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ORIGINAL RESEARCH

# Evolving chemical composition of kidney stones in Jamaica: a biochemical analysis from 2019 to 2021 compared with historical data

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**Purpose:** This study aimed to investigate possible shifts in influencing factors causing kidney stones in Jamaica by comparing the chemical composition of kidney stones over different time periods.

**Materials and methods:** The study had 59 participants. There were no initial exclusion criteria, and all patients scheduled for kidney stone surgery during the study period were considered. Demographic, medical condition, and lifestyle data were collected from participants, along with kidney stone samples. Biochemical testing was done according to Wootton's method (1974). Seven biochemical compounds were tested: calcium (Ca), phosphate ($PO_4$), oxalate (Ox), uric acid (UA), bicarbonate ($HCO_3$), magnesium (Mg), and cystine (Cyst). Results were compared with previous studies from Jamaica.

**Results:** Calcium and phosphate were the most abundant compounds identified in the stone samples, with cystine identified the least. Oxalate and UA were identified in 66.1% and 52.5% of stone samples, respectively. In this study, mixed $CaPO_4$ was identified in 71.2% of stones, followed by mixed CaOx (66.1%) and mixed $CaOxPO_4$ (57.6%). The 71.2% of mixed $CaPO_4$ stones identified in this study was significantly higher than those identified by Choo-Kang (36.5%) and Tapper et al. (42.4%), who both examined kidney stone composition in Kingston, Jamaica.

**Conclusion:** Compared with earlier studies, the increased prevalence of mixed cation-anion stones in Kingston, Jamaica, suggests evolving aetiological factors influencing stone formation, potentially driven by changes in diet, lifestyle, or environmental factors.

**Keywords**: renal stones, urolithiasis, nephrolithiasis, chemical composition

## Introduction

Kidney stone disease, or urolithiasis, is a significant global health burden.[1] Despite extensive research, its aetiology remains largely idiopathic, complicating prevention and treatment efforts.[1] Analysing the chemical composition of kidney stones provides critical insights for disease mitigation. Since JF Heller's pioneering biochemical analyses in the 19th century, this approach has been the standard for characterising kidney stones.[1]

Most stones are calcium-based, primarily calcium oxalate (CaOx) or calcium phosphate ($CaPO_4$), often mixed with compounds such as magnesium, ammonium, UA, or cystine. Calcium-based stones, including brushite ($CaHPO_4{\cdot}2H_2O$), weddellite ($CaC_2O_4{\cdot}2H_2O$), whewellite ($CaC_2O_4{\cdot}H_2O$), and apatite [$Ca_5(PO_4)_3(F,Cl,OH)$], account for over 80% of cases.[2,3] UA stones result from UA precipitation, cystine stones from cystine, and struvite stones from magnesium ammonium phosphate ($MgNH_4PO_4{\cdot}6H_2O$).[4] Stone composition varies by formation site and aetiological factors, including urine chemistry imbalances, anatomical abnormalities, and dietary, environmental, or genetic influences.[5]

Kidney stones may be asymptomatic or present with symptoms such as loin or groin pain, haematuria, and, in severe cases, obstructive uropathy or renal failure.[6,7] The mechanisms of stone formation include Randall's plaque (affixation to interstitial apatite plaques on renal papillae), ductal plugs at Bellini ducts, or crystallisation in the renal collecting system.[6] Effective prevention is critical, as recurrence rates can reach 50% without intervention.[5]

Physicians use stone composition data to guide counselling on dietary and lifestyle changes, tailoring strategies to reduce recurrence risks. This study examines the chemical composition of kidney stones in Jamaica, comparing results with previously published work to identify shifts in aetiological factors over time and inform targeted prevention strategies. The study tested kidney stone samples from participants. No 24-hour urine test was done.

## Materials and methods

A retrospective analysis of biochemical data on kidney stones in Jamaica from 2000 to 2018 was conducted and compared with new data collected between 2019 and 2021. The study included 59 patients undergoing kidney stone surgery (percutaneous nephrolithotomy or open surgery) at the University Hospital of the West Indies and Kingston Public Hospital, Jamaica. No ureteroscopy study was done during the study period at the sites. All patients scheduled for surgical intervention during the study period were eligible, including new and recurrent cases. Outpatients diagnosed with kidney stones but not requiring surgery were excluded. Survey data, including age, gender, kidney stone history, and family history, were collected alongside kidney stone samples. Biochemical analysis followed the method described by Wootton (1974).[8]

No calibration or quality control was required because the biochemical tests were qualitative. Seven compounds were analysed: calcium, phosphate, oxalate, UA, bicarbonate, magnesium, and cystine. Each stone sample was macroscopically described, crushed, and divided into three portions for analysis, described below.

- Portion 1: divided into three sub-portions.
  - Sub-portion 1 (calcium and magnesium): ammonium oxalate solution was added, and the pH was adjusted to alkaline with 5N ammonium hydroxide, then to pH 5 with N-acetic acid. A precipitate indicated calcium presence. The sample was filtered, and potassium phosphate with ammonia was added until the solution became alkaline. A crystalline precipitate confirmed magnesium.
  - Sub-portion 2 (phosphate): ammonium molybdate solution was added and left at room temperature. A yellow colour or precipitate, turning blue upon addition of ascorbic acid (reducing agent), confirmed phosphate.
  - Sub-portion 3 (oxalate): calcium chloride solution was added, and the pH was adjusted to 8 with ammonium hydroxide, then to 5 with N-acetic acid. A precipitate indicated oxalate.
- Portion 2 (UA): N-potassium hydroxide was added, and the sample was boiled, cooled, and filtered. Phosphotungstic acid and sodium cyanide were added to the filtrate. A blue colour confirmed UA; trace colours were disregarded.
- Portion 3 (cystine): sodium cyanide solution was applied to the crushed stone on a white tile, followed by dropwise addition of sodium nitroprusside. A magenta colour indicated cystine.

This study was granted ethical approval by the Mona Campus Research Ethics Committee (approval number ECP 34, 15/16) and the South East Regional Health Authority (approval date 23 November 2017).

## Results

A total of 59 samples were biochemically analysed. Of the participants, 62.7% (*n* = 37) were male, and 37.3% (*n* = 22) were female. Calcium and phosphate were the most abundant compounds identified in the stone samples, with cystine the least abundant. Table I shows the different compounds identified in kidney stones, along with the number and percentage of samples in which they were detected, arranged in descending order. Table II shows the composition of all stones arranged in descending order.

**Table I:** Analysis of the total sample of kidney stones (*n* = 59)

| Biochemical compound | Number of samples present | % of samples present |
|---|---|---|
| Calcium | 49 | 83.1 |
| Phosphate | 49 | 83.1 |
| Oxalate | 39 | 66.1 |
| Uric acid | 31 | 52.5 |
| Bicarbonate | 9 | 15.3 |
| Magnesium | 7 | 11.9 |
| Cystine | 2 | 3.4 |

$CaOxPO_4$ was the most common type of stone mixture (32.2%), followed by $CaOxPO_4UA$ (15.3%).

**Table II:** Composition of all stones

| | Total | % |
|---|---|---|
| $CaOxPO_4$ | 19 | 32.2 |
| $CaOxPO_4UA$ | 9 | 15.3 |
| $UAPO_4$ | 5 | 8.5 |
| $CaPO_4HCO_3UA$ | 4 | 6.8 |
| $CaOxPO_4Mg$ | 4 | 6.8 |
| $CaOxHCO_3UA$ | 3 | 5.1 |
| UA | 3 | 5.1 |
| $CaPO_4$ | 3 | 5.1 |
| CaUA | 2 | 3.4 |
| $UAPO_4Cyst$ | 2 | 3.4 |
| $CaOxPO_4HCO□Mg$ | 1 | 1.7 |
| CaOxUA | 1 | 1.7 |
| $CaPO_4Mg$ | 1 | 1.7 |
| $CaOxPO_4HCO_3UA$ | 1 | 1.7 |
| CaOxMgUA | 1 | 1.7 |
| **Total** | **59** | **100** |

Ca – calcium, Cyst – cystine, $HCO_3$ – bicarbonate, Mg – magnesium, Ox – oxalate, $PO_4$ – phosphate, UA – uric acid

In a cross-comparison of biochemical and survey data, bicarbonate was detected in 31.8% of female participants compared with 5.4% of male participants. Oxalate was identified in 77.3% of female participants compared with 59.5% of males. All cystine identified were from females. Table III shows the compounds identified in the kidney stones, arranged in alphabetical order, along with their distribution by gender.

**Table III:** Analysis of kidney stones by gender

| Compound | Total (%) | Male (%) | Female (%) | M:F ratio |
|---|---|---|---|---|
| Calcium | 49 (83.1) | 29 (59.2) | 20 (40.8) | 1.5 |
| Bicarbonate | 9 (15.3) | 2 (22.2) | 7 (77.8) | 0.3 |
| Cystine | 2 (3.4) | 0 (0.0) | 2 (100) | 0.0 |
| Magnesium | 7 (11.9) | 5 (71.4) | 2 (28.6) | 2.5 |
| Oxalate | 39 (66.1) | 22 (56.4) | 17 (43.6) | 1.3 |
| Phosphate | 49 (83.1) | 31 (63.3) | 18 (36.7) | 1.7 |
| Uric acid | 31 (52.5) | 18 (58.1) | 13 (41.9) | 1.4 |

Except for bicarbonate and cystine, males accounted for most of the compounds identified. In this study, bicarbonate was significantly associated with stone formers' gender at $p = 0.05$ (two-tailed), with phi and Cramér's V values of 0.415 each. Cystine was also significantly associated with stone formers' gender, with $p = 0.03$ (two-tailed) and phi and Cramér's V values of 0.329 each.

When analysed by disease history (new and recurrent patients), 54.2% of participants (*n* = 32) were new patients, and 45.8% (*n* = 27) were recurrent patients. Phosphate was identified in 96.9% of participants listed as new patients, compared with 66.7% listed

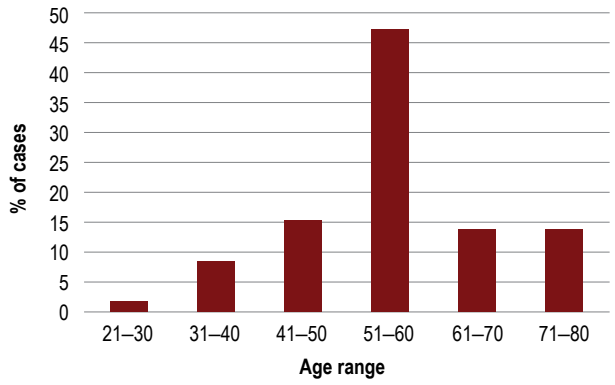


Figure 1: Age distribution of urolithiasis

as recurrent patients. Oxalate was identified in 71.9% of new patients compared with 59.3% in recurrent patients. No cystine was identified in new patients.

When analysed by family history, 23.7% of participants ($n$ = 14) had a family history of the disease, while 76.3% ($n$ = 45) did not. Phosphate was identified in 100% of stone formers with a family history of the disease compared with 77.8% without a family history. Magnesium was found in 13.3% of participants without a family history of the disease compared with 7.1% for those with a family history.

The chart in Figure 1 shows the age distribution of the stone formers in the study. Most participants were aged 51–60 years, followed by a tie between 41–50 and 61–70. The age group 21–30 had the fewest cases.

## Discussion

Consistent with prior studies, most kidney stones in this study were heterogeneous, comprising multiple cations and anions, making single-compound classification challenging.[5,7] Calcium and phosphate were the predominant constituents (83.1% each, Table I), a pattern consistently observed in other studies analysing wider, global datasets.[5,6] This is because their occurrence is tied to specific, but relatively common, conditions driven by dietary practices and metabolic disorders. Conversely, other stone types, such as UA and cystine (genetically linked), are linked to more specific, uncommon disorders.

Although calcium-based stones are prevalent, reducing dietary calcium intake is not recommended because urolithiasis has a multifactorial aetiology, with other ions playing significant roles.[5] Increased water intake is strongly advised to dilute urine and reduce supersaturation, a key driver of stone formation.[5,9,10] Oxalate (66.1%) and UA (52.5%) were frequently detected, linked to idiopathic hypercalciuria and low urinary citrate in calcium oxalate stones, and to hyperuricosuria in UA stones.[7,11] Magnesium, present in 11.9% of samples, may suggest urinary tract infections.[11] Mixed calcium phosphate ($CaPO_4$) stones were identified in 71.2% of samples, followed by calcium oxalate (CaOx, 66.1%) and mixed $CaOxPO_4$ (57.6%). Among consistent mixtures, $CaOxPO_4$ was the most common (32.2%), followed by $CaOxPO_4$UA (15.3%) and $UAPO_4$ (8.5%, Table II).

Pure UA and $CaPO_4$ stones accounted for 5.1% of the samples each. Compared to earlier Jamaican studies, the prevalence of mixed $CaPO_4$ stones (71.2%) was significantly higher than reported by Choo-Kang (36.5%) and Tapper et al.[11] (42.4%) ($p < 0.05$, chi-square test).[7] Similarly, $CaOxPO_4$ prevalence (57.6%) exceeded Choo-Kang's 18.2%.[7] Conversely, pure $CaPO_4$ stones (5.1%) were less common than reported by Choo-Kang (17.7%) and Tapper et al.[11] (35.8%).[7] These findings indicate a shift toward more complex stone compositions in Kingston, Jamaica, likely driven by evolving dietary patterns (higher salt, animal protein, and processed foods), lifestyle changes, and medication use over time.

Moreover, there is a rising global prevalence of metabolic syndrome, obesity, diabetes, and dehydration due to climate warming, along with associated urinary changes, such as altered pH, hypercalciuria, hyperoxaluria, and reduced citrate levels, which promote heterogeneous nucleation and layered crystal aggregation in more complex urine chemistries.[12-14] The 5.1% prevalence of pure UA stones aligns with Kaur et al.[12] (3.2%) and Choo-Kang (5.3%), but it is significantly lower than reported by Spivacow et al.[15] (16.5%), reflecting the rarity of pure UA stones, often associated with urate metabolism disorders.[7,13]

Males comprised 62.7% of stone formers compared with 37.3% females, consistent with Tapper et al.[11] (59.4% male, 40.6% female) and Choo-Kang (69.4% male, 30.6% female), yielding a male-to-female ratio of 1.68:1, similar to global reports.[7,11,16] While males have a historically higher stone incidence, recent studies note a rising incidence among females.[11,17] In this study, males showed a higher prevalence of calcium, magnesium, oxalate, phosphate, and UA. At the same time, females had higher bicarbonate (77.8% vs. 22.2%) and cystine (100% vs. 0%) prevalence, potentially due to hormonal influences, anatomical differences (e.g. the shorter female urethra), or variations in stone-forming inhibitors.[13]

The ratio of new to recurrent stone formers (1.18:1) supports findings that up to 50% of patients experience recurrence without counselling.[5,13] New patients showed higher phosphate (96.9% vs. 66.7%) and oxalate (71.9% vs. 59.3%) prevalence than recurrent patients, while cystine was exclusive to recurrent cases, suggesting cystinuria or renal transport defects.[7,13] Calcium oxalate stones predominate in acidic urine, while calcium phosphate stones favour alkaline environments, both of which are associated with hypercalciuria, indicating multifactorial causes for their prevalence in new patients.[17]

The ratio of stone formers with a family history to those without (1:3.2) aligns with reports from larger studies.[19] Family history correlated with higher phosphate (100% vs. 77.8%) and magnesium (13.3% vs. 7.1%) prevalence, reinforcing genetic predispositions to stone formation.[18] The 51–60 age group had the highest stone prevalence (47.5%), followed by 41–50 (15.3%), 61–70 (13.6%), and 71–80 (13.6%) (Figure 1). The 21–40 age group had the lowest prevalence (10.2%). However, stones can form at any age, with 10.6% of males and 18.4% of females developing their first stone before age 20.[19] Age-specific stone composition differences warrant further investigation.

Our study's findings highlight the evolving complexity of kidney stone composition in Jamaica, necessitating tailored clinical interventions, such as dietary modifications and increased fluid intake, to address changing aetiological factors and reduce recurrence risk.

### *Study limitations*

Study limitations include a small sample size and the use of qualitative biochemical analysis (Wootton 1974), which is less precise than more modern instrumental methods, such as infrared spectroscopy or X-ray diffraction.

## Conclusion

Calcium and phosphate were the predominant ions in kidney stone samples, followed by oxalate and UA. Compared with earlier studies, the increased prevalence of mixed cation-anion stones in Kingston, Jamaica, suggests evolving aetiological factors influencing stone formation, potentially driven by changes in diet, lifestyle, or environmental factors. Males exhibited a higher incidence of kidney stones than females, consistent with global trends. The biochemical analysis method described by Wootton (1974) proved effective in characterising stone composition, providing valuable data to guide recurrence prevention. Biochemical analysis remains critical for tailoring patient counselling and implementing strategies, such as increased fluid intake and dietary modifications, to mitigate kidney stone disease in Jamaica.

### *Conflict of interest*

The authors declare no conflict of interest.

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### *Ethical approval*

This study was granted ethical approval by the Mona Campus Research Ethics Committee (approval number ECP 34, 15/16) and the South East Regional Health Authority (approval date 23 November 2017).

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