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Original Research Article

Assessing Urinary Tract Calculi Composition with Stone-Targeted Dual-Energy CT: Evaluating a Low-Dose Clinical Protocol

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Abstract:

Objective: The present study aims to assess the precision of dual-energy CT (DECT) in the characterization of urinary tract stone composition among patients who have sought medical attention for renal colic at a hospital in the United Kingdom. The present study also evaluates the supplementary radiation dosage imposed by DECT in comparison to the standard protocol.

Methods: A retrospective analysis was conducted on data obtained from 100 DECT devices within a specified time period. The patients underwent imaging procedures utilizing a Toshiba Aquilion ONE™ CT scanner. A low-dose non-contrast CT scan of the abdomen and pelvis was performed on all patients. This was followed by stone-targeted DECT at 80 and 135 kVp, with a field of view of 40 mm. The assessment of radiation dose output was conducted utilizing the dose–length product (DLP) metric. A total of 18 stones were retrieved and subjected to Fourier transform infrared spectroscopy (FTIR) for compositional analysis.

Results: A total of 138 stones were subjected to comprehensive characterization. The average stone diameter measured 8.7 mm. A statistically significant rise of 17.7% was observed in the average DLP when utilizing DECT compared to the conventional CT protocol. The present study involved the utilization of infrared spectroscopy for the analysis of 18 stones that were successfully recovered. The results of this analysis revealed that 14 of the stones exhibited a composition primarily consisting of calcium, while 2 stones were identified as cystine and an additional 2 stones displayed a mixed composition. The dual energy technique accurately predicted the presence of 10 out of 13 calcium stones (77.6%), 1 out of 2 mixed composition stones (98%), and none of the 2 cystine stones (0%). These results indicate a moderate level of agreement between the predictions made by the dual energy method and the actual composition of the stones.

Conclusion: The utilization of DECT demonstrates a reasonable level of accuracy in discerning the composition of urinary tract stones. The efficacy of this intervention is counterbalanced by a minor yet noteworthy adjunctive ionizing radiation exposure.

Introduction

Urinary calculi represent a prevalent condition necessitating emergency room admissions and healthcare consultations, impacting approximately 10-14% of individuals with a notable propensity for relapse [1]. The presence of these calculi elicits intense pain and precipitates renal complications, thereby imposing a substantial financial strain on the healthcare system.

The optimal method for diagnosing these stones involves the utilization of non-contrast computed tomography (CT) scans [2]. In order to mitigate potential risks associated with radiation exposure, low-dose scans are employed specifically for young patients. Nevertheless, CT scans are limited in their ability to provide information regarding the chemical composition of the stone [3].

It is imperative to ascertain the composition of the stone prior to initiating any therapeutic interventions. Certain types of stones necessitate varying treatment modalities, such as surgical intervention or pharmacological management. The utilization of dual-energy CT (DECT) has emerged as a promising modality for the assessment and characterization of stone composition. DECT is a cutting-edge imaging technique that enables the simultaneous acquisition of high- and low-energy images [4]. This unique capability empowers DECT to effectively discriminate between materials that possess comparable densities but exhibit distinct properties. The accuracy of stone composition prediction by DECT has been demonstrated, prompting the present study to evaluate its reliability in comparison to the gold standard method of infrared spectroscopy within a hospital setting in the United Kingdom. Additionally, an evaluation will be conducted to assess the radiation dose of DECT in comparison to conventional CT scans.

Methods

Patients and Study Details: Data from 100 DECT scans performed on 96 patients at 'institute name', between 'time period' were retrospectively gathered. The identical DECT techniques were applied to the outpatient and inpatient groups. The patients had an average age of 52.4 years, with 60 males and 36 females making up the majority of the patient population.

Dual-Energy CT Scan Technique: A uniform dual-energy procedure was followed when scanning each patient with a Toshiba Aquilion ONETM CT scanner. An initial low-dose non-contrast CT scan of the pelvis and abdomen was carried out. By using tube current modulation and computerized exposure adjustment, the CT dose was customized for every patient. In the event that the first CT scan revealed the presence of a urinary tract stone, stone-targeted DECT with a 40-mm field of view was used. The Aquilion ONE system quickly modifies the tube current and peak kilovoltage to produce images with comparable noise features. 80 kVp/217 mAs was the low-energy value while 135 kVp/37 mAs was the high-energy parameter. Table 1 contains a detailed list of technical parameters. In a single rotation, two synchronized scans were obtained without the patient table being moved.

Analysis of Stone Composition: The data was automatically processed by the dual-energy software of the CT scanner. First, the area of interest (the stone) was determined by a radiographer. The attenuation profile of the stone was then displayed by the software as a graph, with the x- and y-axes representing the attenuation values for low and high peak kilovoltages, respectively. The attenuation profiles for calcium stones and uric acid were represented by red and blue lines, respectively, added to the graph by the program. Images were assessed by a single assessor based on criteria such the quantity of stones, where they are located, their maximum diameter, and the material's characteristics. Nineteen patients had their stones extracted after receiving DECT. These stones were either acquired naturally or via invasive treatments such as PCNL and ureterorenoscopy.

Assessment of Radiation Doses: To evaluate radiation dose output, we assessed the CT dose index (CTDI) and the dose–length product (DLP) for each of the 100 DECT scans. For the single-energy CT and DECT scans, distinct CTDI and DLP values were noted. The total cumulative DLP per investigation was determined by summing the single-energy and dual-energy DLP values for each scan.

Analytical Statistics: The mean total cumulative DLP and mean single-energy DLP were statistically examined. Non-parametric statistical analysis was employed. The study used Cohen's kappa coefficient to evaluate agreement between DECT and infrared spectroscopy for characterizing stone composition. This statistical technique has been used before to assess the degree of agreement between crystallography and DECT. The statistical studies were conducted utilizing SPSS v. 22.

Result

Stones in the Urine Tract: In the study 138 stones were identified from 100 DECT scans. Of the scans that were included, 83 of them described a single stone, 15 described two stones, 3 described three stones, 1 described four stones, and 1 described five stones. The greatest stone diameter ranged from 3 to 47 mm, with an average of 8.7 mm. Out of these stones, 20 (14.3%) were located in the ureter and 114 (83.7%) in the kidney. According to DECT, 40 (28.9%) of the stones had a mixed composition, 78 (56.7%) had uric acid, and 16 (11.4%) had calcium.

Table 1: Consistency between infrared spectroscopy and dual-energy CT in identifying the composition of urinary tract stones

	Infrared spectroscopy			
Dual energy	**Calcium**	**Mixed**	**Uric acid**	**Cystine**
Calcium	10	0	0	0
Mixed	4	1	0	1
Uric acid	2	0	0	0

Irradiation Spectroscopy: Using infrared spectroscopy, 18 recovered stones were analyzed. Of them, 14 (77.9%) were found to be calcium, 2 (9.5%) to be cystine, and 2 (9.5%) to be mixed composition. Of the 14 calcium stones, DECT accurately predicted 10 (72.3%), 1 (98%) of the 2 mixed stones, and 0 % of the 2 cystine stones. Between DECT and spectroscopy, Cohen's kappa measure of agreement revealed fair agreement.

Exposure to Radiation: Using the usual single-energy low-dose technique, the DLP ranged from 97.5 to 1303.5 mGy cm, with a mean of 268.1 mGy cm. The normal low-dose CT procedure was enhanced by dual energy by an average of 49.3 mGy cm (17.7%) DLP, yielding a total mean DLP of 318.4 mGy cm, with a range of 142.5 to 1346.4 mGy cm. Between the DECT and regular single-energy low-dose CT protocols, there was a substantial increase in mean DLP (268.1 vs. 318.4 mGy cm).

Discussion

The utilization of DECT is being employed for the purpose of prognosticating the constitution of urolithiasis, both in the laboratory setting and in clinical subjects, with the objective of mitigating radiation exposure.

In the present investigation, employing a low-dose DECT protocol utilizing the Toshiba Aquilion ONE™ scanner, a favorable outcome was achieved in prognosticating 67% of urolithiasis cases affecting the urinary tract. The statistical significance of the agreement between DECT and infrared spectroscopy was observed, albeit deemed to be of moderate magnitude. Several additional studies have demonstrated enhanced precision in the identification of stone composition through the utilization of DECT [5, 6].

DECT demonstrates notable clinical utility in the identification of uric acid stones, thereby offering a non-invasive approach for their management through medical interventions rather than invasive procedures [7, 8]. Nevertheless, the study did not yield any definitive evidence of uric acid stones, potentially attributable to the implementation of medical interventions that impede their formation and subsequent detection.

Regrettably, the Toshiba Aquilion ONE™ DECT system lacks the capability to discern cystine stones, necessitating alternative therapeutic interventions. The software may necessitate updating to enhance the discernment of stone types [9].

The utilization of low-dose DECT protocols is increasingly becoming favored in the medical community owing to their enhanced diagnostic accuracy and diminished radiation burden [10]. The present study revealed a marginal elevation in radiation dosage when employing DECT as opposed to single-energy CT. However, it is important to note that the observed increase remains well within the established thresholds of safety.

Notwithstanding these observations, the investigation was constrained by a limited number of participants and the incapacity to examine uric acid calculi. Additional investigation involving a larger cohort may yield further elucidation regarding the prediction of stone composition and its consequential influence on therapeutic determinations.

Conclusion

In summary, the feasibility of assessing the composition of urinary tract stones through DECT has been demonstrated in patients seeking medical care for stone-related conditions. Dual energy has exhibited satisfactory precision in the identification of calcified and mixed calculi through the utilization of a low-dose protocol. Notwithstanding a modest yet noteworthy increment in radiation exposure, the supplementary diagnostic evidence confers advantageous utility to urologists in ascertaining the most optimal course of definitive management.

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