Urol Res (1990) 18 [Suppl 1]:S3–S8

Urological Research
© Springer-Verlag 1990

Epidemiology of urinary stone disease

W. G. Robertson

King Faisal Specialist Hospital and Research Centre, Department of Biological and Medical Research, Riyadh, Kingdom of Saudi Arabia

As early as the time of Hippocrates, it was recognized that epidemiology was an important factor in the understanding of many disease states. Hippocrates himself emphasised. "Whoever wishes to investigate medicine properly should proceed thus: in the first place to consider the *seasons of the year* and what effects each of them produces. Then the winds, the *hot and the cold,* especially such as are common to all *countries,* and then such as are peculiar to each locality. In the same manner, when one comes into a city, he should consider its *situation,* how it lies as to the winds and the rising of the sun. One should consider most attentively the *waters* which the inhabitants use, ... and *the mode in which the inhabitants live,* and what are their pursuits, whether they are *found of drinking and eating to excess* and *given to indolence* or are fond of exercise and labour".

It is interesting that Hippocrates, who had many clear insights into the factors involved in urinary stone formation, should also pick out many of the epidemiological factors that have subsequently been shown to influence the risk of formation of calcium-containing stones (Table 1). It has taken another 2,300 years to establish the mechanisms by which these epidemiological factors affect the incidence of stones in the population [23]. Broadly, they can be divided into three main groups – demographic, environmental and pathophysiological – all of which can be shown to influence the composition of urine in such a way as to increase the risk of abnormal crystalluria and, hence, stone formation.

Table 1. Main epidemiological factors involved in the formation of calcium-containing stones

Age and sex
Climate and season
Stress
Fluid intake
Occupation
Affluence and diet
Metabolic and genetic disorders

Demographic risk factors

The demographic risk factors for calcium urolithiasis include age, sex, race and geographical location. Calcium-containing stones are much more common in men than in women, particularly the idiopathic form of this disorder. The peak age at onset is around 28 years but, since stones tend to recur, the mean age at which they occur is some 10 years later. In men the peak age at which stones form is about 35 years, whereas in women there is a double peak, the first occurring at about 30 years and the second, at about 55. The incidence of stones in children and in the elderly is very low.

In general, the higher risk of stones in men is due to their higher urinary excretion of calcium, oxalate and uric acid and, to a lesser extent, to their lower excretion of citrate. The low risk of idiopathic calcium stones in children is due to their relatively low excretion of calcium and to their high excretion of polyanionic inhibitors. The reduction in the risk of calcium-containing stones in the elderly is a consequence of the decrease in the excretion of calcium, oxalate and uric acid that occurs with age, presumably because of a fall in the dietary intake and intestinal absorption of the nutrients concerned.

Stone formation is generally more common among whites than among blacks, and at one time this was thought to indicate that blacks are genetically immune to stone disease. Studies in the United States, however, have shown that when the composition of the diet of blacks approximates that of Caucasians, there is no difference between the incidence of stone formation in the two populations [15].

Recent immunological studies suggest the existence of a link between HLA polymorphism and renal stone formation, but the association is weak and the authors cannot rule out the possibility that it is purely adventitious [4, 34].

The dominance of the apparent relationship between the occurrence of stones in fathers and sons and between brothers is striking [13, 14, 32] and suggests the

possibility of a familial link in calcium urolithiasis. However, it is difficult to establish whether this link is due to a specific genetic factor or to environmental factors common to members of a given family, such as diet. The latter possibility is supported by the observation that the incidence of stones is higher among the wives of stone-formers than among the spouses of non-stone-formers [32].

Environmental risk factors

These include geographical location, climate and season, stress, occupation, level of affluence and diet and fluid intake. Indeed, there may be interrelationships between some of these risk factors, e.g. occupation may affect stress and plays a part in the level of affluence, which, in turn, may influence diet.

Geographical location, climate and season

It is well documented that the incidence of upper urinary tract stones in a given population increases with ambient temperature in the United States [20], Australia [3], Japan [9] and countries of the Eastern Mediterranean. An increase in stone formation has also been reported among military personnel when they are transferred from a temperate to a hot climate [5].

Although a high incidence of stones is commonly associated with countries with hot climates, this is not necessarily the case for all such countries. For example, the incidence of stones is low in Nigeria [8, 16] and among the Bantu of South Africa [17] but is extremely high in the oil-rich states of the Arabian Gulf, such as the United Arab Emirates [12], Kuwait and Saudi Arabia [1]. It would seem that the population has to reach some moderate-to-high standard of living before ambient temperature plays a significant role in increasing the incidence of stone formation.

Although a reduction in urinary volume is probably a main cause of stone formation in these situations, there are other changes in urinary composition that increase the risk of stone development, such as an increase in urinary calcium [18] and, consequently, in oxalate and, possibly, uric acid. The higher excretion of calcium may be due to increased exposure to ultraviolet light, which is known to stimulate vitamin D_3 production in the skin and thereby increase calcium (and, secondarily, oxalate) absorption from the intestine. When combined, these changes in urinary biochemistry markedly increase the biochemical risk of stone formation.

The seasonal pattern of stone formation observed in the more temperate areas of the United States [21], Australia [3], Great Britain [28] and East Germany [35] may also be attributed to this mechanism, since it has been shown that rises in both calcium and oxalate excretion during the summer months correlate to some extent with a rise in the blood levels of 25-hydroxyvitamin D_3, one of the acitve metabolites of vitamin D_3. It has also been suggested that seasonal variations in dietary composition are responsible for part of these patterns [11].

Stress

Stress has been suggested to be a risk factor for calcium oxalate stone formation. A study on the effects of stress in stone-formers and normal subjects showed that the patients produced marked increases in the urinary concentrations of calcium, oxalate and uric acid and small decreases in urinary magnesium [7]. The reasons for the alterations in urinary biochemistry are not yet clear but, taken together, the changes would predictably increase the risk of calcium stone formation.

Fluid intake

The passage of gravel and stones in the urine has long been associated with low urinary volume and is particularly enhanced in individuals whose urinary volume is persistently <1 l/day. In contrast, if urinary volume can be maintained at >2–2.5 l/day, the risk of developing calcium-containing stones should be low in the majority of the population.

The main factors that cause a consistently low volume of urine are a low fluid intake, percutaneous loss of water and losses through diarrhoea. In temperate climates, the intake of fluid is usually the dominant factor. Percutaneous loss of water in hotter climates and fluid loss through the stools in areas of poor hygiene become increasingly important. Unless these are offset by an increased intake of fluid, urinary volume will be low. This may partly explain the higher incidence of stones in the hot, dry areas of the Middle East as compared with more temperate zones. It may also partly account for the higher incidence of urolithiasis reported among naval and military personnel posted from the United Kingdom to the Middle and Far East as compared with that occurring in home-based troops [6].

At one time it was considered that water hardness might be an additional risk factor for calcium urolithiasis, but the data thus far collected do not support the hypothesis that continual ingestion of hard water increases the risk of stone formation [38]. In countries that have a hot, dry climate and in which the local supplies of water are hard, the taste of the water may be so unpleasant that insufficient fluid is consumed to keep urinary volume at a level high enough to protect the population of the area against stones. In this way hard water may play a small, indirect role in the genesis of stones and may explain the observation that stone formation is more common in some areas of the United States in which wells represent the sole source of water [38].

Social class and level of affluence

Stone disease is more prevalent among the higher socioeconomic groups than in the less affluent ones [22, 23, 39]. This applies particularly to calcium and, probably, uric acid stone disease. In Leeds, for example, idiopathic calcium urolithiasis is more common among men in the more affluent social classes 1 and 2 than in social classes 4

and 5, and the occurrence of stones in the various postal districts of metropolitan Leeds is directly related to the proportion of men in social classes 1 and 2 in each of these areas [32]. Further studies have shown that the dependence of the occurrence of stone formation on the level of affluence in the population is evident at four separate demographic levels [23].

On a global scale, it is clear that many Third World countries have relatively low incidences of upper urinary tract stones in spite of the fact that the majority have tropical or sub-tropical climates. It would seem that affluence, through its influence on diet, may be a more important risk factor for stone formation than living and working in a hot environment. An example of this is seen in Nigeria; in spite of its hot climate, this country has few idiopathic calcium stone-formers, but those thus for reported belong almost exclusively to the more affluent, professional classes [16].

Occupation

The role of occupation in the aetiology of stone formation is complex. People in some occupations (for example, managerial staff [23], airline pilots and physicians [36] have a high reported incidence of stones, but they also belong to the more affluent sections of society and their high risk of developing stones is more likely to be associated with their corresponding life-style than with some specific aspect of their work. On the other hand, such occupations tend to be more sedentary than physically active and this may be a contributory factor in the genesis of stones, since crystals may be "trapped" by gravity in upward-draining collecting tubules or in the inferior calices of the kidney.

In some instances, an increased risk of stone formation may be associated with a high environmental temperature at work and its effect on urinary volume. This might explain the higher incidence of stones noted amongs stokers and cooks as compared with ordinary seamen in the Royal Navy [5]. The only specific occupational factors thus far reported that appear to increase the risk of stones development are those kown to result in renal damage, such as chronic beryllium or cadmium poisoning [37]. Often the cause is a secondary tubular acidosis.

Diet

Numerous dietary factors have been suggested to have an adverse effect on the incidence of calcium stone formation. These include a high intake of dairy produce, oxalate, vitamin C (assorbic acid), refined carbohydrate, fat, purine and protein (particularly that of animal origin) and a low intake of fibre or vitamin B_6. Such has been the confusion, however, that in several instances the suggested dietary risk factors have been complete opposites. For example, both hard and soft water have been implicated as being risk factors for stone development, as have both a high and a low intake of salt.

A few studies have compared the dietary intake of various nutrients in calcium stone formers with that in controls without reaching a consensus. Broadly, these can be divided into studies in which the controls were matched for age, sex and socio-economic background with the stone-formers [10, 19] and those in which, although the two groups were matched for age and sex, no attempt was made to match them for level of affluence [30]. The studies in which controls were matched for socio-economic background generally failed to find any consistent difference between the diet of stone-formers and that of normals, whereas the unmatched studies revealed several significant differences [25].

None of the studies, either matched or unmatched, found any major differences in the intake of calcium, phosphorus, refined carbohydrates (sugars) or vitamin B_6 between patients and controls. In one of three matched studies, dietary fibre was reported to be lower in stone-formers than in controls; in one of four studies, dietary fat was lower in stone-formers; and ascorbic acid intake was higher in one study but lower in another. Most of these differences were significant only at the 5% level. In the unmatched studies, in contrast, total protein intake was markedly higher in stone-formers than in controls in all of the studies in which it was determined. This difference was almost entirely attributable to a higher intake of animal protein, which, in turn, was accounted for by an increased consumption of flesh protein (i.e. meat, fish and poultry). There was no difference between the two groups in terms of the intake of dairy produce (i.e. milk products, eggs and cheese) or vegetable protein. The higher meat consumption of stone-formers was accompanied by a higher consumption of purine and a lower intake of fibre [24]. In one study, oxalate intake was also significantly higher in idiopathic stone-formers than in normals but was not high enough to account for all cases of mild hyperoxaluria observed in the patient group.

Animal-protein intake. From data obtained at several demographic levels, it would appear that a high-protein diet, particularly with respect to its animal-protein moeity, is an aggravating factor in the formation of calcium stones. There are no such strong correlations between stone formation and dietary calcium (other than at a very low intake) or with the intake of fat, refined carbohydrates or alcohol, nor is there an apparent relationship between stone formation and the intake of vegetable protein. However, there is a weak, inverse relationship between the occurrence of stones and the consumption of "dietary fibre", but this is less significant than that reported for animal-protein intake [24]. As mentioned above, stone-formers appeared to ingest more animal protein than did normal subjects in studies in which controls were not matched for socio-economic background.

Biochemically, a high-animal-protein diet increases the urinary excretion of calcium, oxalate, and uric acid and simultaneously reduces urinary pH and the excretion of citrate [29]. These changes markedly increase the risk of forming calcium oxalate and uric acid stones. Indeed, a strong relationship has been shown between temporal

Table 2. Biochemical effects of a high-meat-protein diet

Urinary factor	Possible mechanism of change
↓pH	↑Acid ash diet
↑Calcium	↑Acid load → ↓tubular reabsorption of calcium → ↑bone resorption or ↑calcium absorption stimulated by ↑methionine (?) or ↑lysine (?)
↑Oxalate	↑Calcium absorption → ↑oxalate absorption or ↑metabolic production from ↑glycine, ↑phenylalanine, ↑tyrosine, ↑tryptophan, ↑hydroxyproline, ↑purine, ↑fat
↑Uric acid	↑Purine
↓Citrate	↑Acid load → ↓renal formation of citrate

Table 3. Dietary factors that influence the risk of calcium stone formation in the urinary tract

Dietary factor	Effect on urinary risk factors	
	Adverse	Beneficial
↑Calcium	↑Calcium	↓Oxalate
↑Oxalate	↑Oxalate	–
↑Phosphorus	↑Phosphate	↓Calcium, ↑Pyrophosphate
↓Magnesium	↓Magnesium	–
↓Vitamin B_6	? ↑Oxalate	–
↑Vitamin C	? ↑Oxalate	–
↑Refined carbohydrate	↑Calcium	–
	? ↑Oxalate	–
↓Fibre	↑Calcium	–
↑Animal protein	↑Calcium	↓pH[2]
	↑Oxalate	–
	↓Citrate	–
↑Purine	↑Uric acid	–
	? ↑Oxalate	–
↑Fat	? ↑Oxalate	–
↑Sodium	↑Calcium	–

[a] May have an adverse effect on the risk of forming uric acid stones

changes in the incidence of both of these types of stone and the consumption of animal protein in the United Kingdom over a 20-year period.

Conversely, a low-meat diet such as that consumed by vegetarians decreases the biochemical risk of stone development and is associated with a lower prevalence of the disorder in this section of the population [30, 31]. There appears to be a qualitative difference between protein of animal vs vegetable origin that influences the composition of urine. For instance, a diet high in flesh protein is known to form an acid ash on chemical analysis, owing to its relatively high content of sulphur-containing amino acids, whereas a vegetarian diet is generally alkaline-ash, and this may affect the absorption and urinary excretion of calcium. Furthermore, meat protein tends to contain more of the amino acids that are partially metabolised to oxalate, such as tyrosine, tryptophan, phenylalanine and hydroxyproline, and this may increase the endogenous production and urinary excretion of oxalate. A summary of the biochemical effects of such a diet is shown in Table 2.

The biochemical changes produced by a high-animal-protein diet may be seen to varying degrees across the population as a whole and may account for some of the increase in the prevalence of stone formation. In addition, if a small proportion of the population is "more metabolically sensitive" to this particular dietary stimulus [2], these individuals may be pushed further into the high-risk region of one or more of the main urinary risk factors and may be put at even greater danger of developing stones [27].

Oxalate/calcium ratio. Mild hyperoxaluria is much more important than hypercalciuria for the generation of abnormal crystals and agglomerates of calcium oxalate in vitro and in urine and is the most important risk factor (next to a low urinary volume) for calcium oxalate stone formation [26]. However, it is not clear to what extent a high dietary intake of oxalate contributes to the mild hyperoxaluria observed in stone-formers. They appear to ingest more oxalate than normal subjects, but the difference in intake (ca. 0.5 mmol/day) is not likely to be enough to account for their higher oxalate excretion. The relationship between urinary and dietary oxalate is relatively flat up to an intake of 2 mmol/day; thus, the amount of additionally absorbed oxalate is maximally only about 0.05 mmol/day (assuming that 10% of the additional oxalate is absorbed), a quantity that is insufficient to account for the mild hyperoxaluria observed in stone-formers. Only at intakes above 2 mmol/day (following the ingestion of foodstuffs containing high amounts of oxalate, such as rhubarb, spinach, chocolate and certain types of nuts) does urinary oxalate increase rapidly in relation to intake. It must be emphasised, however, that this threshold figure may be reduced if the daily intake of calcium is <20 mmol/day. This seems to be the situation in the Arabian Peninsula, where the oxalate/calcium ration of the diet is considerably higher than that in the West as the result of both a higher intake of oxalate *and* a lower intake of calcium [33], leading to the occurrence of mild hyperoxaluria in $>65\%$ of the population.

At all levels of intake (except fasting), stone-formers all over the world have significantly higher urinary oxalate than normals, suggesting either that they absorb more oxalate from a given diet or that they ingest more oxalate-producing nutrients (such as proteins, ascorbic acid and, perhaps, purines). Alternatively, they may metabolise a greater proportion of these oxalate precursors than do normal subjects. The stone-forming population could possibly includes all three subgroups.

Other dietary factors. Although the main dietary factors that increase the incidence of stone disease appear to be a

Table 4. Summary of risk factors for calcium stone formation

Pre-urinary risk factors	Main urinary risk factors
Age and sex	↑Calcium, ↑oxalate, ↑uric acid, ↑pH, ↓volume, ↓inhibitors, ↑promoters
Climate and season	↓Volume, ↑calcium, ↑oxalate
Stress	↑Calcium, ↑oxalate, ↑uric acid, ↓magnesium
Fluid intake	↓Volume
Affluence and diet	↑Calcium, ↑oxalate, ↑uric acid, ↓pH, ↓citrate
Metabolic disorders:	
Primary hyperparathyroidism	↑↑Calcium, ↑pH, ↑oxalate
Renal tubular acidosis	↑ pH, ↑calcium
Hereditary hyperoxaluria	↑↑Oxalate
Enteric hyperoxaluria	↑ Oxalate, ↓citrate, ↓volume, ↓ magnesium
Medullary sponge kidney	↑ Calcium
Cushing's disease	↑ Calcium, ↑pH
Vitamin D intoxication	↑↑Calcium
Milk-alkali syndrome	↑ Calcium, ↑pH
Immobilisation	↑ Calcium, ↑pH (from infection)

high-animal-protein intake and a high oxalate/calcium ratio, other factors may play a small role in some individuals who are more metabolically sensitive to these stimuli. A comprehensive list of the various dietary factors involved and their biochemical effects on urinary composition are shown in Table 3.

Conclusion

A summary of the epidemiological risk factors for calcium stone formation is shown in Table. 4. At present, the data would seem to support the hypothesis that calcium stone disease is a multi-factorial disorder for which no single underlying metabolic or environmental factor is uniquely responsible. That is not to say that certain epidemiological factors are unimportant in the genesis of stones; rather they must be seen as aggravating factors that influence the probability of stone disease within the population by altering urinary composition in such a way as to increase the risk of abnormal crystalluria. It can be shown that increasing the mean value of one of the urinary risk factors in the population by only 10% may almost double the number of people in the upper tail of that distribution, in which the risk of stone formation is considerably greater. In addition, if a small percentage of the population is more metabolically sensitive to the stimulus responsible for the increase in the risk factor concerned, these individuals will show an exaggerated response to it, and this may more than double the number of people at high risk of developing stones. Examples of such aggravating factors include a high-animal protein and low-fibre diet, a high oxalate/calcium ratio in the diet, a hot climate, increased exposure to ultraviolet light, and certain metabolic disorders such as primary hyperparathyroidism, renal tubular acidosis and hereditary and enteric hyperoxaluria. This has been summarised by Robertson [22] in a general risk-factor model of calcium stone formation.

References

1. Abdel-Halim RE, Al-Hadramy MS, Hussein M, Baghlaf AO, Sibbai AA, Noorwali AW, Al-Waseef A, Abdel-Wahab S (1989) The prevalence of urolithiasis in the western region of Saudi Arabia: a population study. In: Walker VR, Sutton RAL, Cameron ECB, Pak CYC, Robertson WG (eds) Urolithiasis. Plenum, New York, p 711
2. Arora B, Selby PL, Norman RW, Peacock M, Robertson WG (1985) The effects of an increased intake of various constituents of a high animal protein diet on the risk of calcium stone-formation. In: Schwille PO, Smith LH, Robertson WG, Vahlensieck W (eds) Urolithiasis and related clinical research. Plenum, New York, p 85
3. Bateson EM (1973) Renal tract calculi and climate. Med J Aust 2:111
4. Bear JC, Churchill DN, Morgan J, Marshall WH, Gault MH (1984) HLA and urolithiasis. Tissue Antigens 23:181
5. Blacklock NJ (1969) The pattern of urolithiasis in the Royal Navy. In: Hodgkinson A, Nordin BEC (eds) Proceedings of the renal stone research symposium. Churchill, London, p 33
6. Blacklock NJ (1979) Epidemiology of renal lithiasis. In: Wickham JEA (ed) Urinary calculous disease. Churchill Livingstone, Edinburgh, p 21
7. Brundig P, Berg W, Schneider HJ (1981) Stress und Harnsteinbildungsrisiko: I. Der Einfluss von Stress auf lithogene Harnsubstanzen. Urol Int 36:199
8. Esho JO (1978) The rarity of urinary calculus in Nigeria. Trop Geogr Med 30:477
9. Fujita K (1979) Weather and the incidence of urinary stone colic. J Urol 121:318
10. Griffith HM, O'Shea B, Kevany JP, McCormick JS (1981) A control study of dietary factors in renal stone-formation. Br J Urol 53:416
11. Hallson PC, Kasidas GP, Rose GA (1977) Seasonal variations in urinary excretion of calcium and oxalate in normal subjects and in patients with idiopathic hypercalciuria. Br J Urol 49:1
12. Husain I, Badsha SA, Al-Ali IH, Walton M, Saheb A, Jafree S (1979) A survey of urinary stone disease in Abu Dhabi. Emirates Med J 1 [Suppl]:17
13. Ljunghall S (1979) Family history of renal stones in a population study of stone-formers and healthy subjects. Br J Urol 51:249
14. Ljunghall S, Danielson BG, Fellström G, Holmgren K, Johansson G, Wikström B (1985) Family history of renal stones in recurrent stone patients. Br J Urol 57:370
15. Mason JC, Miles BJ, Belville WD (1985) Urolithiasis and race: another viewpoint. J Urol 134:501
16. Mbonu O, Attah C, Ikeakor I (1984) Urolithiasis in an African population. Int Urol Nephrol 16:291
17. Modlin M (1967) The aetiology of renal stone. Ann R Coll Surg Engl 40:155
18. Parry ES, Lister IS (1975) Sunlight and hypercalciuria. Lancet I:1063
19. Power C, Barker DJP, Nelson M, Winter PD (1984) Diet and renal stones: a case-control study. Br J Urol 56:456
20. Prince CL, Scardino PL (1960) A statistical analysis of ureteral calculi. J Urol 83:561
21. Prince CL, Scardino PL, Wolan CT (1956) The effect of temperature, humidity, and dehydration on the formation of renal calculi. J Urol 75:209
22. Robertson WG (1984) Urinary tract calculi. In: Nordin BEC (ed) Metabolic bone and stone disease, 2nd edn. Churchill Livingstone, Edinburgh, p 271

23. Robertson WG (1985) Epidemiology of stone disease. In: Whitfield HN, Hendry WF (eds) Textbook of genito-urinary surgery. Churchill Livingstone, Edinburgh, p 603
24. Robertson WG (1985) Dietary factors important in calcium stone formation. In: Schwille PO, Smith LH, Robertson WG Vahlensieck W (eds) Urolithiasis and related clinical research. Plenum, New York, p 61
25. Robertson WG (1987) Diet and calcium stones. Miner Electrolyte Metab 13:228
26. Robertson WG, Peacock M (1980) The cause of idiopathic calcium stone disease: hypercalciuria or hyperoxaluria? Nephron 26:105
27. Robertson WG, Peacock M (1985) Are primary calcium stone-formers abnormal? In: Di Paolo N, Sasdelli M, Sodi A (eds) Litiasi renale. Wichtig Editore, Milan, p 21
28. Robertson WG, Peacock M, Marshall RW, Speed R, Nordin BEC (1975) Seasonal variations in the composition of urine in relation to calcium stone-formation. Clin Sci Mol Med 49:597
29. Robertson WG, Heyburn PJ, Peacock M, Hanes FA, Swaminathan R (1979) The effect of high animal protein intake on the risk of calcium stone-formation in the urinary tract. Clin Sci 57:285
30. Robertson WG, Peacock M, Heyburn PH, Hanes F, Rutherford A, Clementson E, Swaminathan R, Clark P (1979) Should recurrent calcium oxalate stone-formers become vegetarians? Br J Urol 51:427
31. Robertson WG, Peacock M, Marshall DH (1982) Prevalence of urinary stone disease in vegetarians. Eur Urol 8:334
32. Robertson WG, Peacock M, Baker M, Marshall DH, Pearlman B, Speed R, Sergeant V, Smith A (1983) Studies on the prevalence and epidemiology of urinary stone disease in men in Leeds. Br J Urol 55:595
33. Robertson WG, Nisa M, Husain I, Al-Faqih S, Chakrabarty A, Qunibi W, Taher S, Hughes H, Barkworth SA, Holbrow G, Louis S (1989) The importance of diet in the aetiology of primary calcium and uric acid stone-formation – the Arabian experience. In: Walker VR, Sutton RAL, Cameron ECB, Pak CYC, Robertson WG (eds) Urolithiasis. Plenum, New York, p 735
34. Säfwenberg J, Backman U, Danielson BG, Johansson G, Ljunghall S (1978) HLA and kidney stone disease. Scand J Urol Nephrol 12:151
35. Schneider H-J, Hienzsch E (1979) Epidemiologie der Urolithiasis. In: Proceedings of the XVIII Congress of the International Society of Urology, vol. 1. Joly, Paris, p 87
36. Scott R (1971) The incidence of renal colic in the medical profession in the West of Scotland. Health Bull (Edinb) 29:27
37. Scott R, Fitzgerald-Finch OP, Cunningham C, Ottoway JM, Fell GS (1981) The importance of chronic cadmium poisoning in renal stone-formation–a five year study. In: Smith LH, Robertson WG, Finlayson B (eds) Urolithiasis – clinical and basic research. Plenum, New York, p 353
38. Shuster J, Finlayson B, Scheaffer R, Sierakowski R, Zoltek J, Dzegede S (1982) Water hardness and urinary stone disease. J Urol 128:422
39. White RW, Cohen RB, Vince FP, Williams G, Blandy J, Tresidder GC (1969) Minerals in the urine of stone-formers and their spouses. In: Hodgkinson A, Nordin BEC (eds) Proceedings of the renal stone research symposium. Churchill, London, p 289

W. G. Robertson, PhD, DSc
King Faisal Specialist Hospital and Research Centre
Department of Biological and Medical Research
P.O. Box 3354
Riyadh 11211
Kingdom of Saudi Arabia