Original Article

DOI: 10.7860/JCDR/2026/85759.24192

Radiology Section

Role of Spectral CT Imaging in the Evaluation of the Chemical Composition of Urinary Calculi: A Cross-sectional Study

MOHINI GUPTA[1], KARTHIK GADABANAHALLI[2], PRASHANTH KULKARNI[3], VENKATRAMAN BHAT[4]

(cc) BY-NC-ND

ABSTRACT

Introduction: Characterising the composition of urinary calculi is valuable for managing patients with urolithiasis. Prior to Dual-Energy Computed Tomography (DECT), there were limited direct options for precisely evaluating the composition of calculi. This technique by interrogating the tissues with two energy levels can analyse the composition of calculi.

Aim: To assess the diagnostic accuracy of Dual-Energy spectral Computed Tomography (CT) in determining stone composition, using Fourier Transform Infrared (FTIR) spectroscopy as the gold standard.

Materials and Methods: The present cross-sectional study was conducted at Department of Radiology, Narayana Health City Hospital, Bengaluru, Karnataka, India between June 2023 and February 2024. A total of 41 patients with urolithiasis who subsequently were managed by Percutaneous Nephrolithotomy (PCNL) underwent Computed Tomography of the Kidneys, Ureters, and Bladder (CT-KUB) imaging using a 256-slice General Electric (GE) Revolution dual-energy CT scanner following a standardised protocol, and were included. The acquired imaging data were post-processed on the GE Advantage Workstation to assess the chemical composition of urinary stones. Postoperative stone specimens were subjected to Fourier Transform Infrared (FTIR) spectroscopy analysis, and the laboratory findings were compared with the radiological results.

Results: The study included 41 patients aged 24-78 years, with a mean age of 43.6±7.98 years, predominantly males (28/41). Abdominal pain was the commonest symptom (72.3%), and 10.6% were asymptomatic. Multiple stones were more frequent, with 14.9% having more than five calculi. In the present study, the composition of urinary calculi was accurately determined in 32 of 41 cases (78%). Of the 35 calcium oxalate calculi, DECT accurately identified 20, while the remainder were categorised as other compositions. DECT identified all the uric acid stones.

Conclusion: Spectral CT with advanced post-processing software demonstrates strong potential for accurately determining the primary composition of urinary stones.

Keywords: Computed Tomography, Infrared Spectroscopy, Urolithiasis

INTRODUCTION

Urolithiasis is one of the most prevalent urologic conditions in India, and its occurrence is influenced by factors such as age, gender, diet, fluid intake, climate, occupation, socioeconomic status, education, genetics, and metabolic disorders [1]. In most Asian countries, calcium oxalate (75%-90%) is the predominant component of upper urinary tract stones, followed by uric acid (5%-20%), calcium phosphate (6%-13%), struvite (2%-15%), and cystine (0.5%-1%) [1].

Non-Contrast CT (NCCT) is the preferred imaging modality for the routine diagnosis of urolithiasis and provides critical insights into stone size, burden, location, and degree of obstruction that guide treatment decisions. While the chemical composition of stones is valuable information for clinical management, conventional CT cannot reliably differentiate stone compositions because of overlapping attenuation values (measured in Hounsfield units) among different stone types [2].

Precise identification of stone composition is essential for predicting fragility and thus tailoring treatment. For instance, uric acid stones respond well to medical management with urine alkalinisation; on the other hand, cystine, calcium oxalate and brushite stones, being less fragile, are less amenable to Extracorporeal Shock Wave Lithotripsy (ESWL), a common treatment option for renal and ureteral stones [2].

The application of DECT is increasingly prevalent in clinical practice. By utilising two distinct X-ray photon spectra, DECT differentiates materials with varying attenuation properties by varying interactions at different energy levels. Various acquisition technologies exist across vendors; in the present study, a single radiation source was employed, with the option to rapidly switch kilovoltage between high and low tube potentials within the same tube rotation to generate the desired images [3].

The DECT effectively differentiates uric acid stones from non-uric acid (calcium-dominant) stones, leveraging the distinct attenuation profiles of uric acid stones (composed of low atomic number elements), compared to non-uric acid stones, which contain higher atomic number elements [4].

Accurate sub-categorisation of renal stones is an emerging application of DECT. Advances in DECT algorithms and improved spectral separation in next-generation scanners enable further differentiation of renal stones with similar compositions. In the past, characterising mixed renal stones remained challenging; current technology can identify the predominant stone type. The aim of the present study was to evaluate the ability of spectral CT to identify the predominant composition of urinary stones, particularly in cases with mixed stone composition.

MATERIALS AND METHODS

A cross-sectional study was conducted between June 2023 and February 2024, including 41 patients who presented to the Department of Radiology at Narayana Health City Hospital, Bengaluru, Karnataka, India with suspected urolithiasis and underwent both Spectral CT and post-surgical Spectroscopic analysis. The present study was approved by the Institutional Ethics

Committee by a letter of approval, ECR/772/Inst/KA/2016/RR-22 dated 12-1-2023 and informed consent was taken from the patients prior to inclusion in the study.

Inclusion and Exclusion Criteria: The study included all patients who underwent spectral CT of the abdomen and pelvis or CT-KUB during the study period and met the following criteria: patients aged 18 years and above, those with urinary calculus or calculi identified on CT imaging, and who subsequently underwent surgical extraction by PCNL or open surgery within two months of the CT examination. Only patients with available post-surgical spectroscopic analysis of the extracted calculi were included. Patients were excluded, if they had sub optimal quantity of the sample.

Study Procedure

All patients were scanned with a 256-slice multi-detector CT scanner (Revolution CT, GE unit). This system features an ultrafast tube kilovoltage switching mechanism, enabling rapid voltage shifts between 80 and 140 kVp, in under 0.5 ms. This capability is achieved through a high-voltage generator and a garnet crystal scintillator detector with ultra-rapid optical response.

Images acquired with the dual-energy modality were post-processed using a dedicated remote workstation and the Gemstone Spectral Imaging Viewer software. (GE AWS version 2.2) for evaluating the stone's chemical composition. The software displayed the composition of the calculus graphically as histograms and energy spectrum curves.

For each patient, data were recorded on the number of urinary calculi, stone composition, Hounsfield Unit (HU) value, and associated complications. All examinations were reviewed in axial, coronal, and sagittal planes, with urinary stone CT density measured using a Region of Interest (ROI) placed in an area smaller than 50% of the stone's maximum diameter.

Radiation dose in volume CT Dose Index (CTDI vol; mGy), Dose-Length Product (DLP; mGy-cm), and length of acquisition in millimetres were recorded for each patient. Effective radiation dose (mSv) was calculated as DLP × effective factor (0.015 for abdominal CT) for each patient.

The stones extracted by the Percutaneous Nephrolithotomy (PCNL) procedure were sent for spectroscopic analysis by FTIR Spectroscopy. The spectrometer uses fourier transform algorithms to convert the raw data into an infrared absorption spectrum. The primary components of urinary stones, namely, calcium oxalate, uric acid, and other compounds, are identified by their unique absorption peaks.

STATISTICAL ANALYSIS

Statistical analysis was performed using Statistical Package for the Social Sciences (SPSS) version 27.0 (IBM Corp., Armonk, NY, USA). Sensitivity, specificity, Positive Predictive Value (PPV), Negative Predictive Value (NPV), and overall diagnostic accuracy of spectral CT in determining urinary stone composition were calculated using FTIR spectroscopy as the reference standard. Categorical variables were analysed using the chi-square test. A p-value <0.05 was considered statistically significant.

RESULTS

The mean age was 43.6 years Standard Deviation (SD)±7.98. Most patients were male (n=28, 59%). Abdominal pain was the most common symptom, reported by 34 patients (72.3%). Notably, 5 patients (10.6%) were asymptomatic, with urinary stones detected incidentally [Table/Fig-1]. Among the 41 patients, the majority 24 (58.5%) had more than one calculi [Table/Fig-2].

The data reveal that the right renal pelvicalyceal system is the most common site for urinary stones, with 15 patients affected. The left renal pelvicalyceal system was involved in 13 cases. Bilateral urinary calculi were observed in 13 patients, indicating a notable prevalence.

Category	Subcategory	n (%)
Gender	Male	28 (68.3)
	Female	13 (31.7)
	Total	41 (100)
Age group (years)	<30	1 (2.1)
	30-40	6 (12.8)
	41-50	8 (17)
	51-60	15 (31.9)
	>60	11 (23.4)
Symptoms	Pain	34 (72.3)
	Vomiting	6 (12.8)
	Haematuria	7 (14.9)
	Dysuria	10 (21.3)
	Fever	8 (17)
	Asymptomatic	5 (10.6)

[Table/Fig-1]: Demographic data and clinical symptoms.

Number of stones	n (%)
One	17 (36.2)
Two	6 (12.8)
Three	9 (19.1)
Four	1 (2.1)
Five	1 (2.1)
Multiple	7 (14.9)

[Table/Fig-2]: Number of stone and frequency.

The renal pelvis was the most common location for urinary stones, affecting 18 patients. The next most frequent site was the Pelvic Ureteric Junction (PUJ), with 10 patients, a critical site for obstruction and symptoms. A total of 10 patients had stones in the kidney calyces, another frequent site for stone formation. Stones in the proximal ureter were the least common, affecting only three patients. Ureteric location often causes significant symptoms and complications.

Among 41 patients, five exhibited an obstructed collecting system, and three had bulky ipsilateral kidneys with perinephric fat stranding, indicative of infection. One of the five patients with hydronephrosis required emergent percutaneous nephrostomy.

Most patients (13 of 41) had urinary calculi with densities ranging from 1300 to 1600 Hounsfield Unit (HU) [Table/Fig-3].

Hounsfield Unit (HU) value	n (%)
400-700	8 (19.5)
701-1000	6 (14.6)
1001-1300	11 (26.8)
1301-1600	13 (31.7)
>1600	3 (7.3)

[Table/Fig-3]: Frequency distribution of HU values in study population.

As regards the radiation dose received, in the protocols, patient received an average dose of 5.128 mSv [Table/Fig-4].

Acquisition protocol	Findings
Pitch factor	0.3 ratio
Scan length	45-55 cms
Reconstruction algorithm	ASiR-V
Tube current	Automatic
kV range	80-140 kV
Lowest dose (CTDI vol)	0.154 mGy
Highest dose (CTDI vol)	0.212 mGy
Average dose (CTDI vol) for 41 patients	0.160 mGy

Average DLP (mGy/cm)	7.692
Average dose (mSv)	5.128

[Table/Fig-4]: CT Technical parameters and radiation dose in 41 adult patients with urolithiasis. 256-slice multi-detector dual source CT scanner (Revolution CT, GE unit).
Abbreviations: CTDI: Computed tomography dose index; DLP: Dose length product; mGy: milliGray; mSV: milli-Severt.

Of the 35 calcium oxalate calculi, DECT accurately identified 20 cases. However, it misclassified three stones as calcium, three as brushite, one as calcium-hydroxyapatite, and two as cystine. Additionally, mixed stones, including five composed of calcium oxalate monohydrate and brushite and one composed of calcium oxalate monohydrate and cystine, were incorrectly identified as pure calcium oxalate monohydrate by DECT.

Nearly half of the patients 20 (48.8%) had pure calcium oxalate monohydrate stones [Table/Fig-5]. Representative image of calcium oxalate monohydrate shown in [Table/Fig-6]. Cystine-containing stones were less common, occurring in only two patients [Table/Fig-7]. Additionally, 6 (14.6%) of the patients had uric acid-containing stones [Table/Fig-8].

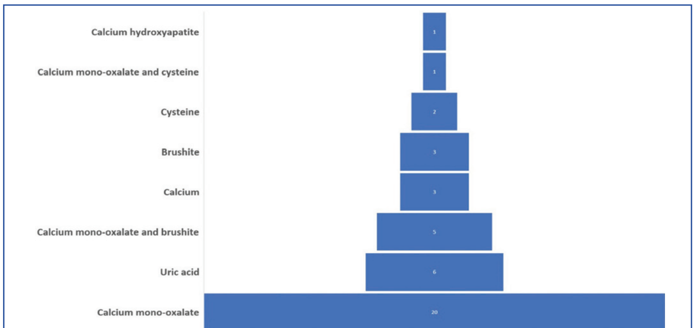
The majority of patients 35 (85.4%) had calcium oxalate monohydrate stones, as determined by FTIR Spectroscopy, while the remaining patients 6 (14.6%) had uric acid-containing calculi.

All six uric acid stones exhibited mean densities ranging from 400 to 700 HU [Table/Fig-9].

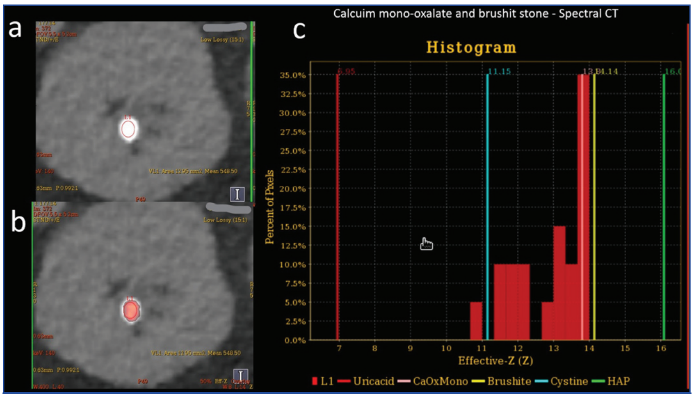
Spectroscopy, the gold standard, confirmed these compositions. Representative images showing different composition of calculi by FTIR are illustrated in [Table/Fig-10-13].

DISCUSSION

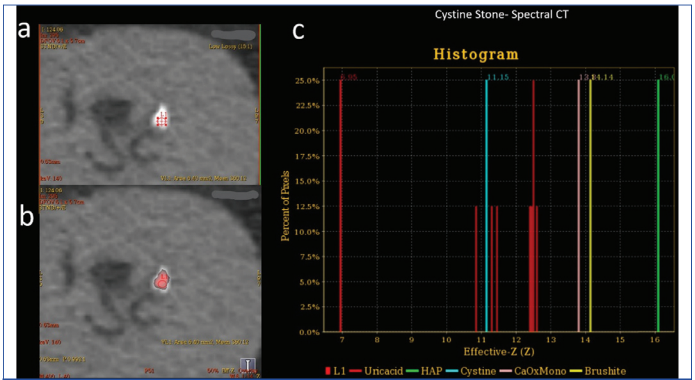
In the present study, the authors aimed to assess the accuracy of DECT in determining the composition of urinary stones compared



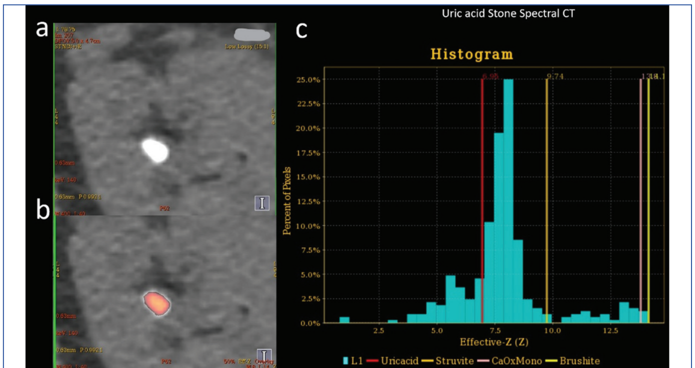
[Table/Fig-5]: DECT composition and frequency of urinary calculi illustrated by a funnel chart.



[Table/Fig-6]: Calcium oxalate monohydrate and brushite stone: DECT axial images with Region Of Interest (ROI) on calculus and composition displayed as colour coded bars by the default software.



[Table/Fig-7]: Cystine stone: DECT axial images with Region Of Interest (ROI) on calculus (a,b) and composition; (c) displayed as colour coded bars by the default software.

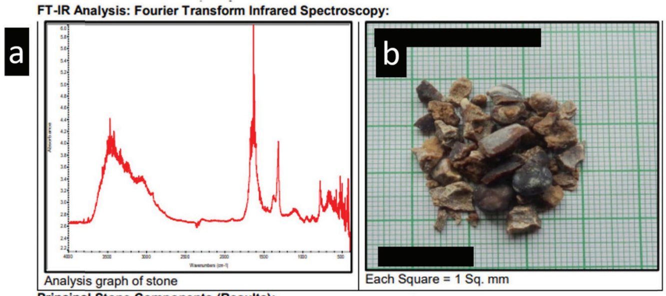


[Table/Fig-8]: Uric acid stone: DECT axial images with Region Of Interest (ROI) on calculus and composition displayed as colour coded bars by the default software.

Composition on CT		Density values (HU)					
		400-700	700-1000	1000-1300	1300-1600	>1600	p-value
Brushite	N	1	0	0	1	1	<0.001*
	%	12.5%	0	0	7.7%	33.3%	
Calcium	N	0	1	1	1	0	
	%	0	16.7%	9.1%	7.7%	0	
Calcium hydroxyapatite	N	0	0	1	0	0	
	%	0	0	9.1%	0	0	
Calcium mono oxalate and brushite	N	0	0	1	2	2	
	%	0	0	9.1%	15.4%	66.7%	
Calcium mono-oxalate	N	0	3	8	9	0	
	%	0	50.0%	72.7%	69.2%	0	
Calcium mono-oxalate and cysteine	N	0	1	0	0	0	
	%	0	16.7%	0	0	0	
Cystine	N	1	1	0	0	0	
	%	12.5%	16.7%	0	0	0	
Uric acid	N	6	0	0	0	0	
	%	75.0%	0	0	0	0	

[Table/Fig-9]: Frequency distribution of density (Hounsfield units) values in different stone compositions.

FT-IR Analysis: Fourier Transform Infrared Spectroscopy:



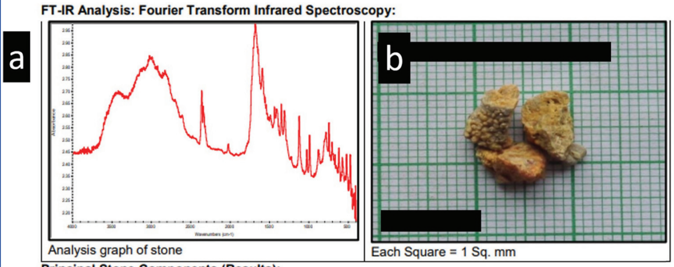
Principal Stone Components (Results):

c

Chemical Name	Approximate Percentage	Mineralogical Name	Formula
Calcium Oxalate Monohydrate	73 %	Whewellite	CaC2O4*H2O
Calcium Oxalate Dihydrate	16 %	Weddellite	CaC2O4*2H2O
Protein and Blood	11 %		

[Table/Fig-10]: Picture showing FTIR graph, gross appearance of the sample and composition of Calcium oxalate monohydrate calculi.

FT-IR Analysis: Fourier Transform Infrared Spectroscopy:



Principal Stone Components (Results):

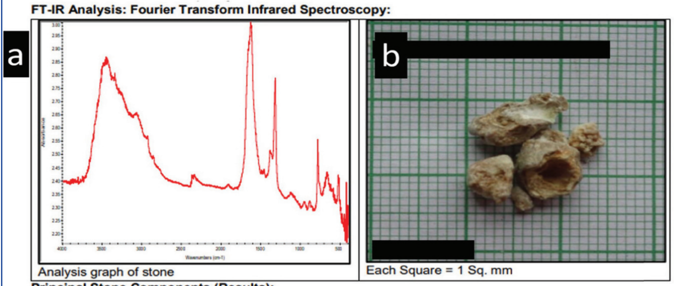
c

Chemical Name	Approximate Percentage	Mineralogical Name	Formula
Uric Acid	83 %		C5H4N4O3
Calcium monohydrogen phosphate dihydrate	13 %	Brushite	CaHPO4*2H2O
Protein and Blood	04 %		

Adv: 24 Hrs.Urine Metabolic Profile.

[Table/Fig-11]: Uric acid calculus. Composite image showing FTIR graph, gross appearance of the sample and composition of uric acid calculi.

FT-IR Analysis: Fourier Transform Infrared Spectroscopy:



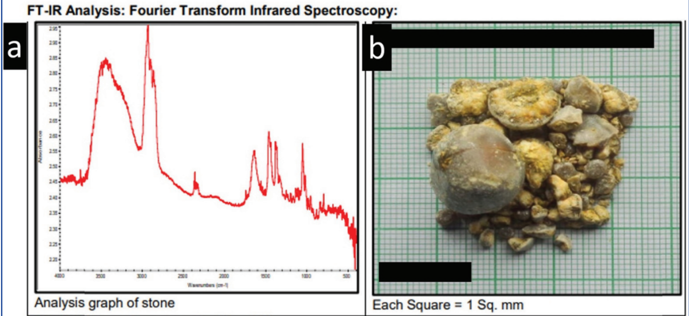
Principal Stone Components (Results):

c

Chemical Name	Approximate Percentage	Mineralogical Name	Formula
Calcium Oxalate Monohydrate	63 %	Whewellite	CaC2O4*H2O
Calcium Oxalate Dihydrate	27 %	Weddellite	CaC2O4*2H2O
Protein and Blood	10 %		

[Table/Fig-12]: Picture showing FTIR graph, gross appearance of the sample and varying composition of Calcium oxalate monohydrate and dihydrate calculus

FT-IR Analysis: Fourier Transform Infrared Spectroscopy:



Principal Stone Components (Results):

c

Chemical Name	Approximate Percentage	Mineralogical Name	Formula
Cholesterol	100 %		C27H46O

[Table/Fig-13]: Picture showing FTIR graph, gross appearance of the sample and varying composition of cholesterol calculus.

to the gold standard for stone analysis, FTIR. Among the 41 urinary stones analysed, spectroscopic findings classified them as either uric acid-based stones (6 cases) or calcium oxalate stones (both monohydrate and dihydrate forms) (35 cases). The predominant composition was calcium oxalate, accounting for 85.4% of the cases.

Interestingly, while all stones were of pure composition according to FTIR. DECT falsely categorised 14.6% calculi as mixed stones, specifically calcium oxalate monohydrate with brushite (5 cases) and calcium oxalate monohydrate with cystine (1 case). The absence of true mixed-composition stones in the present study suggests that pure calculi may be more common. However, this finding contrasts with larger studies. For instance, Li X et al., reported that only 14% of stones had a single composition, while 86% exhibited a mixed composition [5]. Similarly, a study by Johnson JP et al., involving 81 patients, found that approximately 35% of stones were mixed, while the majority was single-composition [6]. Their findings suggest a predominance of mixed urinary stones over pure ones, highlighting potential regional or sample size variations in stone composition.

In a study conducted by Zhang GM et al., dual-source DECT (ds-DECT) demonstrated high accuracy in identifying the primary component of urinary stones [7]. It correctly identified the major component in all 26 predicted pure calculi, although one stone initially classified as pure calcium oxalate was later found to contain hydroxyapatite as a minor component, and another predicted as pure uric acid was found to have calcium oxalate as a minor component. Among the 55 predicted mixed stones, dual source DECT accurately determined the dominant composition in 53 cases, with only two stones being misclassified.

In a study of 64 patients by Spek A et al., a total of 213 urinary stones were identified. Stones were categorised as pure, mixed, uric acid-containing, or non-uric acid-containing [8]. DECT demonstrated a sensitivity of 98.4% and a specificity of 98.1% in identifying uric acid stones and distinguishing them from non-uric acid stones, as confirmed by postoperative infrared spectroscopic analysis. The study corroborates the observation of present study that DECT is a highly reliable imaging modality for detecting and differentiating uric acid stones, offering significantly greater accuracy than conventional single-energy CT scans.

A study by Mohd Ali DM et al., reported that most urinary stones (69%) were non-uric acid-based, while 31% were uric acid [9]. Similarly, an Indian study by Singh A et al., found that 77% of stones were non-uric acid-based, with only 23% composed of uric acid [10]. These findings are consistent with the current study, in which 14.6% of the stones were uric acid stones, while the remaining stones exhibited a variety of other compositions.

The present study demonstrated that DECT accurately identified 100% of uric acid stones (6 of 6 cases), with 100% sensitivity, specificity, PPV, and NPV. Similar findings were reported by Kulkarni NM et al., [11]. Additionally, studies by Khanduri S et al., and Ilyas M et al., have consistently shown 100% sensitivity and nearly 100% specificity in differentiating uric acid calculi from non-uric acid calculi, reinforcing the high diagnostic reliability of DECT for stone composition analysis [12,13].

With regard to the radiation dose received, under the protocols, the patient received an average dose of 5.128 mSv. An earlier study observed that scans performed above the level of the 10th thoracic vertebra had a higher radiation dose (6.37 mSv) than those performed between the 10th and 12th thoracic vertebrae. (4.56 mSv). Significantly lower radiation dose was noted for scans performed below the level of the T12 vertebra (2.47 mSv) [14]. Thus, the current dose range is slightly higher than current DECT radiation doses. It is likely that more refined protocols for state-of-the-art Dual scanners allow further dose reduction.

Limitation(s)

The present study has a relatively small sample size and was conducted at a single centre, which may limit the generalisability of the findings. Additionally, inclusion of only patients undergoing PCNL with available FTIR analysis may have introduced selection bias toward larger or clinically significant stones. These limitations can be overcome with multi-centre studies with larger datasets. The radiation dose received by the patient of present case patient is on the higher side compared to studies conducted with currently available advanced DECT units. These evolving events can be incorporated into future studies.

CONCLUSION(S)

Spectral CT is a reliable non-invasive modality for preoperative characterisation of urinary stone composition. The technique showed excellent accuracy in differentiating uric acid from non-uric acid stones and moderate accuracy in identifying calcium-based stones when compared with FTIR spectroscopy. Given the limited literature on this specific spectral CT technique, the findings of the present study contribute to the growing evidence supporting its clinical utility in the management of urolithiasis.

REFERENCES

[1] Liu Y, Chen Y, Liao B, Luo D, Wang K, Li H, et al. Epidemiology of urolithiasis in Asia. Asian J Urol. 2018;5(4):205-14. Doi: 10.1016/j.ajur.2018.08.007.
[2] Ascenti G, Siragusa C, Racchiusa S, Ielo I, Privitera G, Midili F, et al. Stone-targeted dual-energy CT: A new diagnostic approach to urinary calculosis. AJR Am J Roentgenol. 2010;195(4):953-58. Doi: 10.2214/AJR.09.3635.
[3] McCollough CH, Leng S, Yu L, Fletcher JG. Dual- and multi-energy CT: Principles, technical approaches, and clinical applications. Radiology. 2015;276(3):637-53. Doi: 10.1148/radiol.2015142631.
[4] Li ZX, Jiao GL, Zhou SM, Cheng ZY, Bashir S, Zhou Y. Evaluation of the chemical composition of nephrolithiasis using dual-energy CT in Southern Chinese gout patients. BMC Nephrol. 2019;20(1):273. Doi: 10.1186/s12882-019-1441-8.
[5] Li X, Wang LP, Ou LL, Huang XY, Zeng QS, Wu WQ. Revolution spectral CT for urinary stone with a single/mixed composition in vivo: A large sample analysis. World J Urol. 2021;39(9):3631-42. Doi: 10.1007/s00345-021-03597-6.
[6] Johnson JP, Dhall A, Chawla A, Prakashini K. Renal calculus composition analysis using dual- energy CT: A prospective observational study. Afr J Urol. 2024;30:19. Doi: 10.1186/s12301-024-00412-7.
[7] Zhang GM, Sun H, Xue HD, Xiao H, Zhang XB, Jin ZY. Prospective prediction of the major component of urinary stone composition with dual-source dual-energy CT in vivo. Clin Radiol. 2016;71(11):1178-83.
[8] Spek A, Strittmatter F, Graser A, Kufer P, Stief C, Staehler M. Dual energy can accurately differentiate uric acid-containing urinary calculi from calcium stones. World J Urol. 2016;34(9):1297-302. Doi: 10.1007/s00345-015-1756-4.
[9] Mohd Ali DM, Mahmud MH, Mohamad NS. Pre-operative percutaneous nephrolithotripsy characterisation of kidney stones with second-generation dual-source dual-energy computed tomography. Malays J Med Sci. 2020;27(5):43-52.
[10] Singh A, Khanduri S, Khan N, Yadav P, Husain M, Khan AU, et al. Role of dual-energy computed tomography in characterization of ureteric calculi and urinary obstruction. Cureus. 2020;12(5):e8002.
[11] Kulkarni NM, Eisner BH, Pinho DF, Joshi MC, Kambadakone AR, Sahani DV. Determination of renal stone composition in phantom and patients using single-source dual-energy computed tomography. J Comput Assist Tomogr. 2013;37(1):37-45. Doi: 10.1097/RCT.0b013e3182720f66.
[12] Khanduri S, Sagar UF, Khan N, Chahar N, Jain S, Khan F, et al. Role of dual energy CT scan in evaluation of the chemical composition of renal stones. 2020;14(6):TC01-TC04. Doi: 10.7860/JCDR/2020/44098.13754.
[13] Ilyas M, Dev G, Gupta A, Bhat TA, Sharma S. Dual-energy computed tomography: A reliable and established tool for In vivo differentiation of uric acid from nonuric acid renal Stones. Niger Postgrad Med J. 2018;25(1):52-59.
[14] Jarral F, Hamdy A, Mohamed G, Mobayen R, Dave N, Eltawil M, et al. Standardized CT KUB protocols for nephrolithiasis: A retrospective analysis of radiation exposure and cranial extent guidelines. Cureus. 2024;16(12):e75743.

PARTICULARS OF CONTRIBUTORS:
1. Resident, Department of Radiology, Narayana Health City Hospital, Bengaluru, Karnataka, India.
2. Senior Consultant, Department of Radiology, Narayana Health City Hospital, Bengaluru, Karnataka, India.
3. Senior Consultant, Department of Urology, Narayana Health City Hospital, Bengaluru, Karnataka, India.
4. Senior Consultant, Department of Radiology, Narayana Health City Hospital, Bengaluru, Karnataka, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Dr. Venkatraman Bhat,
Senior Consultant, Department of Radiology, Narayana Health City Hospital, Hosur Road, Bengaluru-560099, Karnataka, India.
E-mail: bvenkatraman@gmail.com

PLAGIARISM CHECKING METHODS: [Jain H et al.]
- Plagiarism X-checker: Dec 29, 2025
- Manual Googling: Apr 15, 2026
- iThenticate Software: Apr 18, 2026 (1%)

ETYMOLOGY: Author Origin

EMENDATIONS: 8

AUTHOR DECLARATION:
- Financial or Other Competing Interests: None
- Was Ethics Committee Approval obtained for this study? Yes
- Was informed consent obtained from the subjects involved in the study? Yes
- For any images presented appropriate consent has been obtained from the subjects. NA

Date of Submission: **Dec 07, 2025**
Date of Peer Review: **Feb 03, 2026**
Date of Acceptance: **Apr 21, 2026**
Date of Publishing: **Aug 01, 2026**