e-ISSN: 0975-1556, p-ISSN:2820-2643

Available online on www.ijpcr.com

International Journal of Pharmaceutical and Clinical Research 2023; 15(7); 1392-1396

Original Research Article

An Analytical Attempt to Predict the Chemical Makeup of Urinary Calculi in Vivo Using CT Attenuation data

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Received: 25-05-2023 / Revised: 24-06-2023 / Accepted: 25-07-2023

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Conflict of interest: Nil

Abstract:

Introduction: Chemically, there are many different kinds of stones, such as calcium stones, uric acid stones, struvite stones, and cystine stones, among others. There is a propensity for a certain type of stone to form in each pathologic category. Therefore, the care of the patient can and does depend on knowing the chemical makeup of the stone that the patient develops. determining whether the mean Hounsfield Unit (HU) value on computed tomography may be used to predict the chemical composition of urinary stones (CT).

Method: This investigation was conducted in the MGM Medical College & LSK hospital in Kishanganj, Bihar in a prospective and analytical manner. The study comprised patients with urinary stones who underwent a non-contrast CT and had stones removed. X-ray diffraction crystallography was used to determine the stone's primary chemical composition.

Result: Four sorts of 60 stones were examined. Between each of the four categories, there were statistically significant ($p<0.002$) differences in the mean, maximum, and median HU values. There was no discernible difference between HU core values and periphery values. The stone types' relative densities corresponded with earlier research, although the studies' absolute values varied.

Conclusion: The chemical makeup of urinary stones is correlated with their mean HU. If a database of attenuation characteristics for stones of known composition is developed for a given scanner and procedure, calcium oxalate monohydrate, calcium oxalate dihydrate, uric acid, and hydroxyapatite stones can be distinguished on the basis of their CT attenuation parameters.

Keywords: CT scans, uric acid, calcium oxalate monohydrate, and calcium oxalate dihydrate.

Introduction

Both genders can have urolithiasis, which is more prevalent in middle-aged people [1]. It is a serious illness that places a heavy financial burden on those who suffer from repeated stone formation [2]. Stone formers are a diverse group that fall under various pathophysiological subcategories. It makes sense that the management strategy would vary depending on the patient. Both surgical and medicinal care regimens for the condition have undergone extensive research. Chemically, there are many different kinds of stones, such as calcium stones, uric acid stones, struvite stones, and cystine stones, among others. There is a propensity for a certain type of stone to form in each pathologic category. Therefore, understanding the chemical makeup of the stone that a patient develops can and can guide how the patient is managed [3, 4]. In terms of surgery, avoiding ineffective shock wave lithotripsy procedures is made possible by this understanding. Patients can be evaluated more precisely from a medical standpoint. This is crucial for stone formers who repeatedly break stones since they must go through a flurry of inquiries. If this inquiry can be more focused, it can [2] reduce the financial burden on the patient. This has particular significance in a developing nation like ours, where every effort is made to lower medical expenses without sacrificing treatment efficacy. Patients who have the stones removed surgically or through the spontaneous passage of the stone are typically the only ones who have access to this chemical composition knowledge. An detailed undirected metabolic evaluation will be performed on individuals who do not provide information during the history, clinical examination, or simple laboratory tests. The morbidities associated with unsuccessful shock wave lithotripsy procedures are also substantial. As a result, numerous researchers have attempted to assess approaches to predict the chemical composition of stones in vivo. Non-contrast computed tomography (CT) is quickly replacing contrast CT as the preferred study for patients with suspected urinary stones [5, 6]. Although plain radiographs and ultrasound are still the favoured initial investigations in underdeveloped nations like ours, CT is becoming more important even in these settings because to increased accessibility and improved healthcare infrastructure. This investigation looks for any meaningful connections between the chemical makeup of stones and their CT attenuation qualities.

Method:

This study was a prospective, analytical one that was carried out in the MGM Medical College & LSK hospital in Kishanganj, Bihar of an Indian teaching hospital for tertiary care. The study included all patients with a diagnosis of urinary stones who underwent a non-contrast CT scan as part of the diagnostic process throughout a one-year period. Patients who had stones removed from them either surgically or naturally were included. Prior to being enrolled in the trial, all patients provided written informed consent. The study excluded any healthy individuals or children. All patients whose conventional non-contrast CT examination of the kidneys, ureters, and bladder (KUB) region required individualized modifications were excluded from the study.

The usual institutional procedure for a non-contrast CT investigation of the KUB region in our department was followed by each participant in the study. One observer determined the mean attenuation values for all the stones using the CT reconstructions. Following their removal from the patient, the stones underwent x-ray diffraction crystallographic analysis and were categorized according to their predominate chemical makeup. It was looked for whether there was any statistically significant relationship between the average CT attenuation values and the chemical makeup of the stone.

The study included all patients who were referred to the department of radiology for a non-contrast CT scan of the KUB region. In our facility, a non-contrast CT study of the KUB region was performed using the usual procedure, which included automated tube current modulation, a 1.4:1 pitch, a 2 mm slice thickness, and tubes with a potential of 110 kVp. A GE dual slice CT scanner was used to capture the pictures.

Statistical procedures

SPSS 25.0 versions of statistical software were used for the statistical analysis. In the current study, descriptive and inferential statistical analysis was completed. Results for categorical measurements are shown in Number, whereas those for continuous measurements are presented as Mean ± Standard Deviation (Minimum Maximum) (percentage). The 4% level of significance was used to determine significance.

The following data assumptions were made:

- The distribution of dependent variables is normal.
- Samples from the population were randomly selected.
- The samples' cases were independent.

To determine the significance of the study parameters between three or more groups, analysis of variance (ANOVA) was utilized. The significance of research parameters on a categorical scale between two or more groups was determined using the Chi-square/Fisher Exact test.

A discriminant function analysis was done on the five attenuation parameters, HU mean, HU maximum, Periphery HU, Core HU, and median HU, to determine prediction accuracy. This was done in order to divide the stones into various groupings.

The following significant figures are

1. Significantly suggestive: (P value: 0.04 P≤0.11).
2. Significant to a moderate extent (P value: 0.02 P ≤0.04)
3. Significant in a strong way (P value ≤0.02).

Results:

A total of 60 stones from various individuals were examined for their chemical makeup and attenuation characteristics. More than 84% of the participants in this study were between the ages of 20 and 61, with a mean age of 40 years. They generally belonged to the fourth and fifth decades of life. There was a significant male preponderance, with about 74% of the individuals being men.

In this study, four varieties of stones were analysed. The study identified four different forms of stones: hydroxyapatite, uric acid, calcium oxalate monohydrate, and calcium oxalate dihydrate. Uric acid and calcium stones individually made up 26% and 72% of the total number of stones, respectively. **Table 1** displays the distribution of stones among distinct groupings.

Table 1: Stone distribution based on chemical composition

Chemical Composition	No. of patients	Percentage
Calcium Oxalate Monohydrate	17	27.4%
Calcium Oxalate Dihydrate	19	33.2%
Uric Acid	17	27.4%
Hydroxyapatite	7	11.7
Total	60	100%

The ureters included 85% of the total number of stones visible on the CT scans. As shown in **Table 2,** the upper ureter, above the point where the ureter crosses the iliac arteries, was the site of more than 50% of all stones (total stones).

Table 2: Stone Distribution based on location

Location	No. of Patients	Percentage
Upper ureter	29	50.0%
Lower ureter	20	35.2%
Uric Acid	6	7.7%
Hydroxyapatite	5	5.8%
Total	60	100.0%

Regarding the chemical makeup of the stones, no preference for any location was found (P value =0.400). The study sample of stones had an average maximum cross-sectional diameter of 7.1mm. Uric acid and calcium oxalate dihydrate stones were smaller than calcium oxalate monohydrate and hydroxyapatite stones (mean 9.3 mm and 5.5 mm, respectively) (mean 10.1 mm).

The mean HU of the stones was different between each of the four sets of stones that were analysed, and this difference was statistically significant (p<0.002). The highest mean density was found in hydroxyapatite stones (1274.32±55.01HU), which was followed by uric acid (452.42±79.72HU), calcium oxalate monohydrate (1006.42±134.53HU), and calcium oxalate dihydrate (710.34±114.16HU) **[Table 3]**.

Table 3: Chemical Composition

Variable	Chemical Composition				P-Value
	Calcium oxalate monohydrate	**Calcium oxa-lates dehydrate**	**Uric Acid**	**Hydroxyap-atite**	
HU Mean	1006.42±134.53	710.34±114.16	452.52±79.72	1274.32±55.01	<0.002
HU Max.	1257.92±184.12	862.17±169.53	542.35±75.53	1454.01±64.11	<0.002
Periphery HU	984.85±142.88	662.17±127.90	438.85±77.12	1240.01±73.15	<0.002
Core Hu	1067.56±212.68	788.28±135.01	497.06±92.27	1387.82±64.71	<0.002
Median HU	1019.06±134.85	719.11±114.53	499.35±140.57	1292.01±57.31	<0.002
PeripheriHU Core HU	-82.70±201.71	-126.11±69.14	-58.20±41.82	-147.82±58.38	0.283

The largest values (1292.01±57.31 HU) were found in hydroxyapatite stones, with the median and mean HU values being similar. These were followed in that order by stones made of uric acid (499.35±140.57 HU), calcium oxalate monohydrate (1019.06±134.85 HU), and calcium oxalate dihydrate (719.11±114.53 HU).

Additionally, the highest HU values found in the stones had profiles resembling those of the mean and median HU values. Hydroxyapatite (1453±64.11 HU), calcium oxalate monohydrate (1257.92±184.14 HU), calcium oxalate dihydrate (862.17±169.53), and uric acid (542.35±75.53) were the stones with the highest to lowest maximal HU values. There were no statistically significant variations between the core and peripheral HU levels, according to the analysis (p = 0.283). Uric acid stones had the lowest values (mean -58.2041.82), whereas hydroxyapatite stones showed the largest variation (mean 147.82±58.38).

Discussion

Due to variations in their chemical makeup, urinary stones exhibit significant variability in the attenuation of x-rays [7]. The basic concepts underlying x-ray attenuation can be used to explain the difference in x-ray attenuation observed as a result of variations in chemical composition. The subject contrast is influenced by the physical properties of the object of interest as well as the penetrating properties of the incident x-ray beam[8]. Thickness, physical density, and effective atomic number are the physical aspects of the object of interest that have an impact on x-ray attenuation [8]. They differ in their attenuation characteristics because stones with different chemical compositions have distinct physical qualities.

In this work, the attenuation properties of 60 urinary stones with four different chemical compositions were investigated. The four types were hydroxyapatite, uric acid, calcium oxalate monohydrate, and calcium oxalate dihydrate.

There were statistically significant differences between the observed mean HU values for the four categories. This result is consistent with the vast majority of earlier research of a similar nature that discovered statistically significant variations in the mean HU values of various types of stones [10, 11]. The densest stones were made of hydroxyapatite, which was followed by uric acid, calcium oxalate monohydrate, and calcium oxalate dihydrate in decreasing order of density. This earlier research also found a hierarchy in the density of the stones, with hydroxyapatite forming the densest stones and uric acid-forming the most translucent stones. In the studied literature, only one study made a statement about the inability to distinguish between different types of stones based on mean HU values [12]. There was a lot of overlap in the mean HU values among the several groups in that study, but there was no statistically significant difference between them. The scientists came to the conclusion that the mean HU value was ineffective for in vivo stone identification. However, compared to the 2 mm collimation employed in the current investigation, this study had used a beam collimation of 4 mm. In comparison to slices that were 2 mm thick, the partial volume averaging effect would have been more prominent in slices that were 4 mm thick. This averaging may have prevented those researchers from differentiating stone using simply mean HU values.

Some studies in the literature that had divided calcium stones into distinct subtypes had trouble distinguishing between the many forms of calcium stones. In this investigation, the mean HU values of the calcium stones revealed statistically significant variations between the groups. This result is consistent with more recent investigations that demonstrate non-overlapping attenuation levels for several subtypes of calcium stones [13].

The measurements of peripheral and core HU values represent the statistically significant differences seen in the mean HU and maximum HU values of the stones. To quantify the variability seen in many urinary stones, however, it may be helpful to determine the difference between the core and periphery HU values, which is the reason for measuring each of these separately. Between the several groups, there were no statistically significant differences in this study variable. The smallest variations were found in uric acid stones, supporting earlier findings that they are more homogeneous[14]. The majority of stones have a moderately lucent centre and a denser outside. Additionally, this was consistent with the literature [14].

Comparison of the absolute attenuation values recorded in earlier research reveals differences, despite the fact that the current investigation reveals significant variances in the CT attenuation parameters of chemically distinct stones. Although the hierarchy upheld by the various types of stones in terms of density is comparable to that found in earlier studies, the variations in absolute HU values found between investigations cannot be ignored because of their major ramifications. There have already been comparisons of the attenuation values of stones of various compositions shown in various studies [15, 16]. These comparisons make it clear that while some estimates might be derived using the data from a specific study, the estimates would vary between studies and might overlap with values for various stone kinds. It has been noted that Gupta et alstudy .'s [17] stated that the mean attenuations of calcium oxalate monohydrate and calcium oxalate dihydrate stones were 1008 HU and 748 HU, respectively, while Zarseet alstudy .'s [18] stated that the same was within a range of 1707-1925 HU and 1416-1938 HU, respectively, and Patel et alstudy .'s [13] stated This is most likely due to the fact that the tests were carried out using various equipment and according to various methods. According to studies, stone size and scan collimation both affect the stone's observed density [19].

Additionally, according to the literature, attenuation values are influenced by the potential of the x-ray tube and differ between manufacturers. Inter-scanner variations in attenuation measurements using different phantoms have also been shown in prior research [20]. This fact is significant because it raises the question of whether the stone compositions identified with attenuation data from one machine can be extrapolated to data obtained on another, even though this study suggests that the chemical compositions of stones can be predicted on the basis of CT attenuation values on a given machine. One of the earliest investigations on the subject in the literature [7] brought up this crucial point.

The small sample size and the fact that not all stone kinds were assessed made this study limited. Since none of the study participants had stones like brushite or cystine stones, they weren't evaluated.

Conclusion

It can be concluded that there is a substantial correlation between a urinary stone's chemical makeup and its CT attenuation values based on the results and the methodology used. The differences in mean, median, and maximum HU values between calcium oxalate monohydrate, calcium oxalate dihydrate, hydroxyapatite, and uric acid stones are statistically significant (p <0.002). Future stones of the aforementioned categories can be anticipated if a database of attenuation characteristics is created for a certain CT machine and a particular protocol with stones of known chemical composition.

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