# Chemical Composition of Urinary Tract Stones at the University Hospital of the West Indies

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***ABSTRACT***

*Urinary tract stones occur frequently with the incidence being about one to fifteen per cent worldwide. Patients may be asymptomatic or sometimes they may present with haematuria. Severe lumbar pain radiating to the loin requiring immediate analgesic treatment may occur. Stones generally consist of organic and inorganic material. The organic material may be present in the nidus and can contribute up to about 2.5% of the total weight. Inorganic minerals make up the bulk of the stone. Data are presented for the inorganic minerals present in the stones seen at the University Hospital of the West Indies over a 25-year period. Six hundred and forty-one (445 males and 196 females) stones were analyzed by routine chemical methods. Calcium was the main constituent, being seen in 93.9% of the stones. This was followed by oxalate 60.1%, urate 37.0%, bicarbonate 16.5% and magnesium 8.6%. There were four cystine containing stones. Treatment includes medical management for the underlying cause and surgical methods for the removal of the stones. Chemical methods of analysis of the stones has its limitations and should be replaced by more sophisticated methods eg X-ray diffraction crystallography which would give more accurate details of the structure of the stones.*

# Composición Química de las Piedras del Tracto Urinario en el Hospital Universitario de West Indies

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***RESUMEN***

*Las piedras del tracto urinario se presentan frecuentemente con una incidencia de aproximadamente uno a quince por ciento a nivel mundial. Los pacientes pueden ser asintomáticos o presentarse con hematuria. Puede producirse dolor lumbar severo que se irradia a toda la región lumbar y que requiere tratamiento analgésico inmediato. Las piedras generalmente están formadas por material orgánico e inorgánico. El material orgánico puede estar presente en el nido y puede contribuir hasta aproximadamente 2.5% del peso total. Los minerales inorgánicos constituyen la mayor parte de las piedras. Se presentan datos de los minerales inorgánicos presentes en las piedras vistas en el Hospital Universitario de West Indies en un periodo de 25 años. Seiscientos cuarenta y una (445 varones y 196 hembras) piedras fueron analizadas mediante métodos químicos de rutina. El calcio fue el constituyente principal, observándosele en el 93.9% de las piedras. El mismo fue seguido por el oxalato (60.1%), el urato (37.0%), el bicarbonato (16.5%) y el magnesio (8.6%). Había cuatro cistinas que contenían piedras. El tratamiento incluye el manejo médico de la causa subyacente y los métodos quirúrgicos para la eliminación de las piedras. Los métodos químicos de análisis de las piedras tienen*

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*sus limitaciones y deben reemplazarse por métodos más sofisticados, tales como la cristalografía por difracción de rayos X. que daría detalles más exactos de la estructura de las piedras.*

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## INTRODUCTION

The development of urinary tract stones is a common occurrence worldwide with about 1–15% of the population affected. The recurrence rate can be up to 50%. Men are more commonly affected. The clinical presentation varies. They may be asymptomatic or may present with painless haematuria or with excruciating colicky loin to groin pain in the flank. Complete or partial obstruction of the urinary tract may occur. The main types of stones are made up of calcium oxalate, calcium phosphate, magnesium ammonium (not tested for in this series) phosphate and uric acid. The chemical composition of urinary stones seen over a 25-year period at the University Hospital of the West Indies (UHWI) is presented.

## MATERIALS AND METHODS

All renal stones sent to the Pathology laboratory of the UHWI over the past 25 years were analyzed for Calcium (Ca), Magnesium (Mg), Oxalate (Ox), Phosphate (PO4), Bicarbonate (HCO3), Urate (UA) and Cystine (Cys). The site of origin of the stones in the urinary tract was not included as in most cases the data were not available. The stones varied in size. Most specimens were fragmented. The stones were first ground into a fine powder and the analysis done by chemical methods as outlined by Wootton (1).

Cold N-nitric acid was added to the powder. Efferevescence indicated the presence of carbonate. The mixture was then boiled, cooled and filtered. The filtrate was then used to detect calcium with ammonium oxalate, magnesium with potassium phosphate and ammonia, phosphate with ammonium molybdate and oxalate with calcium chloride. The powder was boiled with N-potassium hydroxide and Folin's uric acid reagent and sodium cyanide was added to the filtrate to detect uric acid. Cystine was detected with sodium cyanide and sodium nitroprusside. Ammonia was not tested for as it was not included in Wooton's (1) methods.

## RESULTS

A total of 659 [males (M) 457 and females (F) 202] stones were obtained. Most of them were fragmented. Insufficient sample was obtained in 18 patients (M 12: F 6) leaving 641 [445 (69.4%) M and 196 (30.6%) F] for complete analysis. Table 1 shows the composition of all stones. The most common type – 549(85.6%) – contained calcium as the only cation with mixtures of the anions. There were 389 (70.9%) M and 160 (29.1%) F. There were 53 (8.3%) stones that contained both calcium and magnesium with other anions. These showed a more even distribution with 29 (54.7%) males and 24 (45.3%) females. There were only two stones containing magnesiun as the sole cation, one mixed with phosphate and the other with uric acid. Both were from females. Pure uric acid stones were present in 35 (5.5%). There were 27 (77.1%) males and 8 (22.9) females. Two stones from females contained cystine and uric acid.

Table 1: Composition of all stones

| | **Total 641** | **M 445 (69.4%)** | **F 196 (30.6%)** |
|---|---|---|---|
| $CaA^-$ | 549 (85.6%) | 389 (70.9%) | 160 (29.1%) |
| $CaMgA^-$ | 53 (8.0%) | 29 (54.7%) | 24 (45.3%) |
| $MgA^-$ | 2 (0.3%) | 0 | 2 |
| UA | 35 (5.3%) | 27 (77.1%) | 8 (22.9%) |
| CystUA | 2 (0.3%) | 0 | 2 |

$A^-$ = Combinations of oxalate, bicarbonate, phosphate, urate

Table 2 shows the stones that contained calcium as the only cation and mixtures of the various anions. Calcium oxalate [34(24.4%)] was the most common type followed by those with calcium, oxalate and phosphate [100(18.2%)] and then calcium phosphate – [97 (17.7%)]. There were 56 (10.2%) with calcium, oxalate and uric acid and 40(7.3%) with calcium, phosphate and uric acid. Two contained cystine also. Table 3 shows the stones that contained both calcium and magnesium with the anions. The two most common mixtures were with oxalate alone and oxalate with uric acid.

Table 2: Stones with calcium and mixtures of the anions

| | **Total (%)** | **Male (%)** | **Female (%)** |
|---|---|---|---|
| CaOx | 134 (24.4) | 94 (70.2) | 40 (29.8) |
| $CaOxPO_4$ | 100 (18.2) | 65 (65.0) | 35 (35.0) |
| $CaPO_4$ | 97 (17.7) | 66 (68.0) | 31 (32.0) |
| CaOxUA | 56 (10.2) | 45 (80.4) | 11 (19.6) |
| $CaPO_4UA$ | 40 (7.3) | 30 (75.0) | 10 (25.0) |
| CaUA | 20 (3.6) | 13 (65.0) | 7 (35.0) |
| $CaOxPO_4HCO_3$ | 16 (2.9) | 12 (75.0) | 4 (25.0) |
| $CaOxHCO_3UA$ | 15 (2.7) | 11 (73.3) | 4 (26.7) |
| $CaPO_4HCO_3UA$ | 15 (2.7) | 13 (86.7) | 2 (13.3) |
| $CaOxPO_4UA$ | 13 (2.4) | 11 (84.6) | 2 (15.4) |
| $CaHCO_3UA$ | 12 (2.2) | 9 (75.0) | 3 (25.0) |
| $CaOxHCO_3$ | 9 (1.6) | 6 (66.7) | 3 (33.3) |
| $CaPO_4HCO_3$ | 8 (1.5) | 6 (75.0) | 2 (25.0) |
| $CaHCO_3$ | 6 (1.1) | 3 (50.0) | 3 (50.0) |
| $CaOxPO_4HCO_3UA$ | 6 (1.1) | 4 (66.7) | 2 (33.3) |
| $CaPO_4Cys$ | 1 (0.2) | 1 | 0 |
| $CaOxPO_4UACys$ | 1 (0.2) | 0 | 1 |
| **Total** | **549 (100)** | **389 (70.9)** | **160 (29.1)** |

Table 3: Stones with calcium, magnesium and mixtures of the anions

| Composition | Total | Male | Female |
|---|---|---|---|
| CaMgOx | 10 | 6 | 4 |
| $CaMgPO_4$ | 3 | 2 | 1 |
| $CaMgHCO_3$ | 1 | 0 | 1 |
| CaMgOxUA | 9 | 3 | 6 |
| $CaMgOxPO_4$ | 6 | 5 | 1 |
| $CaMgOxHCO_3$ | 3 | 3 | 0 |
| $CaMgPO_4HCO_3$ | 4 | 0 | 4 |
| $CaMgPO_4UA$ | 2 | 1 | 1 |
| $CaMgHCO_3UA$ | 5 | 1 | 4 |
| $CaMgOxPO_4HCO_3$ | 4 | 3 | 1 |
| $CaMgOxPO_4UA$ | 3 | 2 | 1 |
| $CaMgPO_4HCO_3UA$ | 3 | 3 | 0 |
| **Total** | **53** | **29** | **24** |

## DISCUSSION

Urinary tract stones are fairly common worldwide. In North America and other developed countries, the incidence is about 1–15% (2, 3, 4, 14) with a recurrence rate of about 50%. They develop more commonly in the kidneys and ureters than the bladder. The clinical presentation varies. They may be asymptomatic or they may present with loin to groin pain with or without haematuria. Obstructive uropathy and renal failure may occur. There are various methods of analysis such as infrared spectroscopy (11), X-ray diffractometry (8) and solid state nuclear magnetic resonance spectroscopy (9). These have the advantages of determining the structures of the stones. In addition to crystalline inorganic material, stones also contain some organic material called matrix which contributes up to about 2.5% by weight of the stone. Simple qualitative chemical methods were used here to determine the presence of any inorganic minerals.

Calcium was the main constituent. This was found in 602 (93.9%) of our patients. There were 391 (61.0%) stones which contained calcium oxalate. This was generally lower than those reported by Balasi (3), Westenberg (5) and Daudon (10). There were 134 (20.9%) pure calcium oxalate stones. This figure is lower than that quoted by Older (12).

The causes of calcium oxalate stones are idiopathic hypercalciuria, hypercalciuric conditions, low urinary citrate, hyperoxaluria and hyperuricosuria. About 30–60% of these patients with calcium oxalate stones have idiopathic hypercalciuria. There may also be a molecular abnormality where there may be mutations in the genes affecting the transport of chloride, oxalate and uric acid in the tubules of the kidney (13).

Hypercalcaemic conditions causing hypercalciuria include primary hyperparathyroidism, granulomatous disease, hyperthyroidism, phaeochromocytoma, vitamin D intoxication and thiazide diuretic therapy.

There were 97(15.1%) pure calcium phosphate stones. This figure is higher than those reported by Balasi (3), Westenberg (5) and Older (12). These tend to occur in renal tubular acidification defects.

Uric acid was present in 237 (37.0%) stones. There were 35 (5.5%) pure uric acid stones, a figure lower than those reported by Balasi (3), Westenberg (5) and Coe (6). These stones tend to occur in acid urine. Gout, a condition in which about 10–20% of patients produce excess uric acid and which is associated with a diet rich in purines, is a risk factor for uric acid formation. A urine pH below 5.5 is also a potential risk factor. In normouricosuric patients, the primary defect appears to be renal excretion of ammonia. These stones are usually radiolucent but may be somewhat radiopaque if calcium is present. The mixed uric acid stones (178) also contained mixtures of calcium, magnesium and various anions (Tables 2, 3). The male to female ratio in these stones is about 3 to 3.5 to 1.

There were 55 (8.6%) magnesium containing stones, a figure lower than those reported by Balasi (15%) (3) and Westenberg [20%] (5). They were evenly divided between males (30) and females (27). Ammonia, not tested for in this report, is also usually present. These are generally associated with urinary tract infection usually caused by urea splitting bacteria such as proteus, klebsiella and pseudomonas.

There were four cystine containing stones. The presence of these stones is more likely caused by cystinuria, an autosomal recessive disease affecting the transport of the dibasic amino acids: cystine, ornithine, arginine and lysine in the proximal convoluted tubules. This results in excessive secretion of these dibasic amino acids in the urine. Only cystine is insoluble, especially in acidic conditions, resulting in the formation of cystine crystals which have a characteristic hexagonal shape. These crystals are present in about 25–50% of patients with cystinuria. These were the findings in two urine samples examined by thin layer chromatography and microscopy.

Investigations should be conducted to identify hypercalcaemia and hyperuricaemia and their causes and the presence of urinary tract infection with urea splitting organisms. Other relevant diagnostic investigations include unenhanced helical CT, plain abdominal X-ray, intravenous urogram and abdominal ultrasound. Medical management would include adequate hydration and treatment of the underlying cause(s). Preventative measures include adequate hydration, dietary changes or medication depending on the type of stone. However, most stones of size 5 mm or less diameter will be excreted spontaneously within four weeks. Surgical management includes external shock wave lithotripsy, litholopaxy, laparoscopy, ureteroscopy, percutaneous nephrolithotomy and open stone surgery.

In summary, urinary tract stones is a fairly common condition. The male to female ratio is about 3:1 except for those containing magnesium where the ratio is about 1:1. They may be asymptomatic and discovered incidentally or they may present with excruciating lumbar pain. The chemical method of analysis of stones is insensitive and should be

replaced by a better method such as X-ray crystallography where both the structure and chemical composition can be ascertained.

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