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ROLE OF DUAL ENERGY COMPUTED TOMOGRAPHY IN DETERMINING RENAL STONE COMPOSITION – A PROSPECTIVE STUDY.

Radio-Diagnosis

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ABSTRACT

Renal calculi, which commonly cause haematuria and pain, result from decreased urine volume or elevated excretion of substances like calcium, oxalate, uric acid, cystine, and phosphate. Factors such as low urinary citrate and high acidity contribute to stone formation. While a single occurrence usually doesn't lead to kidney failure, recurrent stones can damage renal function over time. Traditional stone analysis methods like X-ray diffraction are performed post-extraction and do not aid preoperative planning. Recent advancements include dual-energy computed tomography (DECT), which uses dual X-ray energy levels to differentiate stone compositions by analysing attenuation properties. This study, conducted over 11 months with 119 patients at a Central Indian tertiary care centre, employed DECT to assess stone composition. Findings revealed that DECT identified calcium oxalate in 54.60% of cases, hydroxyapatite/calcium phosphate in 24.40%, and uric acid in 19.30%. Surgical management was required for 63.90% of patients, particularly for larger or obstructive stones. DECT's ability to differentiate stone types facilitates targeted treatment, demonstrating its value as a diagnostic tool in urology.

KEYWORDS

Dual energy computed tomography (DECT), Renal stone composition, Pelvicalyceal system.

INTRODUCTION

Renal calculi, commonly causing haematuria and abdominal, flank, or groin pain, arise from decreased urine volume or elevated excretion of stone-forming substances such as calcium, oxalate, uric acid, cystine, and phosphate. Contributing factors include low urinary citrate levels, an inhibitor of stone formation, and excessive urinary acidity[1,2]. Although a single instance of renal calculi typically doesn't lead to kidney failure, recurrent stones can damage tubular epithelial cells and potentially impair renal function over time.

Globally, nephrolithiasis prevalence ranges from 1% to 13%, with higher rates in the U.S. (7-13%) compared to Europe (5-9%) and Asia (1-5%)[3]. In Asia, nephrolithiasis is the most common urologic condition, with prevalence differences attributed to genetics, age, climate, diet, race, and metabolic conditions. Management of renal stones is influenced by factors such as stone location, size, composition, degree of obstruction, symptoms, and associated medical conditions.

Urinary Stone Composition: Urinary stones are primarily composed of eight minerals[4]. Traditionally, stone analysis is performed using techniques like X-ray diffraction or spectroscopy after stone removal. However, these methods do not aid in preoperative decision-making. Recent advances in imaging have introduced dual-energy computed tomography (DECT) as a promising tool for in vivo assessment of urinary stone composition.

Dual-Energy CT (DECT): DECT employs two X-ray energy levels (typically 140 kV and 80-100 kV) to generate images based on material absorption and attenuation properties. This technique facilitates material differentiation, such as bone removal in angiography, metal artefact reduction, and iodine mapping in various pathologies. For renal stones, DECT distinguishes compositions by analysing specific dual-energy ratios, enhancing the accuracy of diagnosis.

Studies by Thomas C. and Ascenti G. have highlighted DECT's effectiveness in characterizing renal stones[5,6]. Li ZX further demonstrated DECT's capability in differentiating uric acid stones from non-uric acid stones in gout patients, underlining its potential in clinical practice.

Importance of Stone Composition: Accurate characterization of renal stones is essential for effective treatment planning, as management strategies vary based on stone type, location, size, and composition. Understanding stone composition allows for more precise treatment plans and can potentially minimize unnecessary surgical interventions. This study aims to evaluate renal stone composition using DECT, optimizing treatment strategies and improving patient outcomes.

Review Of Literature

Recent studies on dual-energy computed tomography (DECT) highlight its growing role in urinary stone characterization.

Hidas et al. (2010)[7] found that DECT accurately diagnosed 82% of stones, distinguishing uric acid, cystine, and calcified stones based on attenuation ratios. However, struvite stones overlapped with calcified stones, making differentiation challenging. Stolzmann et al. (2010)[8] showed that using a tin filter with DECT improved discrimination between uric acid (UA) and non-UA stones. Li et al. (2013)[9] demonstrated that spectral imaging better characterizes urinary stones, showing significant differences in calcium-water ratio across stone types.

Kulkarni et al. (2013)[10] showed DECT's 100% sensitivity for UA vs. non-UA stones, using effective atomic numbers to identify non-UA subtypes. Kriegshauser et al. (2016)[11] found multiparametric DECT accurately distinguishes UA from non-UA stones, with a 97% success rate. Yadav et al. (2017)[12] demonstrated DECT's ability to classify calcium oxalate, uric acid, and cystine stones based on attenuation values, confirming the predominance of calcium oxalate stones.

More recently, Singh et al. (2020)[13] highlighted DECT's accuracy in ureteric stone morphology and composition, with 94.3% sensitivity for high-grade obstructions. Khanduri et al. (2020)[14] emphasized DECT's precision in identifying hydroxyapatite and cystine stones. Sheikhi et al. (2023)[15] confirmed DECT's 97-100% accuracy in detecting pure stone subtypes. Lastly, Johnson et al. (2024)[16] found spectral analysis marginally superior to DE ratios for renal stone classification.

MATERIALS AND METHODOLOGY

This prospective observational study was conducted over 11 months at a tertiary care centre in Central India. It included 119 patients suspected of having renal stones, excluding those under 20, pregnant, previously diagnosed with nephrolithiasis, or unwilling to consent. DECT was performed using a Siemens 128-slice CT machine, employing post-processing algorithms to analyse attenuation values. Key measurements included stone size, location, and attenuation at 80 kV and 140 kV. Data analysis was conducted with SPSS v24, with continuous variables presented as mean ± SD and categorical as frequency and percentage. Statistical significance was assessed using the chi-square test ($p \leq 0.05$).

RESULTS AND OBSERVATION

The study included 119 participants, with a mean age of 54.39 years. The majority (58.80%) were aged 31-60 years, and 65.50% were male. Clinically, 50.40% reported left flank pain, while 49.60% had right flank pain. Ultrasound revealed renal calculi in 48.70% on the left and 46.20% on the right. Most stones (44.50%) were found in the upper pole, and 93.30% were non-obstructive. DECT identified calcium oxalate in 54.60% of cases, hydroxyapatite/calcium phosphate in 24.40%, and uric acid in 19.30%.

Stone diameter ranged from ≤10 mm (37%) to >30 mm (2.5%), with a mean of 14.24 mm. Stone attenuation most commonly ranged from 501-1000 HU (51.3%), with a mean of 886 HU. Surgical management was required in 63.90% of cases, especially for obstructive calculi and larger stones. The composition strongly influenced management: 73.8% of oxalate, 75.9% of hydroxyapatite, and 100% of cystine stones required surgery, while 82.6% of uric acid stones were managed medically, with statistically significant associations for both calculi nature and composition ($p=0.028$ and $p<0.001$, respectively).

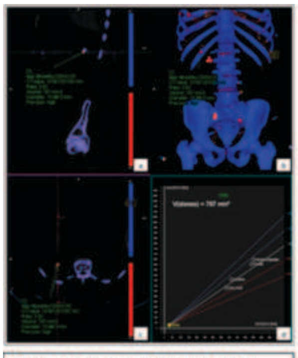

FIG.1: 11 mm stone in the mid-pole of right kidney measuring 1076 Hounsfield units in density. Sagittal view (a), 3D VRT iodine scan (b), Axial iodine scan (c), Dual-energy material evaluation graph (d) demonstrates that this is a non-uric acid stone, most likely Hydroxyapatite/ calcium phosphate

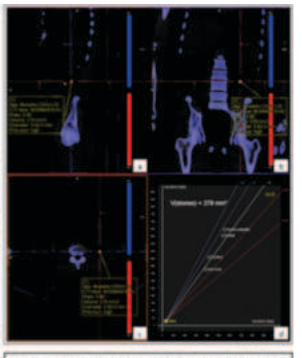

FIG.2: 5.5 mm stone in the lower-pole of left kidney measuring 903 Hounsfield units in density. Iodine scan sagittal view (a), coronal view (b), Axial view (c) and Dual-energy material evaluation graph (d) demonstrates that this is most likely a uric acid stone.

SUMMARY AND CONCLUSION

This study evaluated the efficacy of dual-energy computed tomography (DECT) in determining the composition of renal stones. Key findings include:

- **Participant Demographics:** The mean age was 54.39 years, with 58.80% aged 31-60 years. Males comprised 65.50% of the sample.
- **Clinical Findings:** Pain was reported equally in the left and right flank regions. Renal calculi were predominantly found in the left (48.70%) and right kidneys (46.20%). Only 5.00% had normal USG findings.
- **Stone Characteristics:** The majority of stones were in the 11-20 mm diameter range, with a mean diameter of 14.24 mm. Most stones had an attenuation range of 501-1000 HU, with a mean attenuation of 886.00 HU.
- **Stone Composition:** DECT revealed 54.60% of stones were calcium oxalate, 24.40% hydroxyapatite/calcium phosphate, 19.30% uric acid, and 1.70% cystine.
- **Management:** 63.90% of participants underwent surgical management, while 36.10% received medical treatment. Obstructive stones were always surgically managed, while uric acid stones were more likely managed medically.

DECT effectively differentiates renal stone types, guiding accurate treatment decisions and showing potential as a standard diagnostic tool in urology. Further research could solidify its clinical utility in varied populations.

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