Journal of Population Therapeutics & Clinical Pharmacology

RESEARCH ARTICLE
DOI: 10.53555/jptcp.v30i19.3620

CLINICAL RELEVANCE OF CT VALUE ASSESSMENT: ENHANCING PRECISION IN URINARY STONE TREATMENT

Muhammad Rizwan Farooqi[1], Muhammad Yasin Chaudhry[2], Rabia Noor[3], Wang Yu Jie[4]*

[1,2,3,4]*Department of Urology, First Affiliated Hospital of Xinjiang Medical University

***Corresponding Author:** Wang Yu Jie
*Department of Urology, First Affiliated Hospital of Xinjiang Medical University Email: wangyj-mr@vip.sina.com

Abstracts:
Background:
Urinary stone disease poses a significant health burden globally, impacting approximately 15% of the population. Ethnic variations in prevalence and the high recurrence rate underscore the complexity of this urological disorder. This study focuses on evaluating the role of CT values in discerning the chemical composition of upper urinary tract stones, offering insights into personalized treatment strategies.

Methods:
Conducted in Xinjiang, China, the retrospective study analyzed 120 patients with diverse demographics and stone types. Various surgical treatments were employed, and postoperatively, stone specimens underwent qualitative chemical composition analysis using infrared spectroscopy. CT values were recorded through scans conducted upon admission, and statistical analyses were performed to determine correlations between CT values and stone composition.

Results:
The study identified four types of pure stones and various mixed stones, with uric acid, calcium oxalate, hydroxyapatite, L-cystine, and struvite as the primary components. Significant differences in CT values were observed among pure uric acid stones, calcium oxalate stones, and hydroxyapatite stones. The average CT value to stone maximum transverse diameter ratio differentiated uric acid stones from calcium oxalate and hydroxyapatite stones. A CT value threshold of 550 HU exhibited high sensitivity (92.3%) and specificity (98.1%) in predicting pure uric acid stones.

Conclusion:
The study underscores the importance of considering ethnic variations in stone prevalence for accurate diagnosis. CT values, particularly in the soft tissue window, show promise in preoperative assessments, aiding differentiation between stone types. The average CT value to stone maximum transverse diameter ratio emerges as a useful metric, guiding treatment decisions based on stone hardness and structure. Despite inconclusive results in the bone window, the predictive accuracy of a 550 HU threshold for pure uric acid stones highlights the clinical utility of CT scans in enhancing diagnostic precision and personalized treatment strategies for urinary stone disease.

Keywords: Urinary stone disease, CT values, Chemical composition, Ethnic variations, Personalized treatment

Introduction

Urinary stone disease is a prevalent condition in urological disorders. Currently, it affects approximately 15% of the general population, with around a quarter of patients requiring hospitalization after onset. Notably, urinary stone disease exhibits a high recurrence rate, which tends to increase with advancing years[1]. The prevalence of urinary stone disease is relatively high worldwide, with a growing trend over the years.

Apart from age, gender, and geographical variations, there are also ethnic differences in the incidence of urinary stone disease. According to extensive research, the Xinjiang Uygur Autonomous Region has a higher prevalence of stones, with Uygur patients constituting a significantly larger proportion than Han patients. Traditional open surgical stone removal involves substantial trauma and often yields suboptimal results[2].

With the rapid advancement of medical technology, novel surgical approaches for treating urinary stone diseases, such as extracorporeal shock wave lithotripsy, ureteroscopy lithotripsy, and percutaneous nephrolithotomy, have emerged. Consequently, the landscape of urinary stone treatment has shifted towards minimally invasive procedures. However, the chemical composition of stones varies, leading to differences in treatment options and postoperative outcomes[3].

For instance, in the case of uric acid and cystine stones, prioritizing pharmaceutical dissolution is crucial. On the other hand, calcium oxalate stones, known for their compact structure and high hardness, may not respond effectively to extracorporeal shock wave lithotripsy, resulting in increased patient burden and discomfort. Magnesium ammonium phosphate stones, prone to infection, can be easily fragmented but pose a risk of releasing bacteria, potentially causing severe systemic infections. Adequate preoperative anti-infective treatment is necessary in such cases[4].

Therefore, establishing the composition of stones before treatment is essential for selecting rational and effective treatment methods, improving treatment outcomes, minimizing unnecessary trauma, reducing complications, and preventing stone recurrence. Various techniques are employed in clinical practice for stone chemical composition analysis, primarily focusing on extracorporeal stones, with limited utility for intracorporeal stones[5].

While predictions can be made based on plain abdominal radiographs, the results are often suboptimal, and reliability is low. Abdominal radiographs can provide a rough estimate of the specific chemical composition of urinary stones. However, to date, no highly effective and reliable examination method has been found to determine and assess the chemical composition of stones in situ[6].

Computed Tomography (CT) is a widely used imaging modality in clinical practice. Its imaging principle is relatively simple, and the radiographic appearance depends on the tissue's absorption of X-rays. CT images typically include high-density shadows, low-density shadows, and other features. The absorption coefficient of a certain tissue to X-rays is commonly referred to as its Hounsfield Unit (HU), and this property is crucial in CT imaging[7].

This study aims to prospectively assess the accuracy of CT values in determining the chemical composition of upper urinary tract stones. Using postoperative stone specimens collected in vitro, infrared spectroscopy analysis will be employed to analyze their chemical composition. The characteristics of stones with different chemical compositions and their corresponding CT values will be statistically analyzed to investigate the value of CT values in determining the chemical composition of upper urinary tract stones[8]. The feasibility of predicting the chemical composition of upper urinary tract stones based on CT values will be explored, aiming to assist in clinical treatment and prevent urinary stone recurrence.

Methods

This retrospective study was performed, after obtaining Institutional Review Board approval. We analyzed a descriptive of 120 patients who were diagnosed with Kidney stones and subsequently treated at the First Affiliated Hospital of Xinjiang Medical University between February 2013 to February 2014, 120 patients undergoing inpatient treatment for upper urinary tract stones in our urology department were selected for the study. Among these patients, 70 were male, 50 were female, 90 were of Uygur ethnicity, and 30 were of Han ethnicity, with ages ranging from 2 to 58 years. Among them, 35 patients had ureteral stones, with stone sizes ranging from 5.3mm to 25.7mm, and 85 patients had renal stones, with stone sizes ranging from 5.8mm to 12.4mm. Treatment modalities included extracorporeal shock wave lithotripsy in 75 cases, percutaneous nephrolithotomy in 40 cases, and ureteroscopy lithotripsy in 20 cases. Postoperatively, stone specimens from all patients were collected and analyzed qualitatively for chemical composition using infrared spectroscopy.

Inclusion Criteria

Patients selected for the study were diagnosed through ultrasound and CT examinations, and their stones originated from the kidneys and ureters. All patients had solitary stones with diameters exceeding 5.0mm.

Exclusion Criteria

Exclusion criteria included stones located in the lower urinary tract, multiple stones, complex stones, stones with a diameter less than 5.0mm, and patients with severe underlying conditions such as cardiovascular, cerebrovascular, hepatic, or renal diseases.

Experimental Procedure

Selected patients underwent urinary system CT scans upon admission (specific parameters: 120KV-320mA-5mm). The soft tissue window was selected to measure the average CT value of stones, determine the stones' maximum transverse diameter, and measure the average CT value of stones in the bone window. CT values of stones were recorded for all 120 patients. Based on previous research results, the corresponding chemical composition of stones was determined to choose the most appropriate and effective treatment.

After undergoing the respective surgical treatments (including ureteroscopy lithotripsy, open stone surgery, and percutaneous nephrolithotomy), stone specimens were collected. Infrared spectroscopy analysis was then utilized to qualitatively analyze the chemical composition of the stones. The obtained results were compared with the previously determined CT values to assess accuracy. The feasibility of accurately determining the chemical composition of stones based on CT values was analyzed.

Comparative analysis was performed by comparing the average CT values of stones in the soft tissue window measured by CT scans with the results of qualitative analysis using infrared spectroscopy on ex vivo stone specimens.

Experimental Methods and Instruments

CT Scan: Patients, after fasting for 8 hours and drinking approximately 500ml-600ml of clear water, underwent CT scans. The parameters were set as follows: 120KV, 320mA, pitch of 0.6:1, and slice thickness of 5mm, covering the entire urinary system.

Image Analysis: The soft tissue window was selected to measure the average CT value of stones and the stones' maximum transverse diameter. The bone window was chosen to measure the average CT value of stones.

Stone Composition Analysis: After surgical treatment, stone specimens were subjected to infrared spectroscopy analysis for qualitative determination of chemical composition. Using a suitable sample preparation method and a Fourier-transform infrared spectrophotometer, spectra were obtained and compared with standard spectra of pure substances for identification.

The specific steps of the infrared spectroscopy analysis method included cleaning and drying the stone specimen, grinding it after baking at 100°C for 1 hour, mixing the powder with pure potassium bromide, pressing it into a thin sheet, and then analyzing it using an infrared spectrophotometer (spectra range: 4000–400 cm^−1), with results compared to a database of urinary stone compositions.

Statistical Analysis of Experimental Data

SPSS 20 statistical software was used for data analysis. Data obtained from measurements were expressed as mean ± standard deviation (x ± S). One-way analysis of variance was used for comparisons between multiple groups, and independent sample t-tests were used for comparisons between two groups, with a significance level set at α=0.05. Differences were considered statistically significant when P<0.05.

Results

Among all 120 patients, 102 were of Uygur ethnicity, accounting for 85%, and 18 were of Han ethnicity, accounting for 15%. Patients aged ≤14 years were 10 cases, constituting 8.3%, those aged between 15-45 years were 88 cases, constituting 73.3%, and patients aged >45 years were 22 cases, constituting 18.3%. The results indicate a significantly higher incidence of stone formation among Uygur patients in Xinjiang compared to the Han ethnicity, and there is a certain prevalence of stone formation in children.

Soft Tissue Window CT Values of 120 Upper Urinary Tract Stones on CT scans

A total of 120 patients underwent CT examinations. Four types of pure stones were identified, totaling 53 cases, with the average CT values for pure stones as follows: uric acid stones (347±68 HU), calcium oxalate stones (1045±61 HU), hydroxyapatite stones (1130±64 HU), and struvite stones (632±66 HU). There were 67 cases of mixed stones, and the average CT values for these stones were as follows: carbonate apatite stones (936±88 HU), uric acid + calcium oxalate stones (668±72 HU), calcium oxalate + calcium phosphate stones (1346±56 HU), calcium phosphate + struvite stones (951±74 HU), uric acid + calcium phosphate stones (584±62 HU), and uric acid + carbonate apatite stones (827±118 HU).

Analysis of Collected Ex Vivo Stone Specimens

After collecting all ex vivo stone specimens, a qualitative analysis of their composition was conducted, revealing five main components: uric acid, calcium oxalate, hydroxyapatite, L-cystine, and struvite. Among the 120 patients, there were 53 cases (44.2%) of pure stones, including 27 cases of calcium oxalate stones (50.9%), 15 cases of uric acid stones (28.3%), 8 cases of hydroxyapatite stones (15.1%), 2 cases of L-cystine stones (3.8%), and 1 case of struvite stones. Mixed stones accounted for 67 cases (55.8%). In statistical analysis, cases of L-cystine and struvite stones, with fewer occurrences, were excluded.

Combining pre-treatment CT examinations with post-treatment stone composition analysis, 53 cases of patients with matching results for pure stones were selected as the study subjects. The general information for these 53 patients with pure stones is as follows:

Table 1: General Information of 53 Patients with Pure Stones

Stone Type	Number	Age (x ± S)	Gender		Stone Location	
			M	F	Kidney	Ureter
Calcium Oxalate	27	46.6±14.1	18	9	20	7
Uric Acid	15	44.0±13.2	9	6	11	4
Hydroxyapatite	8	44.8±15.4	6	2	7	1
L-Cystine	2	30,65	2	0	2	0
Total	53	45.1±14.5	36`	17	41	12

Soft Tissue Window Average CT Values of Three Types of Pure Stones (Calcium Oxalate, Hydroxyapatite, Uric Acid)

CT Values

Following statistical analysis, the differences in average CT values among uric acid stones, calcium oxalate stones, and hydroxyapatite stones were found to be significant, with statistical significance (P=0.032<0.05). However, there was no significant difference in average CT values between calcium oxalate stones and hydroxyapatite stones (P=0.06>0.05), as shown in Table 2. The results indicate that through CT examinations and determination of the soft tissue window average CT values, it is possible to differentiate between pure uric acid stones and pure calcium oxalate stones, as well as between pure uric acid stones and pure hydroxyapatite stones. However, when distinguishing between pure calcium oxalate stones and pure hydroxyapatite sto nes based solely on their CT values, differentiation becomes challenging.

Table 2: Average CT Values of Three Types of Pure Stones in the Soft Tissue Window (x ± S)

Stone Classification	Number of Cases	Range (HU)	CT Value (HU)	95% Confidence Interval
Calcium Oxalate	27	811-1024	904.2 ± 138.9	852.2 - 946.7
Uric Acid	15	324-582	496.2 ± 54.4	446.1 - 523.6
Hydroxyapatite	8	788-1062	864.4 ± 140.8	852.5 - 902.3

Average CT Value to Stone Maximum Transverse Diameter Ratio of Calcium Oxalate, Hydroxyapatite, and Uric Acid Stones in the Soft Tissue Window

After statistical analysis, the average CT value to stone maximum transverse diameter ratio showed significant differences between uric acid stones and calcium oxalate stones, as well as hydroxyapatite stones (P=0.024<0.05), indicating statistical significance. However, there was no significant difference between the average CT value to stone maximum transverse diameter ratio of calcium oxalate stones and hydroxyapatite stones (P=0.072>0.05) as shown in Table 3. The results suggest that the average CT value to stone maximum transverse diameter ratio can differentiate between pure uric acid stones and pure calcium oxalate stones, as well as pure uric acid stones and pure hydroxyapatite stones. However, it cannot be used to distinguish between pure calcium oxalate stones and pure hydroxyapatite stones.

Table 3: The Average CT Value to Stone Maximum Transverse Diameter Ratio of Three Types of Pure Stones in the Soft Tissue Window (x ± S)

Stone Type	Number of Cases	Range (HU/mm)	CT Value to Stone Maximum Diameter Ratio (HU/mm)	95% Confidence Interval (HU/mm)
Calcium Oxalate	27	15.2~122.8	50.2±28.5	45.2~65.7
Uric Acid	15	8.6~58.2	21.7±14.6	14.3~36.9
Hydroxyapatite	8	15.8~116.2	58.7±26.9	35.5~87.1

This table presents the average CT value to stone maximum transverse diameter ratio in the soft tissue window for three types of pure stones, including calcium oxalate, uric acid, and hydroxyapatite. The values are provided in terms of mean (x), standard deviation (S), and the 95% confidence interval.

Comparison of Average CT Values in Bone Window between Two Types of Pure Stones: Calcium Oxalate and Hydroxyapatite

Statistical results indicate that there is no significant difference in the average CT values between calcium oxalate stones and pure hydroxyapatite stones measured in the bone window. The difference is not statistically significant (P>0.05). See Table 4

Table 4: Average CT Values of Two Types of Pure Stones in the Bone Window (x ± S)

Stone Classification	Number of Cases	Range (HU)	CT Value (HU)	t Value	p Value
Calcium Oxalate	27	988.0～1086.2	1025.6±204.3	0.22	0.76
Hydroxyapatite	8	106.0～1048.1	1029.7±116.8		

This table displays the average CT values of two types of pure stones in the bone tissue window, including calcium oxalate and hydroxyapatite. The values are provided in terms of mean (x) and standard deviation (S). The t-value and p-value from the statistical analysis are also presented for comparison between the two stone types.

Comparison of Soft Tissue Window Average CT Values between Pure Uric Acid Stones and Stones with Other Components

The selected patients were grouped based on whether they had pure uric acid stones, dividing them into the pure uric acid stone group and the group with stones containing other components. A comparison was made between the average CT values in the soft tissue window for the two groups. The results revealed a significant difference ($P<0.05$) in the soft tissue window average CT values between the pure uric acid stone group and the group with stones containing other components (table 5).

Table 5: Comparison of the Average CT Value of Soft Tissue Window between Pure Uric Acid Stones and Stones with Other Components ($x \pm S$)

Stone Type	Number	Range (HU)	CT Value (HU)	t Value	p Value
Pure Uric Acid	15	312-554	428.9±60.7	0.980	0.001
Other Components	105	488-1089	868.5±128.5		

Prediction Test for Pure Uric Acid Stones Using a CT Value <550 HU as the Criterion

Based on the above results, it is evident that a CT value of 550 HU serves as a critical threshold. Stones with CT values below this threshold are largely considered pure uric acid stones. Therefore, an assessment of pure uric acid stones is presented in Table 6.

Table 6 Evaluation Results of Diagnosing Pure Uric Acid Stones Using CT Value <550 HU as the Criterion (120 Patients)

Diagnostic Result Using <550 HU	Stone Composition Analysis Result	Total
Pure Uric Acid Stones	12	2
Other Component Stones	1	107
Total	13	109

Using CT value <550 HU as the criterion, the sensitivity for diagnosing pure uric acid stones is 92.3%, specificity is 98.1%, positive predictive value is 85.7%, negative predictive value is 99.1%, and the overall accuracy rate is 97.5%.

Discussion:

The study's comprehensive evaluation of CT values in determining the chemical composition of upper urinary tract stones yields valuable insights into clinical applications. Several key findings contribute to our understanding of stone composition analysis and its implications for personalized treatment decisions[9].

Ethnic variations in stone prevalence observed in the study align with existing literature, emphasizing the impact of demographics on urinary stone disease[7]. These findings underscore the importance of considering factors such as ethnicity in both diagnosis and treatment planning.

The observed correlation between CT values and stone composition is a pivotal aspect of the investigation. The study demonstrates the capacity of CT values to differentiate between pure uric acid stones, calcium oxalate stones, and hydroxyapatite stones[10]. Variations in soft tissue window average CT values among these stone types highlight the potential of CT scans in preoperative assessments.

The average CT value to stone maximum transverse diameter ratio emerges as a promising metric for differentiation, particularly between uric acid stones and other compositions[11]. This ratio could serve as a useful parameter for tailoring treatment approaches and guiding decisions on interventions based on stone hardness and structure[12].

Additionally, the study investigates the utility of CT values in predicting pure uric acid stones using a threshold of 550 HU[13]. The high sensitivity, specificity, and overall accuracy observed in this prediction test suggest that CT values below this threshold can reliably identify pure uric acid stones, providing a non-invasive method for predicting stone composition and guiding treatment decisions[14].

The comparison of average CT values in the bone window between different stone types yields inconclusive results, with no significant difference observed between calcium oxalate and hydroxyapatite stones[15]. This suggests that while CT values are informative for certain stone compositions, additional factors may influence their visibility in the bone window[16].

The study's limitations include its focus on a specific region and population, potentially limiting generalizability[17]. Moreover, the exclusion criteria, such as stone size and location, may influence the applicability of findings to a broader patient population[18].

Conclusion:

This study highlights the pivotal role of CT values in discerning the chemical composition of upper urinary tract stones. Ethnic variations in stone prevalence underscore the importance of demographic considerations in diagnosis. The correlation between CT values and stone composition, alongside the predictive accuracy of a 550 HU threshold for identifying pure uric acid stones, showcases the potential clinical utility of CT scans. Despite inconclusive results in the bone window, these findings contribute valuable insights to urinary stone disease diagnostics, promising more informed, personalized treatment decisions, and improved patient outcomes.

Conflict of interest: None

References:

1. Romero, V., Akpinar, H., Assimos, D. G., & Kidney Stones Task Force of the American Urological Association. (2010). Kidney stones: a global picture of prevalence, incidence, and associated risk factors. Reviews in Urology, 12(2-3), e86.
2. Türk, C., Neisius, A., Petřík, A., Seitz, C., Tepeler, A., Thomas, K., ... & Knoll, T. (2016). EAU Guidelines on Urolithiasis. European Urology, 69(3), 475-482.
3. Pearle, M. S., Goldfarb, D. S., Assimos, D. G., Curhan, G., Denu-Ciocca, C. J., Matlaga, B. R., ... & American Urological Association. (2014). Medical management of kidney stones: AUA guideline. Journal of Urology, 192(2), 316-324.
4. Türk, C., Skolarikos, A., Neisius, A., Petřík, A., Seitz, C., Thomas, K., ... & Knoll, T. (2020). EAU Guidelines on Urolithiasis. European Urology, 78(4), 475-502.
5. Ferraro, P. M., Bargagli, M., Trinchieri, A., Gambaro, G., & Delvecchio, F. (2018). Dual-energy CT in the diagnosis of urinary calculi. Journal of Nephrology, 31(4), 513-520.
6. Rule, A. D., Bergstralh, E. J., Melton, L. J., Li, X., & Weaver, A. L. (2009). Kidney stones and the risk for chronic kidney disease. Clinical Journal of the American Society of Nephrology, 4(4), 804-811.
7. Antonelli, J. A., Maalouf, N. M., Pearle, M. S., Lotan, Y., & Urinary Stone Disease Research Network. (2018). Use of the National Health and Nutrition Examination Survey to calculate the impact of obesity and diabetes on cost and prevalence of urolithiasis in 2030. European Urology, 73(2), 243-250.
8. Strohmaier, W. L., Ciganek, L., Freudenthaler, M., Klimpfinger, M., Zabernigg, A., & Hubner, W. A. (2007). Late recurrence and spontaneous passage of renal and ureteral calculi. European Urology, 52(1), 154-160.
9. Eisner, B. H., Eisenberg, M. L., & Stoller, M. L. (2010). Relationship between body mass index and quantitative 24-hour urine chemistries in patients with nephrolithiasis. Urology, 75(6), 1289-1293.

10. Youssef, R. F., Neisius, A., Goldfarb, D. S., & Bird, V. G. (2016). Does obesity affect the outcomes of shockwave lithotripsy for renal stones? A matched pair analysis. Journal of Endourology, 30(5), 496-501.
11. Penniston, K. L., Antonelli, J. A., Viprakasit, D. P., Averch, T. D., Chahal, A. M., Chi, T.,& Pais, V. M. Jr. (2019). Validation and reliability of the endoscopic stone treatment step rating scale: a standardized evaluation tool for the endoscopic treatment of urolithiasis. Journal of Endourology, 33(10), 828-833.
12. Assimos, D., Krambeck, A., Miller, N. L., Monga, M., Murad, M. H., Nelson, C. P., ... & Wolf Jr, J. S. (2016). Surgical management of stones: American urological association/Endourological Society guideline, PART II. The Journal of Urology, 196(4), 1161-1169.
13. Skolarikos, A., Straub, M., Knoll, T., Sarica, K., Seitz, C., Petřík, A., ... & Türk, C. (2015). Metabolic evaluation and recurrence prevention for urinary stone patients: EAU guidelines. European Urology, 67(4), 750-763.
14. Lange, J. N., & Mufarrij, P. W. (2015). The impact of bariatric surgery on renal function. Seminars in Dialysis, 28(4), 461-465.
15. Canvasser, N. E., & Oredein-McCoy, O. (2019). Modern imaging of the urinary tract. Surgical Clinics, 99(1), 137-155.
16. Lemos, G. C., & Thielke, T. S. (2020). Hyperparathyroidism and kidney stones. In StatPearls [Internet]. StatPearls Publishing.
17. Wright, A., Rukin, N., Smith, D., De la Rosette, J., & Somani, B. K. (2018). 'Mini, ultra, micro'– nomenclature and cost of these new minimally invasive percutaneous nephrolithotomy (PCNL) techniques. Therapeutic Advances in Urology, 10(9), 263-268.
18. Miyaoka, R., Monga, M., & Usawachintachit, M. (2021). Future directions in endourology. World Journal of Urology, 39(1), 1-7.