mode of 7.1±0.2, 7.2, and 7.2 respectively. ANOVA between the pH values of the different types of stones showed a significant difference in pH values between the stones with struvite stones showing the highest pH value, followed by calcium oxalate, calcium phosphate, and uric acid stones respectively (f=52.362, p<0.00001) [Table 12] [Fig 20].

Table 12: Analysis of variance of pH values of different stones in the study

Stone composition	CT HU value	p value
Calcium oxalate	6.1±0.4	0.00001
Calcium phosphate	5.7±0.2	
Uric acid	5.6±0.3	
Struvite	7.1±0.2	

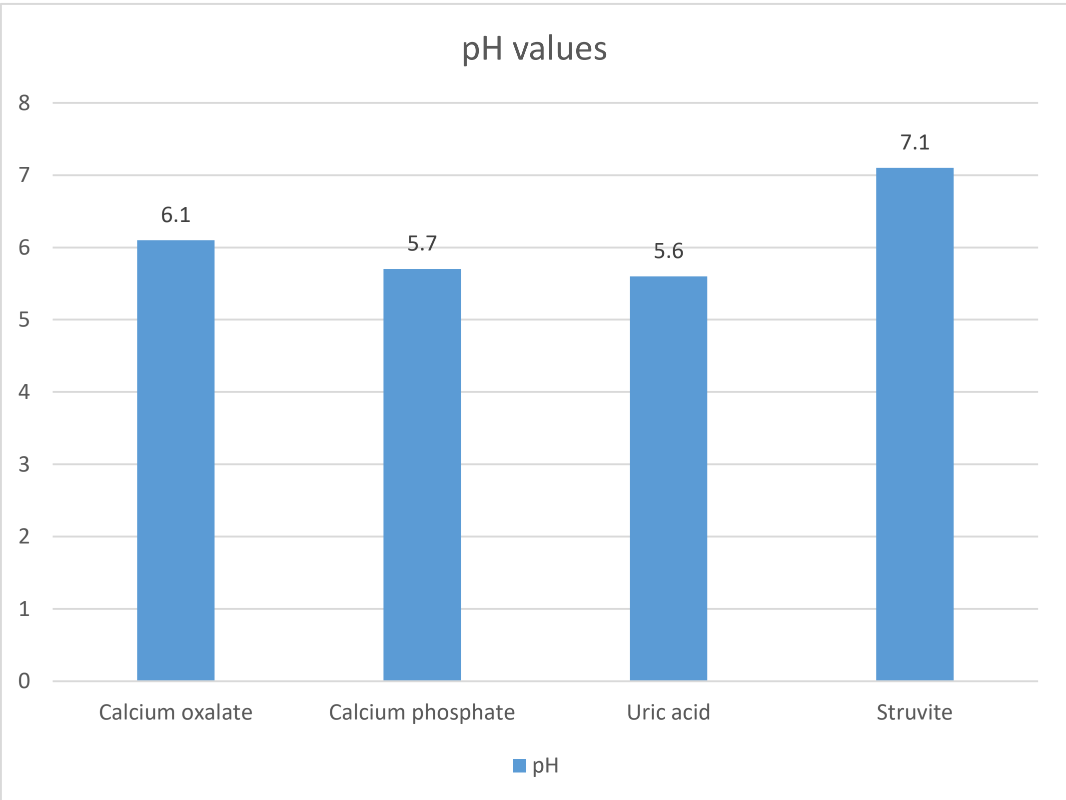

Fig 20: bar diagram showing the comparison of pH values between different types of stones in the study

CT HU and urinary pH:

On comparison of the CT HU values and urinary pH in this study, Pearson's correlation coefficient analysis failed to demonstrate a significant association between these two parameters (R=-0.022, p=0.817) [Fig 21].

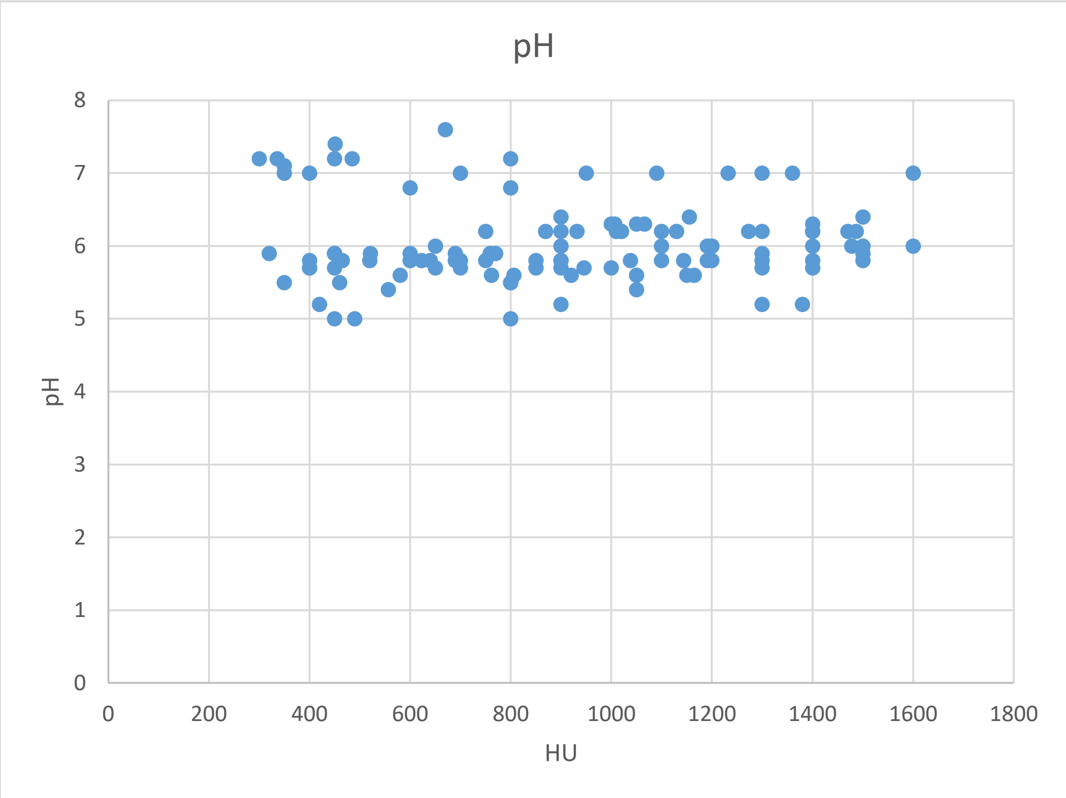

Fig 21: Scatter plot showing the comparison of CT HU values with pH values in the study

Receiver operator curve (ROC) analysis:

An ROC analysis of CT HU for the identification of calcium oxalate stones which were of the highest frequency in the present study showed an area under the curve (AUC) of 0.995 [Fig 22].

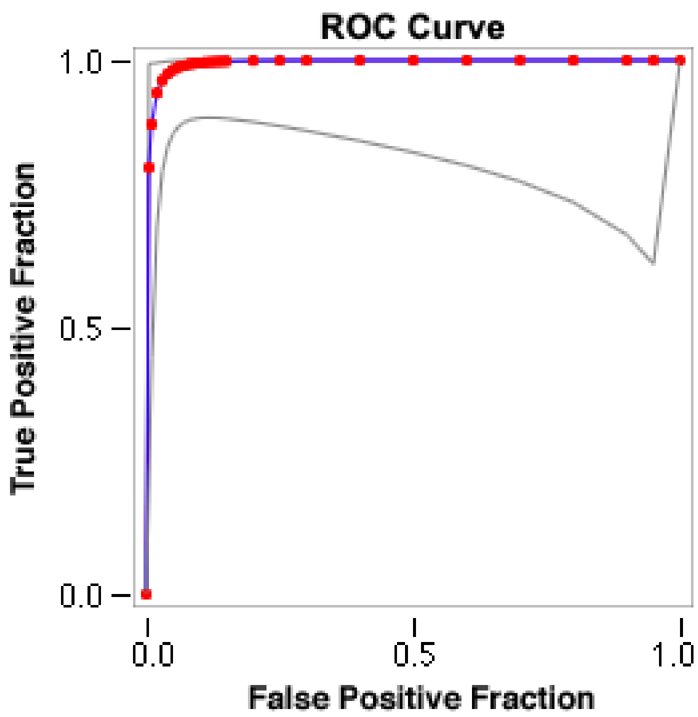

Fig 22: Receiver operator curve analysis of CT HU value in distinguishing calcium oxalate stone from other type of stones

DISCUSSION

DISCUSSION

This was a prospective observational study which looked at the utility of CT Hounsfield unit values in identifying the chemical composition of urinary stones in patients suffering from urolithiasis. The secondary objective in the study was to compare the HU value with urinary pH to look for a correlation between these parameters.

Urolithiasis is a very common disorder with an ever-increasing incidence and prevalence all over the world [6]. Even with newly developed diagnostic and therapeutic modalities for the management of urolithiasis, the determination of stone chemical composition still depends heavily on biochemical techniques and spectroscopy after stone extraction. The need for a non-invasive investigative technique to determine the chemical composition pre-operatively is the need of the hour and this study was performed as an attempt to address that need.

With respect to gender, there was a male predominance identified in this study. This has been the case in most previous reports that looked at the incidence and prevalence of urolithiasis, with heterogeneous reports in different geographic locations. These have ranged from between 8% to 19% in males as compared to a lower incidence of 3% to 5% in females in the Western population [42][43][44]. This has also been noted in the Asian population with a male-to-female ratio ranging between from 1.15:1 in Iran [45], 1.6:1 from Thailand [46], to 2.5:1 from Iraq [47], and 5:1 from Saudi Arabia [48].

With respect to the age, we had a predominantly middle-aged population with an average age of 40.7 years. There was no significant difference in ages between the two genders suggesting a uniform distribution of the study group.

In terms of HU in the study, we identified a significant difference in the mean HU values between the different types of stones. The highest HU was identified in calcium oxalate stones, followed by calcium phosphate, struvite, and uric acid stones respectively. Our results reflected those of some previous reports which looked at the utility of CT HU in identifying the chemical composition of renal calculi. Mostafavi et al [32] found that although HU was not precise in differentiating calcium oxalate calculi from brushite stone and struvite calculi from cystine stones, CT was able to differentiate the latter stones from the former and uric acid stones from all other stones.

Our study further found that it is possible to differentiate each type of stone from the other types based on the HU value. Motley et al [33] reported a statistically significant differences between the mean HU density of calcium and uric acid stones but failed to demonstrate a significant difference in HU between calcium and struvite stones. They also did not demonstrate any significant differences among the other stones. They also found that Hounsfield density was more useful than HU for differentiating the different types of stones, however, we eliminated smaller stones in our study and hence this confounder was possibly eliminated.

Another highlight of our study was that we found significant differences in HU values between the subtypes of calcium stones, ie, calcium oxalate and calcium phosphate stones which was not reported extensively before this study. Similar to our findings, Patel et al [34] found that the calcium oxalate monohydrate stones had a significantly higher HU when compared to the calcium oxalate dihydrate stones. However, other reports have found that CT HU values may not be useful in differentiating different types of calcium stones. In contrast to our findings, Shahnani et al [37] and Motley et al [33] found that calcium stones had a distinct range of HU without any overlap with other types of renal stones and they concluded that CT HU values were only useful in differentiating calcium stones from non-calcium stones but not for differentiating subtypes of calcium stones.

Somewhat similar to our findings, Torricelli et al [35] found that the HU values and HU density were significantly different among calcium oxalate, uric acid, and cystine calculi. We did not study cysteine stones due to a relatively low prevalence in our geographical location and instead included struvite which is seen in association with infections in India, and we could demonstrate a significant difference in the HU values all these stones.

An ROC analysis in our study found that CT HU was extremely useful in differentiating calcium oxalate stones from the other type of stones with an excellent AUC of 0.995. Silva et al [38] reported similar finding with an ROC analysis, the showing an optimal cutoff value being 1548 HU to determine the likelihood of a calculus being calcium oxalate monohydrate. Similar to our findings, they found that a higher HU value favoured calcium oxalate monohydrate calculi over other type of stones.

Urinary pH is known to be a major factor for the formation of kidney stones. The supersaturation of calcium phosphate tends to increase quickly as urine pH goes above 6. A low urinary pH is an important factor for uric acid stones to form. The role of urinary pH in calcium oxalate stone formation is less clear [49]. Despite there being a strong positive correlation between the urinary pH values and the nature of the chemical composition of different types of urinary calculi, and with there being an association found between different HU values and chemical composition of different stones, our study failed to demonstrate a significant association between urinary pH and CT HU values. The reason for this is in most likelihood the fact that the majority of stones identified in our study were calcium oxalate stones. Since the role of urinary pH in calcium oxalate stone formation is controversial with multiple reports failing to show an association between these two parameters, urinary pH may not be a useful marker in differentiating these stones. Hence, the role of CT HU values become all the more important as a non-invasive tool in identifying the chemical composition of renal calculi pre-operatively.

ESWL remains the most commonly used treatment modality in renal stones and ESWL is useful only in a select group of renal stones with specific chemical compositions [15]. Hence, the pre-procedure identification of chemical composition of the stone becomes extremely important to direct treatment and this study shows that non contrast CT with HU value estimation may be a useful tool for this purpose.

LIMITATIONS OF THE STUDY

LIMITATIONS OF THE STUDY

This study has its limitations.

First, even though the sample size was calculated based on established prevalence, it could still be under-powered to assess the potential predictive ability of CT HU value for determining renal calculi chemical composition.

Second, this was a single centre study and the findings may not be representative of a larger population. Further multi-centric studies are warranted to address this limitation.

Third, we did not account for reporter bias, where inter-observer agreement between the reporting radiologists were not studied.

Finally, absolute CT HU values were used rather than HU density which would account for the stone size as well, however, smaller stones with diameter <6mm were excluded from the study to avoid this bias.

CONCLUSIONS

CONCLUSIONS

From the results of this study, CT HU is a reasonable non-invasive investigative technique in determining chemical composition of renal calculi pre-operatively which helps in deciding the mode of treatment. Renal calculi with higher CT HU values are likely to be calcium oxalate stones. Urinary pH, although useful in predicting the chemical composition of certain type of stones, does not correlate well with CT HU values and may be less useful in the pre-procedure determination of stone composition

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APPENDIX

CONSENT FORM

TITLE OF RESEARCH: EVALUATION OF RENAL STONE HOUNSFIELD UNIT VALUE WITH MULTIDETECTOR COMPUTED TOMOGRAPHY (32 SLICE THICKNESS) AND COMPARISION WITH RENAL STONE BIOCHEMISTRY AND URINARY PH

GUIDE : DR. SATISH PATIL

P.G. STUDENT : DR. K.VALLI MANASA

PURPOSE OF RESEARCH:

I have been informed that the purpose of this study is to evaluate the renal stone HU value with MDCT (32 slice thickness) and to compare it with renal stone biochemistry and urinary pH.

PROCEDURE:

I understand that I will undergo history, clinical examination, CT scan and urinary PH and renal stone biochemistry.

RISKS AND DISCOMFORTS:

I understand that there is no risk involved in the above study.

BENEFITS:

I understand that my participation in this study will help to assess the role of CT in evaluation of renal stone composition pre-operatively.

CONFIDENTIALITY:

I understand that the medical information produced by the study will become a part of hospital record and will be subjected to confidentiality and privacy regulations of hospital. If the data is used for publications the identity of the patient will not be revealed.

REQUEST FOR MORE INFORMATION:

I understand that I may ask for more information about the study at any time.

REFUSAL OR WITHDRAWL OF PARTICIPATION:

I understand that my participation is voluntary and I may refuse to participate or withdraw from study at any time

INJURY STATEMENT:

I understand in the unlikely event of injury to me during the study I will get medical treatment but no further compensations. I will not hold the hospital and its staff responsible for any untoward incidence during the course of study.

Date:

Dr. Satish. D. Patil (Guide)

Dr. K.Valli Manasa (Investigator)

STUDY SUBJECT CONSENT STATEMENT:

I/my ward confirm that Dr. K.Valli Manasa has explained to me the purpose of this research, the study procedure that I will undergo and the possible discomforts and benefits that I may experience, in my own language.

I/my ward have been explained all the above in detail in my own language and I understand the same. Therefore, I agree to give my consent to participate as a subject in this project.

____________________________ ________________

(Participant) (Date)

________________________________ __________________

(Witness to above signature) (Date)

PROFORMA

'EVALUATION OF RENAL STONE HOUNSFIELD UNIT (HU) VALUE WITH MULTIDETECTOR COMPUTED TOMOGRAPHY (32 SLICE THICKNESS) AND COMPARISION WITH RENAL STONE BIOCHEMISTRY AND URINARY PH'

1. Name:

2. Age/Sex

3. Hospital No.:

4. Relevant complaints &history:

5. CT Findings:

6. Biochemical findings:

7. Urinary PH:

8. Radiological Diagnosis:

ETHICAL COMMITTEE CLEARANCE CERTIFICATE

IEC/NO - 131/2019
22-11-2019

B.L.D.E. (DEEMED TO BE UNIVERSITY)

(Declared vide notification No. F.9-37/2007-U.3 (A) Dated. 29-2-2008 of the MHRD, Government of India under Section 3 of the UGC Act, 1956)

The Constituent College

SHRI. B. M. PATIL MEDICAL COLLEGE, HOSPITAL AND RESEARCH CENTRE

INSTITUTIONAL ETHICAL CLEARANCE CERTIFICATE

The ethical committee of this college met on 13-11-2019 at 3-15 pm to scrutinize the synopsis of Postgraduate students of this college from Ethical Clearance point of view. After scrutiny the following original/corrected and revised version synopsis of the Thesis has been accorded Ethical Clearance

Title: Evaluation of renal stone hu value with mdct (32 slice thickness) and comparision with renal stone biochemistry and urinary ph

Name of PG student: : Dr. K .Valli Manasa, Department of Radiodiagnosis

Name of Guide/Co-investigator: Dr. Satish Patil, Associate Professor Department of Radiodiagnosis

DR RAGHVENDRA KULKARNI
CHAIRMAN
Institutional Ethical Committee
BLDEU's Shri B.M. Patil
Medical College,BIJAPUR-586103

Following documents were placed before Ethical Committee for Scrutinization:

1. Copy of Synopsis / Research project
2. Copy of informed consent form
3. Any other relevant documents.

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MASTERCHART

Sl. No	Age	Sex	Clinical findings	CT findings	CT HU	Biochemical composition	pH
1	58	F	Abdominal pain with hematuria	8 x 4 mm sized right distal ureteric calculus causing mild hydroureteronephrosis	600	struvite	6.8
2	62	F	Right flank pain	10 x 6 mm sized calculus is noted in lower pole of right kidney	700	struvite	7
3	33	F	Right flank pain	10 x 3 mm sized calculus of is noted in right distal ureter causing mild hydroureteronephrosis	950	calcium oxalate	7
4	48	M	Left abdominal pain	4 mm sized calculus in lower pole calyx of left kidney	800	struvite	6.8
5	50	F	Left flank pain	6 x 4.5 mm sized calculus in midpole calyx of left kidney	1050	calcium oxalate	5.6
6	32	F	Right flank pain	10 x 16 mm sized calculus in right vesico-ureteric junction causing mild hydroureteronephrosis	1300	calcium oxalate	5.2
7	33	F	Abdominal pain with hematuria	6 x 5 mm sized calculus is noted in right kidney lower pole calyx	800	struvite	7.2
8	24	F	Right flank pain and hematuria	5.5 x 4.6 mm sized calculus in lower pole calyx of right kidney	1300	calcium oxalate	5.8
9	65	F	Pain abdomen with difficulty passing urine	4 x 3.2 mm sized calculus in the urinary bladder	450	uric acid	5

10	26	M	Left flank pain and burning micturition	6 x 4mm sized calculus in lower pole of left kidney	1150	calcium oxalate	5.6
11	20	M	Left flank pain	11 x 7 mm sized calculus in left proximal ureter causing moderate hydroureteronephrosis	1300	calcium oxalate	5.7
12	28	M	Right iliac fossa pain	6 x 4.7 mm sized calculus in upper pole calyx of left kidney	1090	calcium oxalate	7
13	29	F	Lower abdominal pain	8.3 x 5 mm sized calculus in lower pole of left kidney	800	uric acid	5
14	46	M	Right flank pain	7.4 x 5 mm sized calculus in right distal ureter	1380	calcium oxalate	5.2
15	27	M	Abdominal pain	4 x 3 mm sized calculus in left lower pole calyx	485	struvite	7.2
16	36	F	Left flank pain	10 x 4 mm sized calculus in lower pole calyx	1050	calcium oxalate	5.4
17	70	M	Severe abdominal pain	10 x 19 mm sized calculus in right proximal ureter causing gross hydroureteronephrosis	1300	calcium oxalate	7
18	40	M	Abdominal pain	7.8 x 6 mm sized calculus in right proximal ureter causing mild hydroureteronephrosis0	670	struvite	7.6
19	36	F	Abdominal pain	14 x 8 mm sized calculus in left distal ureter causing mild hydroureteronephrosis	1232	calcium oxalate	7
20	44	F	Abdominal pain	14 x 9 mm sized calculus in right renal pelvis	900	calcium oxalate	5.2
21	48	F	Abdominal pain	14 x 7 mm sized calculus in left kidney lower pole calyx	920	calcium oxalate	5.6
22	45	M	Right flank pain	10.3 x 9 mm sixed right pelvi-ureteric junction calculus causing moderate hydronephrosis	1360	calcium oxalate	7
23	35	M	Abdominal pain	9.8 x 8 mm sized calculus in left proximal ureter causing moderate hydroureteronephrosis	1144	calcium oxalate	5.8
24	58	F	Right flank pain	4.5 x 3 mm sized calculus in midpole of right kidney	490	calcium phosphate	5
25	20	F	Left flank pain	10 x 9 mm sized calculus in left proximal ureter causing mild	1600	Calcium oxalate	7

				hydroureteronephrosis			
26	33	M	Left flank pain and burning micturition	6 x 6 mm sized calculus in upper pole of left kidney	350	uric acid	5.5
27	42	F	Abdominal pain	7 x 6.5 mm sized calculus in lower pole of left kidney	336	struvite	7.2
28	31	M	Abdominal pain	8 x 6 mm sized calculus is note din upper pole of right kidney	806	calcium phosphate	5.6
29	54	F	Right flank pain	6 x 5mm sized calculus is noted in midpole of right kidney	900	calcium oxalate	6
30	65	F	Abdominal pain and hematuria	4 x 3.5 mm sized calculus is noted in right kidney lower pole	762	calcium phosphate	5.6
31	40	F	Right flank pain with burning micturition	20 x 12 mm sized calculus in right renal pelvis	1500	calcium oxalate	6.4
32	55	M	Left sided abdominal pain	9.5 x 4.8 mm sized calculus in left mid ureter causing mild hydroureteronephrosis	640	calcium phospahte	5.8
33	55	M	Left sided abdominal pain	6 x 5 mm sized calculus in left kidney lower pole	1487	calcium oxalate	6.2
34	55	F	Right sided abdominal pain	22 x 16 mm sized calculus in right pelvi-ureteric junction n	1038	calcium oxalate	5.8
35	57	M	Hematuria	5 x 4 mm sized calculus in left kidney midpole	750	calcium phosphate	5.8
36	56	F	Right flank pain	8.5 x 6.5 mm sized calculus in right distal ureter causing moderate hydronephrosis	1300	calcium oxalate	6.2
37	75	M	Left flank pain	12 x 7 mm size calculus in left proximal ureter causing mild hydroureteronephrosis	1200	calcium oxalate	5.8
38	23	F	Left sided abdominal pain	9 x 6.5 mm sized calculus in left kidney lower pole	900	calcium phosphate	5.8
39	68	M	Abdominal pain	24 x 17 mm sized calculus in left pelvi-ureteric junction	1100	calcium oxalate	6.2
40	33	M	Left flank	7 x 5 mm sized calculus in left	900	calcium	5.7

			pain	pelvi-ureteric junction		phosphate	
41	68	F	Right sided abdominal pain	7 x 5.8 mm sized calculus in right renal pelvis	1478	calcium oxalate	6
42	24	F	Abdominal pain with burning micturition	3.8 x 4 mm sized calculus in right vesico-ureteric junction causing mild hydroureteronephrosis	869	calcium oxalate	6.2
43	75	F	Right sided abdominal pain	14 x 8 mm sized calculus in Right proximal ureter causing moderate hydroureteronephrosis	320	uric acid	5.9
44	22	F	Abdominal pain	15 x 10 mm sized calculus in right pelvis causing mild hydronephrosis	850	calcium phosphate	5.7
45	20	M	Left flank pain	5 x 4 mm sized calculus in left VUJ causing mild hydroureteronephrosis	1200	calcium oxalate	6
46	23	M	Right abdominal pain	9 x 6 mm sized calculus in right kidney lower pole	1130	calcium oxalate	6.2
47	45	F	Right abdominal pain	4 x 3 mm sized calculus in right lower pole calyx	400	uric acid	5.7
48	25	M	Right flank pain	5 x 3.6 mm sized calculus in right distal ureter	770	calcium phosphate	5.9
49	24	M	Left flank pain with hematuria	15 x 6 mm sized calculus in left mid ureter causing moderate hydroureteronephrosis	1470	calcium oxalate	6.2
50	30	M	Abdominal pain	9 x 5 mm sized calculus in left kidney lower pole	1100	calcium oxalate	5.8
51	65	F	Right flank pain	22 x 6 mm sized calculus in right distal ureter causing mild hydronephrosis	1300	calcium oxalate	5.9
52	55	M	Right flank pain with hematuria	9 x 5 mm sized calculus in right distal ureter causing moderate hydroureteronephrosis	450	uric acid	5.9
53	57	M	Right flank pain	3.3 x 2 mm right distal ureteric calculus causing mild hydronephrosis	750	calcium phosphate	6.2
54	55	M	Abdominal pain	4 x 3 mm sized calculus in left lower pole calyx	300	struvite	7.2

55	26	F	Left flank pain	7 x 5 mm sized calculus in left distal ureter causing moderate hydronephrosis	900	calcium oxalate	6.4
56	75	M	Right sided abdominal pain	8 x 7.7 mm sized calculus in right kidney mid pole	650	calcium phosphate	5.7
57	62	M	Left abdominal pain	5 x 4 mm sized calculus in left kidney lower pole	400	uric acid	5.8
58	50	M	Burning micturition with hematuria	11 x 7 mm sized calculus in urinary bladder lumen	1050	calcium oxalate	6.3
59	24	M	Right flank pain with burning micturition	4 x 3 mm sized calculus in right mid ureter	600	calcium phosphate	5.9
60	45	F	Right flank pain	9 x 8 mm sized calculus in right distal ureter causing moderate hydroureteronephrosis	700	calcium phosphate	5.8
61	40	F	Right flank pain	6 x 5 mm sized calculus in right distal ureter causing mild hydroureteronephrosis	932	calcium oxalate	6.2
62	25	M	Right abdominal pain	6 x 4 mm calculus in right kidney upper pole	1191	Calcium oxalate	5.8
63	59	M	Right flank pain	20 x 9 mm sized calculus in right kidney mid pole	1000	calcium oxalate	5.7
64	36	M	Left flank pain	4 x 5 mm sized in midpole left kidney	1165	calcium oxalate	5.6
65	65	M	Left flank pain	6 x 5 mm sized calculus in right kidney lower pole	1400	calcium oxalate	6
66	23	M	Abdominal pain	4 x 3 mm sized calculus in left kidney lower pole	450	calcium phosphate	5.9
67	19	F	Right flank pain	7 x 5 mm sized calculus in right proximal ureter causing mild hydroureteronephrosis	1020	calcium oxalate	6.2
68	40	M	Abdominal pain	17 x 4 mm sized calculus in left kidney mid pole	690	calcium phosphate	5.9
69	25	M	Right lower abdominal	13 x 7 mm sized calculus in right vesico-ureteric junction causing	1100	calcium oxalate	6

			pain	mild hydroureteronephrosis			
70	35	M	Left flank pain	4 x 5.7 mm sized calculus in left kidney lower pole	450	calcium phosphate	5.9
71	35	F	Abdominal pain	4 x 3 mm sized calculus in left kidney upper pole calyx	850	calcium phosphate	5.8
72	54	M	Right flank pain	6.8 x 5 mm sized calculus in right mid ureter causing mild hydroureteronephrosis	1010	calcium oxalate	6.2
73	25	M	Left flank pain	3 x 2 mm sized calculus in left kidney upper pole	465	uric acid	5.8
74	60	M	Right sided abdominal pain	8 x 7 mm sized calculus in right distal ureter causing hydroureteronephrosis	623	calcium phosphate	5.8
75	26	M	Abdominal pain	7 x 5 mm sized calculus in left distal ureter causing hydroureteronephrosis	759	calcium phosphate	5.9
76	28	M	Left flank pain	9 x 7 mm sized calculus in left kidney upper pole	1273	calcium oxalate	6.2
77	20	M	Right flank pain	4.4 x 8 mm sized calculus in right kidney upper pole	521	Calcium phosphate	5.9
78	52	M	Abdominal pain	4 x 3.5 mm sized calculus in right vesico-ureteric junction causing hydroureteronephrosis	451	struvite	7.4
79	28	F	Left flank pain	6 x 4.5 mm sized calculus in left vesico-ureteric junction causing mild hydroureteronephrosis	1155	calcium oxalate	6.4
80	84	M	Right abdominal pain	10 x 7 mm sized calculus in right proximal ureter causing mild hydroureteronephrosis	1400	calcium oxalate	6.2
81	61	M	Right abdominal pain	6 x 8 mm sized calculus in right VUJ causing moderate hydroureteronephrosis	420	uric acid	5.2
82	18	M	Left abdominal pain	5.8 x 4 mm sized calculus in left VUJ causing mild hydroureteronephrosis	946	calcium phosphate	5.7
83	60	F	Left abdominal pain	4.2 x 3.3 mm sized calculus in left kidney lower pole	557	calcium phosphate	5.4
84	28	M	Right abdominal pain	11 x 7 mm sized calculus in right renal pelvis causing mild hydronephrosis	900	calcium oxalate	6.2

85	60	M	Right flank pain	11 x 8 mm sized calculus in right proximal ureter causing gross hydroureteronephrosis	1000	calcium oxalate	6.3
86	29	F	Right flank pain	7 x 7 mm sized calculus in right kidney midpole	1600	calcium oxalate	6
87	22	M	Right flank pain	5 x 4 mm sized calculus in right kidney upper pole	700	calcium phosphate	5.7
88	30	M	Left abdominal pain	9 x 5 mm sized calculus in left kidney upper pole	1500	calcium oxalate	6
89	23	F	Right flank pain	5 x 4 mm sized calculus in right kidney midpole	1066	calcium oxalate	6.3
90	25	F	Right abdominal pain	14 x 7 mm sized calculus in left kidney lower pole calyx	1400	calcium oxalate	5.8
91	28	M	Right sided abdominal pain	5 x 4 mm sized calculus in right kidney upper pole	800	calcium phosphate	5.5
92	35	F	Left flank pain with hematuria	23 x 18 mm sized calculus in left renal pelvis causing hydronephrosis	1500	calcium oxalate	5.8
93	48	M	Left flank pain	10 x 6 mm sized calculus is noted in lower pole of right kidney	800	calcium phosphate	5.5
94	31	M	Right abdominal pain	3 x 3.5 mm sized calculus in right kidney upper pole	400	uric acid	5.7
95	25	M	Left abdominal pain	7 x 6 mm sized calculus in lower pole of left kidney	1500	calcium oxalate	5.9
96	22	M	Left flank pain	7 x 7 mm sized calculus in left vesico-ureteric junction causing hydroureteronephrosis	1200	calcium oxalate	6
97	46	M	Right flank pain	3 x 3 mm sized calculus in right kidney upper pole	460	uric acid	5.5
98	34	M	Right abdominal pain	12 x 9 mm sized calculus in right kidney midpole	520	calcium phosphate	5.8
99	19	F	Right abdominal pain	8 x 8.5 mm sized calculus in right renal pelvis causing hydronephrosis	1400	calcium oxalate	5.7
100	30	M	Right flank	11 x 13 mm sized calculus in	900	calcium	5.8

			pain	right mid ureter causing hydroureteronephrosis		phosphate	
101	55	F	Left abdominal pain	15 x 13 mm sized calculus in left renal pelvis causing hydronephrosis	1400	calcium oxalate	6.3
102	54	M	Right abdominal pain	6 x 6.8 mm sized calculus in right mid ureter causing mild hydroureteronephrosis	1007	calcium oxalate	6.3
103	35	F	Left flank pain	4 x 3 mm sized calculus in left kidney lower pole	650	calcium phosphate	6
104	35	M	Left flank pain	4.7 x 5 mm sized calculus in left kidney lower pole	450	Struvite	7.2
105	40	M	Left abdominal pain	17 x 14 mm sized calculus in left kidney mid pole	690	calcium phosphate	5.8
106	23	M	Left flank pain	4.2 x 3 mm sized calculus in left kidney lower pole	450	uric acid	5.7
107	65	M	Right abdominal pain	5 x 4.6 mm sized calculus in right kidney lower pole	1400	calcium oxalate	6.2
108	28	M	Right abdominal pain	6.7 x 4.2 mm sized calculus in upper pole of right kidney	1191	calcium oxalate	6
109	28	M	Right flank pain with hematuria	11 x 8 mm sized calculus in right proximal ureter causing hydroureteronephrosis	580	calcium phosphate	5.6
110	46	F	Right flank pain	4 x 3 mm sized calculus in right distal ureter causing hydroureteronephrosis	600	calcium phosphate	5.8
111	45	M	Left abdominal pain	4 x 5 mm sized in mid-pole left kidney	400	Struvite	7
112	26	M	Left abdominal pain	3 x 2 mm sized calculus in left kidney upper pole	350	Struvite	7.1
113	40	M	Right flank pain	12 x 6 mm sized calculus is noted in right mid ureter causing hydroureteronephrosis	350	Struvite	7