Scand J Urol Nephrol 27: 155–162, 1993

IONIC ASSOCIATIONS WITHIN 460 NON-INFECTION URINARY STONES

A Quantitative Chemical Analytical Study Applying a New Classification

R. E. Abdel-Halim,[1] A. Al-Sibaai[2] and A. O. Baghlaf[2]

From the Departments of [1]Urology and [2]Chemistry, King Abdel-Aziz University, Jeddah, Saudi Arabia

(Submitted September 10, 1991. Accepted for publication March 10, 1992)

Scand J Urol Nephrol Downloaded from informahealthcare.com by Moorfields Eye Hospital on 07/14/10
For personal use only.

Abstract. In addition to standard quantitative wet chemical and inductively coupled plasma atomic-emission spectrometric stone analytic techniques, elemental analysis for the determination of nitrogen, carbon and hydrogen was utilized in this study of 460 category I (non-infection) urinary stone samples from western Saudi Arabia. They were classified according to the percentage composition of detected ions, including trace or minimum amounts. The incidence of uric acid stones (24%) is higher than that reported from western countries but similar to those reported from eastern Europe and other parts of the middle east and most are in the group with the highest uric acid content (UrI4). Oxalate stones are the most common type (61%) and phosphate stones (15%) the least common. The results confirm the reliability of elemental microanalysis and support its use for the quick identification of stones especially those that weigh <1 mg and are too small for wet chemical analysis. Within the various stone types, however, the ionic associations shown by wet chemical analysis denoted the presence of mutual indirect associations between the characterising ion oxalate and both uric acid and phosphate ions, but no association between the characterizing ion uric acid and phosphate ions. Factors that affect these ionic correlations may influence the processes of stone initiation and type of stone formed.

Key words: urinary stones, non-infection stones, stone analysis, elemental microanalysis, percent ionic composition, classification, inter-ionic associations, stone formation, type of stone, geographical variations, Saudi Arabia.

Quantitative chemical analysis of the urinary stones has been preferred by many investigators (12, 14, 16, 17, 18, 23, 33, 34) and particularly important are the microanalytic techniques that can be used for stones that weigh less than 5 mg (22, 44).

Almost all these investigators apply calculations, based on certain assumptions, to the findings of their chemical analysis to arrive at estimates of the composition for compounds. Accordingly, several classifications of urinary stones have been suggested (14, 40, 41, 42, 43, 45), but it is difficult to compare them as the chemical analysis results are presented differently (28).

We have proposed a different scheme for the classification of urinary stones (4), which is based only on the percentage composition of detected ions without the need for such cumbersome calculations which introduce an element of uncertainty (28). In addition, our classification includes specification and consideration of both the trace and minimum amounts of ions present.

We report the application of our classification system to 460 urinary stone samples from patients in the western region of Saudi Arabia.

MATERIAL AND METHODS

Analytical methods

A total of 540 stone samples were coded and prepared. Those that weighed more than 60 mg ($n=451$) were subjected to wet chemical analysis to measure the oxalate (46) and phosphate (6) in a sulphuric acid digest and urates and xanthine in a lithium carbonate digest (12).

In all 540 samples we performed elemental microanalysis to measure total concentrations of carbon, nitrogen and hydrogen, using tungsten trioxide to help combustion, in addition to standard methods (5, 8, 9, 47). Calcium and magnesium were measured by inductively coupled plasma atomic-emission spectrometry.

RIGHTSLINK

Table I. *Identification of the three urinary stone types by the percentage of their characterising ions and further classification into groups by the percentage of particular ions*

Type of stone	Characterising ion and its percentage composition		Stone group	Indicating ion and its percentage composition	
Uric acid stones (Ur)	Uric acid	⩾20	UrI1	Oxalate	<40–>33
			UrI2	Oxalate	33–>21
			UrI3	Oxalate	21–10
			UrI4	Oxalate	<10
Oxalate stones (Ox)	Oxalate	⩾40	OxI1	Uric acid	<20
			OxI2	Phosphate	<20
			OxI3	Uric acid & phosphate	<20 each
Phosphate stones (Ph)	Phosphate	⩾10 &	PhI1	Oxalate	<40–10
	Uric acid	<20 &	PhI2	Oxalate	<10
	Oxalate	<40			

Details of the classification scheme

The three types of urinary calculi were identified by the percentage composition of their characterising ions (Table I). The stone was designated a uric acid stone, therefore, when the uric acid radical was 20% or more. Though a stone was designated an oxalate stone when the oxalate radical was 40% or more the amount of phosphate radical required to designate a stone as phosphate stone was 10% or more with uric acid or oxalate being less than 20% or less than 40%, respectively.

The two main categories of stones; non-infection stones (Category I) and infection stones (Category II), were differentiated by the percentage of magnesium (Table II). Unlike category I stones, category II contain 3% of magnesium or more.

In category I stones, the characterising ion of one type, at a different percentage, was the indicating ion for the subgrouping of another type (Table I). Accordingly, category I uric acid stones, which always contained trace amounts of phosphate radical (less than 2%) and variable amounts of oxalate (up to 39%), were further divided into four groups (UrI1, UrI2, UrI3, UrI4) according to the percentage of oxalate radical that was present (Table I).

Category I oxalate stones always contained other radicals in addition to oxalate (uric acid or phosphate or both). So we further divided oxalate stones into three groups (Table I) according to whether they contained uric acid (OxI1) or phosphate (OxI2), or both (OxI3). The amount of uric acid or phosphate was always less than 20% in all three groups.

Category I phosphate stones contained up to a minimum amount (2–10%) of uric acid and variable amounts of oxalate radicle so the phosphate stones were divided into two groups (PhI1 and PhI2) according to the percentage of oxalate radical that was present (Table I).

Quick identification of the three types of urinary calculi could also be made from measurements of the percentages of total organic nitrogen, carbon and hydrogen in the stones. The percentage of nitrogen differentiates the uric acid stones from both the oxalate and phosphate stones (Table III). Furthermore, the percentage of carbon differentiates the oxalate from the phosphate stones. Meanwhile, in the oxalate stones, the percentage of hydrogen may differentiate oxalate monohydrate stones from the dihydrate or mixed mono and dihydrate oxalate stones (Table III).

Samples were labelled according to this classification, using an abbreviation to refer to their type (Ur for uric acid, Ox for oxalate or Ph for phosphate), followed by a Roman numeral to indicate their category (I, the non-infection or II, the infection stone) and then an Arabic numeral to indicate the group (four groups in the uric acid, three in the oxalate and two in phosphate types). For example, UrI1 denotes a group 1 uric acid stone sample of the non-infection category (category I).

RESULTS

In this series we are presenting only the results for the 460 category I stone samples. The identi-

Table II. *Differentiation of category I (the non-infection stones) from category II (the infection stones) by the percentage of magnesium*

Category	Definition	Percentage of magnesium
1. Category I	Non-infection stones	<3
2. Category II	Infection stones	⩾3

Scand J Urol Nephrol Downloaded from informahealthcare.com by Moorfields Eye Hospital on 07/14/10
For personal use only.

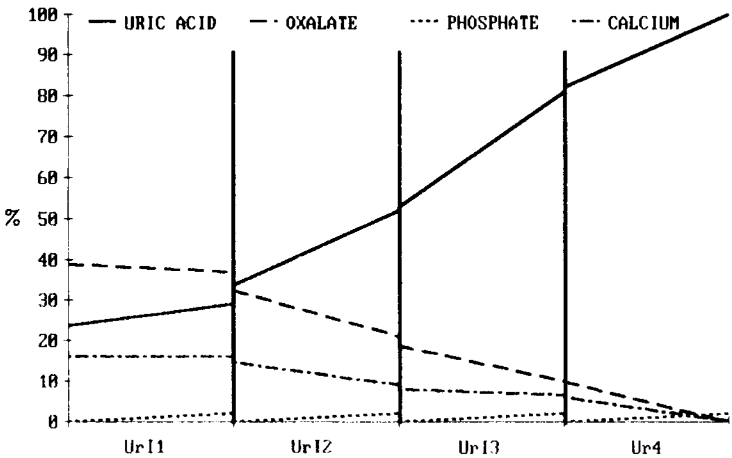

Fig. 1. Percentage composition of uric acid, oxalate, phosphate and calcium ions in the four urate stone groups (UrI1, UrI2, UrI3 and UrI4).

fication of the various types or groups was both easy and precise. Correlations with current observations about stone composition were possible and some ionic association within the various types were obvious.

The uric acid stones

One hundred and eight of the samples (24%) were uric acid stones (Table IV). Their classification into four groups by both the wet chemical and elemental micro-analytical studies is shown in Table V.

The results of the wet chemical analysis in the four groups of uric acid stones showed that the amount of oxalate directly associated with the amount of calcium and indirectly with the amount of uric acid (Fig. 1). The uric acid content is indirectly associated with either the oxalate or calcium content but not with the phosphate content (Fig. 1).

The results of elemental microanalysis of category I uric acid stones (Table V) confirms their classification into four groups by the wet chemical analysis. Each group had a definite range of percentages of total organic carbon or nitrogen, and the results showed a direct association between the uric acid content and the total carbon or nitrogen content (Fig. 2).

The Oxalate stones

Oxalate stones were the most common (61% of the total, Table IV) and their chemical compo-

Table III. *Identification of the three types of urinary stone by the percentage of nitrogen and carbon, and differentiation, in the oxalate stones, between the monohydrous and dihydrous forms by hydrogen content*

Type of stone	Nitrogen	Carbon	Hydrogen
Uric acid stones (Ur)	≥8	≥22	<3
Oxalate stones (Ox)	<8	17–<26	<2 (monohydrate) ≥2 (dihydrate & mixture of both forms)
Phosphate stones (Ph)	<8	<12.8	<3

Table IV. *Relative percentage incidence of category I stone types and groups in 460 stone samples*

Type of stone	Incidence No. (%)	Group	Incidence No. (%)
Uric acid stones	108 (24)	UrI1	5 (5)
		UrI2	14 (13)
		UrI3	17 (16)
		UrI4	72 (67)
Oxalate stones	281 (61)	OxI1	22 (8)
		OxI2	24 (9)
		OxI3	235 (84)
Phosphate stones	71 (15)	PhI1	47 (66)
		PhI2	24 (34)

Scand J Urol Nephrol Downloaded from informahealthcare.com by Moorfields Eye Hospital on 07/14/10
For personal use only.
RIGHTSLINK

Table V. *Percentage of ions in 108 category I uric acid stone samples*

Constituents	UrI1	UrI2	UrI3	UrI4
Oxalate	38.8–36.8	32.4–21.0	18.7–10.0	9.9–0
Uric acid	23.7–29.1	33.6–51.8	52.6–80.8	81.9–100
Phosphate	0–2.0	0–2.0	0–2.0	0–2.0
Calcium	16.0	14.5–9.1	7.8–6.5	5.9–0.1
Magnesium	0–0.5	0–0.5	0–0.5	0–0.5
Nitrogen	0.2–10.7	14.3–21.5	21.7–27.2	28.5–33.3
Carbon	22.3–22.5	23.7–27.3	28.1–30.9	31.2–35.8
Hydrogen	2.0–2.3	2.2–2.9	2.3–2.9	2.3–2.9

Scand J Urol Nephrol Downloaded from informahealthcare.com by Moorfields Eye Hospital on 07/14/10
For personal use only.

sition and subclassification is shown in Table VI.

Wet chemical analysis in the oxalate stones showed that the oxalate radical is indirectly associated with the uric acid or phosphate radicals present. Meanwhile, its direct association with the calcium radical (described in the uric acid stones), was best comfirmed in group 1 oxalate stones (OxI1).

The results of elemental microanalysis showed that the highest ranges for the percentage of nitrogen (more than 1 %) or carbon (more than 19%), were in groups 1 and 3 of the oxalate stones (OxI1, OxI3) which contained variable amounts (less than 20%) of uric acid (Fig. 3), confirming the previously mentioned direct association between uric acid and both nitrogen and carbon.

The phosphate stones

Phosphate stones were the least common (15%, Tables IV and VII). Wet chemical analysis showed a higher percentage of phosphate in group PhI2 than group PhI1, confirming the indirect association between phosphate and oxalate radicals (Fig. 4). The calcium content in the two groups (PhI1 and PhI2) was within the same range indicating its direct association with both ions (Fig. 4).

Elemental microanalysis showed that high percentages of carbon (more than 9%) were present in group PhI1 phosphate, which also contained a higher percentage of oxalate indicating a direct association between the oxalate and carbon content (Fig. 5). This was not obvious in either the uric acid or the oxalate (OxI1, OxI3) stones, because of the presence of uric acid, as its content of carbon is much higher than that of the oxalate.

DISCUSSION

The percentage incidence of uric acid stones is much higher than that (2–12%) reported from western countries (7, 11, 14, 15, 26, 33, 34, 35, 36, 37, 43) but is similar to previous reports about urolithiasis in Saudi Arabia (1, 2, 17, 25), Kuwait, Central Europe and Israel (39), Turkey (38), Jordan (10), Sudan (19) and Iraq (3). The percentage incidence of group UrI1 (the highest

Table VI. *Percentage of ions in 281 category I oxalate stone samples*

Constituents	OxI1	OxI2	OxI3
Oxalate	45.6–55.42	42.37–52.5	40.87–60.54
Uric acid	0.05–10.92	0	0.01–17.23
Phosphate	0	3.6 –10.9	0.10–16.20
Calcium	19.2–26.48	22.85–26.78	16.54–29.85
Magnesium	0.01–0.92	0.01–0.92	0.01–0.92
Nitrogen	0.22–5.11	0.21–0.56	0.22–7.68
Carbon	15.3–21.48	13.2–16.06	12.8–25.54
Hydrogen	1.67–2.35	1.56–2.2	1.34–2.88

RIGHTSLINK

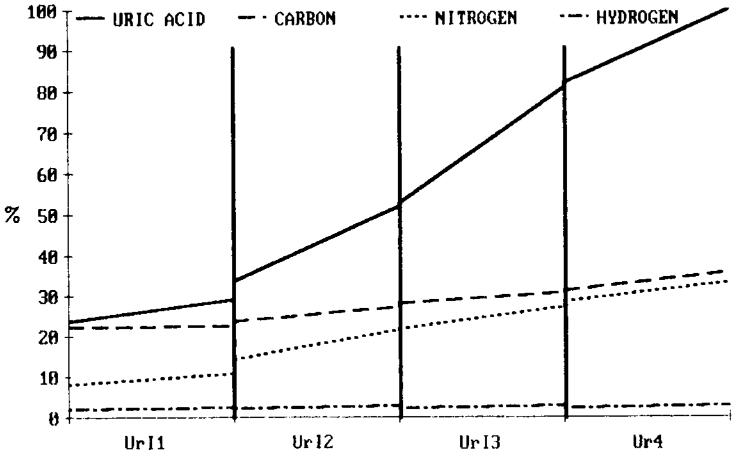

Fig. 2. Percentage composition of carbon, nitrogen, hydrogen and uric acid ions in the four uric acid stone groups.

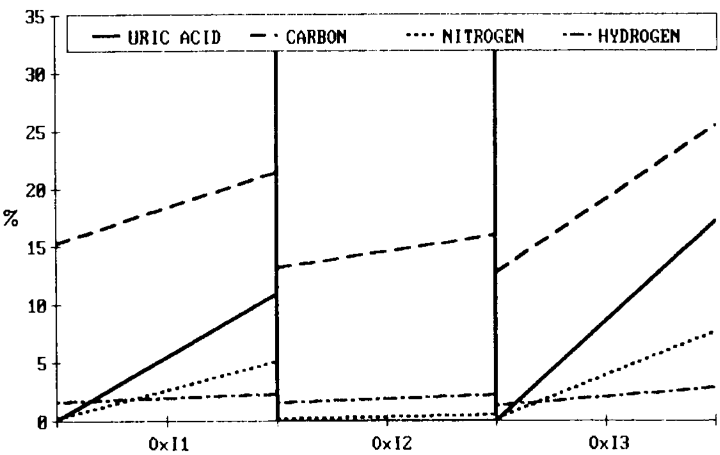

Fig. 3. Percentage composition of carbon, nitrogen, hydrogen and uric acid ions in the three oxalate stone groups (OxI1, OxI2 and OxI3).

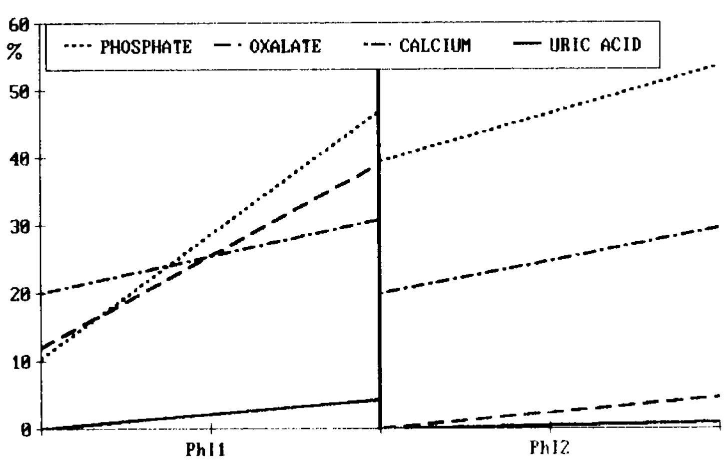

Fig. 4. Percentage composition of uric acid, oxalate, phosphate and calcium ions in the two phosphate stone groups (PhI1 and PhI2).

Scand J Urol Nephrol Downloaded from informahealthcare.com by Moorfields Eye Hospital on 07/14/10
For personal use only.

RIGHTSLINK

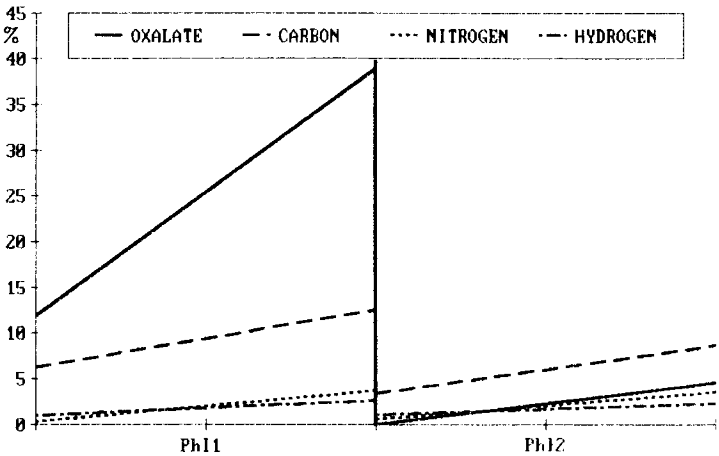

Fig. 5. Percentage composition of carbon, nitrogen, hydrogen and oxalate ions in the two phosphate stone groups.

oxalate content) is close to that reported by Fuss et al. (14), while group UrI4 (the purest form of uric acid stones as they contained trace or no oxalate or phosphate) is the most common in Saudi Arabia (Table IV).

Oxalate stones seem to be the most common type which is in agreement with western reports (14, 24, 26, 32, 38–42) as well as that in Sudan (20, 21) and with reports from Saudi Arabia (2, 25, 27).

The presence of some uric acid in the oxalate stones has previously been described (7, 14) and the amount of less than 20% is in agreement with the report of Prasongwatana et al. (29). The presence of a phosphate radical points to the calcium phosphate compound often described in calcium oxalate stones (11, 14, 19, 21, 31, 38–42).

In the present study, the oxalate stone with trace amount of uric acid (in group OxI1), phosphate (in group OxI2), or both (in group OxI3) was considered to be the purest form of oxalate stones.

The phosphate stones represent the least common type of category I (non-infection) stones. This is in agreement with previous reports from Saudi Arabia (2, 25, 27). Its relative percentage incidence (15.4) is less than that reported by Schmucki & Asper (36) and Esho (11) and this supports the findings of Westbury (45).

The relative percentage incidence of the phosphate stones group PhI1, which contains variable amounts of oxalate (less than 40%) is nearly double that of group PhI2 (Table IV): this is in agreement with the findings of Sutor & Wooley (38, 39) in industrialised countries.

Only Fuss et al. (14) reported the presence of some uric acid in the calcium phosphate stones. As there is no pure calcium phosphate stone (21) in the present study, we designated group PhI2 as the purest form of the non-infection phosphate stones, because it contained a trace of uric acid and a minimum amount of oxalate ions.

The various correlations shown by the results of elemental microanalysis (Fig. 6) confirm its reliability and support its use for quick identification of stones particularly those that weigh less than 1 mg, which are too small for wet chemical analysis.

Within the various stone types, the ionic relations shown by wet chemical analysis denote the presence of mutual indirect associations between the characterising ion oxalate, and the

Table VII. *Percentage of ions in 71 category I phosphate stone samples*

Constituents	PhI1	PhI2
Oxalate	11.9–38.89	0–4.60
Uric acid	0–0.26	0–0.77
Phosphate	10.26–46.75	39.40–53.50
Calcium	19.90–30.65	19.82–29.40
Magnesium	0.01–2.95	0.01–2.95
Nitrogen	0.33–3.76	0.54–3.51
Carbon	6.3–12.60	3.37–8.67
Hydrogen	0.99–2.63	1.03–2.20

Scand J Urol Nephrol Downloaded from informahealthcare.com by Moorfields Eye Hospital on 07/14/10
For personal use only.

RIGHTSLINK

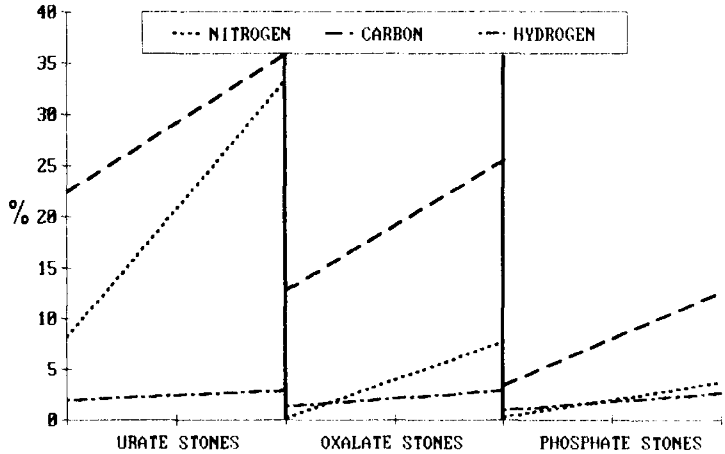

Fig. 6. Percentage composition of carbon, nitrogen and hydrogen ions in the three stone types.

uric acid and phosphate ions; there was, however, no association between the characterising ion uric acid and phosphate ions (Fig. 1). This suggests that the process of stone formation may be initiated by an association between the uric acid and oxalate rather than phosphate ions or between the oxalate and phosphate ions. Hence, the presence of up to 39% oxalate ions in group 1 uric acid stones, and presence of group 2 in the oxalate stones. To influence the type of stone that is formed, this association may be acted on by more than one external factor as denoted by the indirect relations between those ions within the stone.

ACKNOWLEDGEMENT

This work was supported by a grant from King Abdul-Aziz City for Science and Technology, Riyadh, Saudi Arabia.

REFERENCES

1. Abdel-Halim RE, Baghlaf AO, Farag AB. Clinical chemical study of urinary stones in Saudi Arabia. I—Uric Acid stones. In: Schwille PO, Smith, LH, Robertson, WG, Vahlensieck W (Eds.) Urolithiasis and related clinical research. London: Plenum press, N.Y., 1985: 715–718.
2. Abomelha MS, Abdullah AA, Arnold J. Urolithiasis in Saudi Arabia. Urology 1990; 35: 31–34.
3. Al-Naama LM, Luay SP, Baqir YA, Rasoul HA, Abdel-Khaddar M. The incidence and composition of urinary stones in Southern Iraq. Saudi Med J 1987; 8: 456.
4. Baghlaf AO, Al-Sibaai AA, Abdel-Halim RE, Al-Hadramy MS, Abdul-Wahab S, Noorwali AW, Al-Waseef A. Chemical composition of urinary stones in Jeddah: A study of 331 stones and a proposed new classification. In: Valerie R, Walker et al., eds. Urolithiasis, London, New York: Plenum Press, 1989: 713–714.
5. Belcher R, Fildes JE, Nutten AJ. The microdetermination of carbon and hydrogen in organic compounds containing phosphorus. Anal Chim Acta 1955; 13: 431.
6. Belcher R, Nutten AJ. Quantitative inorganic analysis. London: Butterworths, 1970.
7. Cifuentes JM, Pourmand G. Mineral composition of 103 stones from Iran. Br J Urol 1980; 55: 465–468.
8. Condon RD. A new automatic organic elemental microanalyzer. Microchem J 1966; 10: 408.
9. Culmo RF. Automatic microdetermination of carbon, hydrogen and nitrogen: Improved compustion train and handling technique. Mikrochim Acta 1969; 175.
10. Dajani AM, Björnesjö KB, Shehabi AA. Urinary stone disease in Jordan. In: Brockis JG, Finlayson B, eds. Urinary calculus. International Urinary Stone Conference. Littleton, Mass. PSG, 1991; 35–45.
11. Esho JO. Analysis of urinary calculi formed by Nigerians. Eur Urol 1978; 4: 288–291.
12. Farrington CJ, Liddy ML, Chalmers AC. A simplified sensitive method for the analysis of renal calculi. Am J Clin Pathol 1980; 73: 96–99.
13. Fernandez FJ, Kahn HL. Clinical methods for atomic absorption spectroscopy. Clin Chem Newsl 1971; 3: 34.
14. Fuss M, Simon J, Verbeelen D, Weiser M, Van landuyt P, Elskens J. Chemical analysis of renal stones from 377 Belgian patients by using qualitative or quantitative methods. Eur Urol 1978; 4: 90–93.
15. Herring LC. Observations on the analysis of ten thousand urinary calculi. J Urol 1962; 88: 545.
16. Hodgkinson A. A combined qualitative and quantitative procedure for the chemical analysis

Scand J Urol Nephrol Downloaded from informahealthcare.com by Moorfields Eye Hospital on 07/14/10
For personal use only.

of urinary calculi. J Clin Pathol 1971; 24: 147–151.
17. Hodgkinson A. Composition of urinary tract calculi from some developing countries. Urol Int 1979; 34: 26–35.
18. Hodgkinson A, Williams A. An improved calorimetric procedure for urinary oxalate. Clin Chem Acta 1972; 36: 127.
19. Ibrahim A, Zein M, Beleil O. Uric acid lithiasis in the Sudan. J Trop Med Hyg 1977; 80: 173–176.
20. Kambal A, Abdel-Wahab EM, Khattab AHH. Urolithiasis in the Sudanese; geographical distribution and the influence of climate. Trop Geogr Med 1979; 31: 75.
21. Kambal A, Abdel-Wahab EM, Khattab AHH. The composition of urinary stones in the Sudan, Br J Urol 1979; 51: 342–344.
22. Larsson L, Sorbo B, Tiselius HG, Ohman O. On the analysis of urinary calculi. In: Brockis JG, Finlayson B, eds. Urinary calculus. International Urinary Stone Conference. Littleton, Mass: PSG, 1981: 383–386.
23. Larsson L, Sorbo B, Tiselius HG, Öhman S. A method for quantitative wet chemical analysis of urinary calculi. Clin Chim Acta 1984; 140: 9–20.
24. Mesaric S, Radonic M, Tucak A. The pattern of urinary tract stone disease in Crotia. In: Valerie Walker R, Sutton RAI, Bert Cameron EC, Pak CYC, Robertson WG, eds. Urolithiasis. New York: Plenum Press, 1989: 701.
25. Mitry N, Taha S, Knudson M, Kader A, Kamal B. Urinary stone composition in the Eastern Province—Saudi Arabia. Proceedings, XXᵉ Congres de la Société Internationale Urologie, Ed. Jardon, A Et al., Paris, 1985: 221.
26. Murphy BT, Pyrah LN. The composition, structure and mechanisms of the formation of urinary calculi. Br J Urol 1962; 34: 129–159.
27. Narebor EM, Abo Haimed SA. Renal calculi in Saudi Arabia, Letter to the editor, Saudi Med J 1988; 9: 102–103.
28. Otnes B. Urinary stone analysis, methods, materials and value. Scand J Urol Nephrol 1983; Suppl 71.
29. Prasongwatana V, Striboonlue P, Suntarapa S. Urinary stone composition in North-East Thailand. Br J Urol 1983; 55: 353–355.
30. Prien EL. Crystallographic analysis of urinary calculi: A 23-year survey study. J Urol 1963; 89: 917.
31. Prien EL. The analysis of urinary calculi. Urol Clin North Am 1974; 1: 229–240.
32. Rao MVR, Agarwal JS, Taneja OP. Studies in urolithiasis. II. X-ray diffraction analysis of calculi from Delhi region. Indian J Med Res 1976; 64: 1.
33. Rose GA. Other metabolic causes of stones. In: Urinary stones, clinical and laboratory aspects. Lancaster: MTP Press, 1982: 233–255.
34. Rose GA. Stone analysis by wet chemistry. In: Urinary stones: Clinical and laboratory aspects. Lancaster, MTP Press, 1982: 67–75.
35. Royce PL, Fuchs GJ, Lupu AN, Chaussy CG. The treatment of uric acid calculi with extracorporeal shock wave lithotripsy. Br J Urol 1987; 60: 6–9.
36. Schmucki O, Asper R. Clinical significance of stone analysis. J Urol Int 1986; 41: 343–347.
37. Still BM. The composition and mode of formation of renal calculi. Proc Assoc Clin Bioch 1963; 2: 168.
38. Sutor DJ, Wooley SE. Composition of urinary calculi by X-ray diffraction: Collected data from various localities. Br J Urol 1971; 43: 268–272.
39. Sutor DJ, Wooley SE. Composition of urinary calculi by X-ray diffraction. Br J Urol 1972; 44: 287–291.
40. Sutor DJ, Wooley SE. Composition of urinary calculi by X-ray diffraction. Collected data from various localities. Parts XV–XVII. Br J Urol 1974; 46: 229–232.
41. Sutor DJ, Wooley SE, Illingworth JJ. Some aspects of the adult urinary stone problem in Great Britain and Northern Ireland. Br J Urol 1974; 46: 275–288.
42. Sutor DJ, Wooley SE, Illingworth JJ. A geographical and historical survey of the composition of urinary stones. Br J Urol 1974; 46: 393–407.
43. Takasaki E. An observation of the composition and recurrence of urinary calculi. Urol Int 1975; 30: 228.
44. Uldall A. A wet chemistry method for the analysis of urinary calculi. Scand J Clin Lab Invest 1983; 43: 727–733.
45. Westbury EJ. Some observations on the quantitative analysis of over 1 000 calculi. Br J Urol 1974; 46: 215.
46. Wooton JDP. Medical biochemistry, London: Churchill Livingstone, 1964.
47. Yeh CS. Rapid microdetermination of carbon and hydrogen. A new universal combustion tube filling. Microchem J 1963; 7: 303.

Scand J Urol Nephrol Downloaded from informahealthcare.com by Moorfields Eye Hospital on 07/14/10
For personal use only.