The management of urolithiasis

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Abstract

The incidence and prevalence of urolithiasis is on the rise; though inevitably the increasing availability of cross-sectional imaging has some contribution to this rise in diagnoses, it cannot take all the blame. Urolithiasis is now more commonly being recognized as a symptom of a more systemic disease which has a constellation of presenting signs and complaints. The authors aim to outline the precipitating causes of urolithiasis, along with a comprehensive discussion of the current operative trends available to the practising endourologist. Despite largely being tailored to trainees within Core Training, in parts the discussion will head beyond that what is expected during basic surgical training and move into topics of debate within higher specialist training.

Keywords metabolic syndrome; percutaneous nephrolithotomy; renal stones; shockwave lithotripsy; ureteroscopy; urolithiasis

The epidemiology of urolithiasis

Urolithiasis affects 1 in 2 people per 1000, per year in the United Kingdom. The prevalence is dependent upon age, sex, race and geography; with a rise seen in the last 25 years regardless of ethnicity and the most prevalent composition being that of calcium oxalate (Table 1). The increased use of imaging modalities is seen as a significant contributor to overall number. There is a lifetime risk between 5% and 10% of developing urinary stone disease in the UK, whereas in the USA this is quoted as 6% in women and 12% in men. Eighty per cent of urinary tract stones are calcium based and seems to disproportionately involve economically active individuals – which inevitably leads to a substantial burden on society. Although traditionally gender ratios are approximated to 2–3:1 (M:F), the latest evidence seems to point to a vast change in this dynamic distribution with a reduction in this difference to less than 2:1, respectively.

The incidence – seen as the first 'stone event' – is disproportionately higher in Caucasian males. The incidence rises from the age of 20 and peaks between 40 and 60 years of age. Women start later (in their 20s) with the incidence peaking earlier before decreasing to 1/1000/year in their late 40–50 years.

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The percentage recurrence of urolithiasis is a difficult topic to place a blanket value upon due to the heterogeneity of factors involved, with few studies providing reliable data. In general, case series indicate that 30–40% of patients who are *not treated* will form another stone within 5 years of the first incidence of stone disease. However, prevention of stone recurrence is very feasible – with randomized trials pointing to a greater than 50% risk reduction.

Dietary risk factors

Diet influences the composition of urine and by inference will directly influence the risk of urolithiasis. Implicated nutrients within the diet include calcium, animal protein, oxalate, sodium, sucrose, fructose, magnesium and potassium.

Calcium: in the past it was presumed that a higher intake of calcium was proportional to the risk of urolithiasis. However, three landmark trials (HPFS, NHS I and NHS II) showed that increased calcium intake was seen as protective of urolithiasis – independent of other risk factors. At first glance, this may seem somewhat counter-intuitive, but a higher calcium intake will subsequently increase dietary oxalate absorption and in effect reduce urinary calcium oxalate excretion. In contrast to dietary calcium, supplemented calcium does not seem to appear to reduce risk in men or younger women and may increase the risk within older women.

Oxalate: the proportion of dietary oxalate that is absorbed ranges from 10% to 50%, with itself affected by concurrent dietary factors (as calcium), intestinal flora and disease. It has a positive correlation with calcium oxalate urolithiasis. Urinary oxalate is also derived from the endogenous metabolism of glycine, hydroxyproline, vitamin C and glycolate.

Potassium: higher dietary potassium intake was seen as decreasing risk in men and older women – potentially by reducing urine calcium excretion or increasing urinary citrate.

Sodium/sucrose: a higher intake of sodium or sucrose is directly proportional to urinary calcium and independent of calcium intake.

Vitamin C: ascorbic acid (vitamin C) can be metabolized to oxalate. In a prospective trial, men who consumed greater than 1 g of vitamin C had a greater than 40% risk of stone formation

Prevalence of composition of calculi

Stone composition	% of renal calculi
Calcium oxalate	80
Struvite (infection related)	2–20
Uric acid	5–10
Calcium phosphate + calcium oxalate	10%
Pure calcium phosphate	<1%
Cystine	1%

Table 1

compared to men ingesting lower than the recommended daily allowance. Calcium oxalate stone formers should in general avoid vitamin C supplements.

Animal protein: high levels of animal protein in the diet cause high urinary oxalate, a low pH and low urinary citrate.

Fluid intake: the single most important determinant of urolithiasis risk in the absence metabolic factors is urinary volume. The risk of stone formation is substantially increased when the urine output is less than 1 L/day. Interestingly, increasing water hardness (high calcium content) may reduce risk by concurrently reducing urinary oxalate excretion.

Urinary risk factors

Hypercalciuria: greater than 300 mg/day in men and 250 mg/day in women on a 1 g/day calcium diet; this is seen in approximately 20%–40% of patients with calcium urolithiasis and is a major factor in calcium oxalate stone formation by increasing the supersaturation of urine. Around 50% of patients with calcium-based urolithiasis will have hypercalciuria:

- absorptive – due to increased intestinal absorption of calcium
- renal – due to renal leak of calcium
- resorptive – due to bone demineralization.

Dietary calcium restriction is not recommended for stone formers with nephrolithiasis. Diets with a calcium content *≥1 g/day* could be protective against the risk of stone formation in hypercalciuric stone-forming adults. Moderate dietary salt restriction is useful in limiting urinary calcium excretion and thus may be helpful for primary and secondary prevention of nephrolithiasis. A low-normal protein intake decreases calciuria and is useful in stone prevention.

Hypercalcaemia: it can be said that nearly all hypercalcaemic patients who form stones will have *primary hyperparathyroidism*. However, of those who have hyperparathyroidism – *only 1%* will tend to form stones.

Hyperoxaluria: greater than 45 mg/day and is three to four times more common in males than females. However, it is noted that the risk of stone disease begins much below this value. This can be due to *primary hyperoxaluria* causing increased hepatic production of oxalate or *increased oxalate absorption* in short bowel syndrome, so-called enteric hyperoxaluria – here the gut is overexposed to bile-salts, leading to an increased permeability to oxalate. A diet low in oxalate and/or a calcium intake which is normal to high, reduces the urinary excretion of oxalate. However, a diet rich in oxalates and/or a diet low in calcium increases urinary oxalate. A restriction in protein intake may also reduce the urinary excretion of oxalate although a vegetarian diet may lead to an increase in urinary oxalate.

Hypocitraturia: less than 320 mg/day is found in 5–11% of first-time stone formers. Citrate forms a soluble complex when it binds to calcium, thereby preventing the binding of calcium to oxalate.

Low urine volume: less than 1 L/day, 12–25% of first-time stone formers will have this abnormality.

Hyperuricosuria: elevated levels of uric acid cause spontaneous precipitation within solution, which can help to act as a 'scaffold' for mainly calcium oxalate crystal aggregation and subsequent stone formation. Uric acid exists in solution as uric acid *and* sodium urate in an ionic balance. Sodium urate is 20 times more soluble than uric acid. But at a pH of 5, less than 20% is sodium urate. This is increased to 50% at a pH of 5.5 and further increased to >90% when the pH goes to 6.5 or greater.

Non-dietary risk factors

Family history: common forms of stone disease can be inherited, with the risk of stone formation being 25%–50% higher in individuals with a positive family history of urolithiasis. This contribution is probably as a result of both genetic predisposition as well as similar environmental exposures. Familial renal tubular acidosis (which predisposes to calcium phosphate stones) and cystinuria (predisposition to cysteine stones) are inherited.

Systemic disorders: there is a wealth of evidence which points to urolithiasis as a systemic disorder. Furthermore, there are recognized conditions that are associated with calcium-containing stones such as hyperparathyroidism, Crohn's disease and renal tubular acidosis. Obesity, gout and diabetes (part of the 'metabolic syndrome' complex) have also been recently linked to the incidence of renal stone disease – increasing an individual's BMI increases the risk of stone formation, with other contributory factors controlled.

Ethnicity: individuals of Arabic, Latin American and West Indian descent are more likely to be stone formers than individuals of European descent. Africans have the lowest incidence of urolithiasis.

Environmental factors: while urolithiasis is more common in hot climates, this is confounded by some endogenous populations having a lower prevalence of stones (e.g. African subcontinent) and vice-versa (e.g. Northern Europe). The latter discrepancy is thought to relate to the 'Western lifestyle' of excessive consumption of animal protein, inadequate fluid intake and sedentary lifestyle.

Pathology of urinary stone disease

Vitamin D acts as a steroidal hormone and is pivotal in maintaining calcium and phosphate haemostasis. Calcium-containing stones result from excessive urinary calcium excretion (hypercalciuria) from either increased intestinal absorption of calcium, increased bone resorption or renal calcium loss. Urine is said to be *saturated* when the product of the concentrations exceeds that of the *solubility product (SP)*. Below this value, crystallization will not form. Whereas above the SP, spontaneous crystallization is possible but does not happen due to the inhibitors. Despite these inhibitors, over a certain concentration *above* the SP the effect of inhibitors ceases to prevent crystallization – this value is called the *formation product* (*FP*). Therefore, above this concentration the solute is termed *supersaturated*. The solute is termed *metastable* in the concentration range between SP and FP.