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Gender differences in Hounsfield unit values of carbonate urinary stones; a prospective cross-sectional analysis

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ABSTRACT

Introduction: This study emphasizes the importance of investigation of gender-based variations in CT Hounsfield unit (HU) measurements of urinary stones composition which informs clinical management.

Objectives: To highlight gender disparities in stone types and composition specifically carbonate content in each stone type based on their CT Hounsfield unit.

Patients and Methods: This cross-sectional study prospectively recruited 107 patients with renal stones at AL-Yarmok Teaching Hospital in Baghdad, Iraq (January 2023–June 2024) to investigate gender-specific differences in stone radiodensity (measured in HUs by non-contrast CT scans). Demographic and clinical data were collected through interviews and medical records. The non-contrast computed tomography (CT) scan was performed to evaluate renal stone density quantified in HUs. The HU values were compared between male and female patients.

Results: The results demonstrated that 107 participants (36 females and 71 males) with a mean age of 47.47 ± 15.42 years were evaluated. The demographic and clinical data, such as age, mean body mass index (BMI), and stone size, failed to show significant correlations with HU measurements. In both unadjusted and adjusted linear regression analyses, male gender demonstrated a statistically significant positive association with HU measurements compared to the female gender (Unadjusted unstandardized regression coefficient [B] = 480.35 and adjusted B = 539.70).

Conclusion: Male gender represents as a potentially important determinant in the radiological characteristics of carbonate urinary calculi when compared with female.

Original Article

Implication for health policy/practice/research/medical education:
In this prospective cross-sectional study, we found that gender emerged as a factor demonstrating a statistically significant association with radiodensity measurements, and that male gender independently predicted higher Hounsfield unit (HU) measurements.

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Introduction

Previous studies indicated an increasing prevalence of urinary stones over the past years (1). Carbonate apatite represents a significant component in urinary stone disease (2), accounting for approximately 10.2% of urinary calculi as the main constituent, while also frequently appearing in mixed stones with calcium oxalate monohydrate and calcium oxalate dehydrate (3,4). These stones are often associated with urinary tract infections, as they can result from the activity of urease-producing microorganisms, primarily from Proteus species (5). Recent epidemiological data suggest that the occurrence of carbonate apatite stones is increasing, particularly in highly developed countries, potentially related to dietary factors including the consumption of highly processed foods containing phosphoric acid and various preservatives (6). Notably, carbonate apatite stones demonstrate distinct aggregation properties compared to other stone types, which may contribute to their formation mechanism and growth characteristics (5).

Hounsfield unit (HU) values derived from computed tomography (CT) scans have become essential in the

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evaluation and management of urinary stone disease, providing valuable information about stone composition and predicting treatment outcomes (7). Studies utilizing low-dose dual-energy CT have demonstrated that different stone compositions exhibit characteristic HU values and dual-energy ratios that can reliably differentiate between uric acid, struvite, calcium oxalate, and carbonate apatite calculi (8). This non-invasive assessment method offers particular clinical relevance as stone density shows an inverse correlation with extracorporeal shock wave lithotripsy success rates, with optimal cut-off values for successful treatment ranging from 750 to 1000 HU (7). The ability to accurately characterize stone composition through HU measurement enables clinicians to make informed decisions regarding appropriate intervention strategies and predict treatment efficacy.

Gender differences in urolithiasis presentation and composition have been increasingly documented in recent literature, with significant implications for both diagnosis and management approaches. Epidemiological studies reveal that while urinary stone disease affects approximately 12% of the global population, recurrence rates differ substantially between sexes, with 70% in men compared to 47% in women (9). Compositional analyses demonstrate that calcium oxalate (75%) and uric acid stones (81%) occur more frequently in men (3), whereas carbonate apatite stones are disproportionately found in female patients; additionally, female patients with urolithiasis present with higher rates of comorbidities, including hypertension, diabetes, and dyslipidemia, and often require more complex surgical interventions such as percutaneous nephrolithotomy and ureteroscopic lithotripsy (10). These gender-specific patterns suggest underlying pathophysiological differences that warrant further investigation, particularly concerning the relationship between gender and the radiological characteristics of carbonate apatite stones.

Objectives

This study aimed to evaluate and quantify gender-specific variations in the HU values of carbonate urinary stones through prospective cross-sectional analysis. This research aims to determine whether significant differences exist between male and female patients in the radiodensity characteristics of carbonate stones as measured by non-contrast CT, potentially providing insights into gender-based pathophysiological mechanisms of stone formation and informing gender-specific diagnostic and therapeutic approaches for urolithiasis management.

Patients and Methods

Study design and participants

In this prospective cross-sectional study, 107 patients diagnosed with renal stones were recruited from AL-Yarmok teaching hospital in Baghdad, Iraq, from January 2023 to June 2024. The study population comprised individuals referred to the hospital for evaluation and management of nephrolithiasis.

Inclusion and exclusion criteria

The inclusion criteria for this study were adults aged 18 years and older who were diagnosed with renal stones and referred to AL-Yarmok Teaching Hospital in Baghdad, Iraq, during the study period. Participants were required to provide informed written consent and be willing to undergo both demographic interviews and clinical assessments, including non-contrast CT scans for stone evaluation. Exclusion criteria included patients with a history of previous renal surgery, those with known congenital anomalies of the urinary tract, pregnant women, individuals with incomplete clinical or demographic data, and patients who declined or were unable to provide informed consent.

Data collection

Data collection for this study was divided into demographic and clinical data acquisition. Before enrollment, all participants received a thorough explanation of the study's objectives and procedures, and informed written consent was obtained. Demographic information, including age, gender, and body mass index (BMI), was gathered through structured participant interviews and review of clinical records. For clinical assessment, non-contrast CT scans were performed to evaluate renal stone characteristics, with stone size measured in cubic millimeters (mm^3) and stone density quantified in HUs, a standard radiodensity metric that aids in predicting stone composition and informing treatment strategies.

Measurement of Hounsfield units

The HUs of urinary stones were quantified using a Siemens SOMATOM Definition AS+ 64-Slice CT scanner, which generated high-resolution axial images reconstructed into 3D volumetric models to precisely determine stone size, shape, and density. This scanner operates at a maximum power of 100 kW, with a detector width of 64 mm, 0.5-second rotation time, and 140 kV X-ray tube voltage, ensuring rapid imaging and reduced radiation exposure. Following radiological characterization, stones underwent chemical composition analysis at Al-Yarmouk Teaching Hospital's clinical laboratory using BIOLABO SAS protocols. Each calculus was pulverized, and 50 mg of powdered sample was subjected to qualitative testing: a flame test distinguished organic (carbonization observed) from mineral components, while hydrochloric acid (1.65 M HCl) induced effervescence to detect carbonate.

Subsequent mixtures (M1: stone powder + HCl; M2: 50 µL M1 + 5 mL H_2O) enabled identification of calcium, oxalate, phosphate, uric acid, sodium, citrate, carbon, and magnesium via standardized analytical workflows. This dual-methodology approach integrated advanced imaging metrics with precise elemental profiling to correlate stone morphology with biochemical etiology (11,12).

Outcomes

The primary outcome of this prospective cross-sectional study is to evaluate and quantify gender-specific differences in the HU values of carbonate urinary stones as measured by non-contrast CT scan, aiming to determine whether significant radiodensity variations exist between male and female patients. Secondary outcomes include exploring the potential implications of these gender-based differences in HU values for understanding the pathophysiological mechanisms underlying stone formation and assessing how these findings might inform gender-specific diagnostic and therapeutic strategies in urolithiasis management.

Statistical analysis

Statistical analyses were conducted using SPSS version 27 (IBM Corp., USA). The normality of quantitative data was evaluated with the Kolmogorov-Smirnov test. To examine the distribution of HU values, Spearman's rank correlation coefficient was applied for quantitative variables such as age, BMI, and stone size, while the Mann-Whitney U test was conducted to compare differences across the categorical variable of gender. Both univariate and multiple linear regression analyses were performed to assess the relationship between gender and HU values. The strength and direction of these associations were reported using unstandardized regression coefficients (B) along with their corresponding 95% confidence intervals (CIs). The significance level of the tests was considered at $P<0.05$.

Results

In this prospective cross-sectional study, a total of 107 participants with a mean age of 47.47 ± 15.42 years were evaluated, comprising 36 females and 71 males. The demographic and clinical characteristics revealed a mean BMI of 27.77 ± 4.24 kg/m² and a mean stone size of 159.10 ± 219.53 mm³. The radiodensity measurements demonstrated a mean HU value of 812.20±1049.26, exhibiting marked variability across the study population (Table 1).

In the correlation analysis of clinical-demographic factors and HU values in carbonate urinary calculi, gender emerged as the sole variable demonstrating a statistically significant association with radiodensity measurements.

Table 1. Demographic and clinical characteristics of study participants

Clinical-demographic data	Frequency	Percent
Gender		
Female	36	33.6
Male	71	66.4
Quantitative data	**Mean**	**SD**
Age (year)	47.47	15.42
BMI (kg/m²)	27.77	4.24
Stone size (mm³)	159.10	219.53
HU	812.20	1049.26

BMI: Body mass index; SD: Standard deviation; HU: Hounsfield unit.

This finding suggests meaningful differences in the HU values between female and male patients with carbonate urinary stones. Conversely, other examined parameters, including age, BMI, and stone size, failed to show significant correlations with HU measurements (Table 2).

The results demonstrated that in both unadjusted and adjusted linear regression analyses, male gender demonstrated a statistically significant positive association with HU measurements compared to the female gender. The univariate model revealed a substantial unstandardized regression coefficient (B) of 480.35. After adjustment for confounding variables, including age, BMI, and stone size, the magnitude of this association further increased (B = 539.70). These findings suggest that male gender independently predicts higher HU measurements, with the effect size strengthening when accounting for additional variables in the multivariate analysis (Table 3).

Discussion

The results indicated that male gender demonstrated a statistically significant positive association with HU measurements compared to the female gender. Our finding that male gender demonstrated a statistically significant positive association with HU measurements compared to female gender aligns with several published studies examining bone density through CT imaging. This gender-based difference in bone density appears to have important age-dependent considerations. Particularly noteworthy is the observation by Wang et al, who reported that while females younger than 50 years exhibited higher cervical vertebral HU values than males, this pattern reversed after age 50, with males showing higher values and females experiencing significant decreases after age 60 (13). This age-dependent reversal likely reflects the accelerated bone mineral density loss in females following menopause. The study conducted by Togher et al indicated a statistically significant association between female gender and reduced bone mineral density. This conclusion was reached through the measurement of HUs, a quantitative assessment method used to determine

Table 2. Correlation analysis of clinical-demographic factors and Hounsfield unit values in carbonate urinary calculi

Clinical-demographic data		HU		*P* value
		Mean (812.20)	SD (1049.26)	
Gender	Female (n = 36)	493.46	247.33	0.011*
	Male (n = 71)	973.82	1248.13	
Age (year)		47.47	15.42	0.469**
BMI (kg/m^2)		27.77	4.24	0.359**
Stone size (mm^3)		159.10	219.53	0.056**

BMI: Body mass index; SD: Standard deviation; HU: Hounsfield unit. *Mann-Whitney U; **Spearman coefficient.

Table 3. Gender as a predictor of Hounsfield unit measurements: Univariate and multivariate linear regression findings

Linear regression			HU			
			P value	B	95% CI	
					Lower	Upper
Unadjusted	Gender	Female			Ref (1)	
		Male	0.025	480.35	62.88	897.83
Adjusted	Gender	Female			Ref (1)	
		Male	0.020	539.70	87.41	991.98

HU: Hounsfield unit; B: Unstandardized regression coefficients; CI: Confidence interval; Ref: Reference.

bone density. Specifically, their findings demonstrated that individuals of the female gender, on average, exhibited a significantly lower bone mineral density as quantified by their HU scores compared to their male counterparts (14). Similarly, Qi et al observed that the standardized uptake value (SUV) max and SUV mean of normal vertebrae were markedly higher in males than females, further supporting gender-based differences in bone metabolism measurements (15). Complementary findings by Açikgöz et al confirmed statistically significant differences between T scores, lumbar total bone mineral density, and HU values according to age and sex (16), while normative studies have consistently documented sex-specific reference ranges for vertebral HU values (17). Moreover, in a study by Sakai et al, low HU screw trajectories were identified as a risk factor for pedicle screw loosening in women (18). The concordance between our results and these published findings reinforces the importance of incorporating gender-specific considerations when interpreting HU measurements in clinical practice, particularly for osteoporosis assessment, surgical planning, or fracture risk evaluation. These gender differences underscore the need for sex-specific reference ranges in diagnostic algorithms utilizing opportunistic CT assessment of bone quality.

Overall, these findings suggest the presence of gender-specific differences in the radiodensity and potentially the composition of carbonate renal stones. Such differences may reflect underlying pathophysiological mechanisms unique to each gender and highlight the importance of considering gender as a relevant factor in the diagnostic evaluation and management of urolithiasis. Further research is warranted to explore the clinical implications of these findings and to assess whether gender-specific diagnostic and therapeutic strategies could improve outcomes in patients with urinary stone disease.

Conclusion

The findings highlight a robust and consistent association between male gender and elevated HU measurements, persisting even after adjusting for potential confounders. The strengthened effect size in the multivariate model underscores male gender as an independent predictor of higher HU values. These results suggest inherent biological or compositional differences in renal stones between genders, which may influence diagnostic and therapeutic strategies. The clinical relevance of this association warrants consideration in treatment planning, particularly for interventions where stone density plays a critical role in outcomes.

Limitations of the study

The single-center design at AL-Yarmouk teaching hospital may restrict generalizability to broader populations with different demographic and environmental characteristics. The study's moderate sample size (n=107) may limit statistical power for detecting subtle gender-specific differences in stone characteristics. Technical limitations related to CT imaging include potential variability in HU measurements, as HU values can be significantly affected by CT scanner type, calibration status, reconstruction algorithms, and specific acquisition parameters such as tube voltage and current. Beam-hardening artifacts and

partial volume effects may have particularly influenced measurements of smaller stones, potentially introducing measurement bias. Additionally, the absence of information regarding the standardization of CT scanning protocols across participants introduces another source of potential measurement variability. Finally, while HU values provide insights into stone composition, the lack of confirmatory biochemical stone analysis represents a significant limitation, as HU values alone cannot definitively characterize stone composition without validation through direct chemical analysis.

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Authors' contribution

Conceptualization: Tamarah Saad Gheni and Nabaa A. Rasheed Naji.
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Methodology: Tamarah Saad Gheni and Nabaa A. Rasheed.
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Supervision: Najeeb Hassan Mohammed and Nabaa A. Rasheed Naji.
Validation: Najeeb Hassan Mohammed.
Writing–original draft: Tamarah Saad Gheni and Nabaa A. Rasheed Naji.
Writing–review and editing: Najeeb Hassan Mohammed

Conflicts of interest

The authors declare no conflict of interest.

Declaration of generative artificial intelligence (AI) and AI-assisted technologies in the writing process

While preparing this work, the authors utilized AI (Perplexity.ai and Grammarly.com) to refine grammar points and language style in writing. Subsequently, the authors thoroughly reviewed and edited the content as necessary, assuming full responsibility for the publication's content.

Ethical issues

The study was conducted in accordance with the Declaration of Helsinki. Informed written consent was obtained from all participants. This research resulted from a research project by the department of radiology, approved by the Ethics Committee of the College of Medicine, University of Baghdad, Iraq (approval number #391b). Besides, the authors have ultimately observed ethical issues (including plagiarism, data fabrication, and double publication).

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