

The management of stone disease

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Introduction

Countries in the Afro-Asian stone belt (stretching from Egypt and Sudan, through the Middle East, India, Pakistan, Burma, Thailand, Indonesia and the Philippines) falling within the tropical and subtropical regions have consistently reported a high incidence of urolithiasis. Generally in this region the population density is high, the gross national product is low and 30–50% of the population live below the poverty line. Poor nutritional status and inadequate health facilities are common in the region. More than half the people live in rural areas and the climate is moderate to hot [1]. Against this background urolithiasis constitutes 40–50% of the urological workload in hospitals [2]. A specific problem of this region is the neglected asymptomatic large and/or staghorn calculi which present with renal failure [3,4].

The diagnostic and management facilities in the region show a wide spectrum in different countries, depending on their economic status. Most of the centres have minimal facilities for X-ray, ultrasonography, urine analysis and open surgery, the main procedure [5]. However, there are centres, mostly private, which are fully equipped with diagnostic methods, e.g. ultrasonography, IVU, CT, laboratories for metabolic studies and technology for minimally invasive surgery [6].

A survey of stone disease in the subcontinent by McCarrison in 1931 [7] showed a high incidence in the northern part, while south India had the lowest. The highest incidence was in the Sindh and Punjab provinces (now Pakistan). The Sindh Institute of Urology and Transplantation (SIUT) is the main tertiary care centre for the province of Sindh and in the last 30 years it has managed 18 490 patients with urolithiasis. At SIUT in the last three decades there have been changes in stone management, from the era of open surgery to the advent of minimally invasive procedures [2], an experience similar to that in developed countries [6,8]. This review describes our experience of stone management in this region. The approach has been to develop a management strategy which is practical and sustainable for the increasing number of stone-formers.

Epidemiology

The epidemiology of urolithiasis remains poorly investigated in the region. Incidence or prevalence rates are mostly based on hospital admissions. Countries of the region show wide variations in prevalence and the site of stone disease (Table 1) [4,9–16]. Bladder stones constitute 10–15% of the stone burden in adult and 15–30% in paediatric stone-formers [4,17]. Affluence in some of the countries of the region has increased the prevalence rates, with a reduction in the prevalence of bladder calculi, especially in children, where bladder stones have reduced from $\approx 50\%$ to $<20\%$ [17,18]. The stone burden remains high in males (M:F, 2:1) with peak ages in the third and fourth decade in most countries of the region [4].

Aetiology

The aetiology of stone formation in a given population is reflected in the composition of calculi, metabolic studies, and dietary habits. In the region, 60–65% of the patients form calcium oxalate, 15–30% uric acid and 10–15% struvite stones (Table 1). Ammonium hydrogen urate is found in $\approx 30\%$ of renal calculi in children and in 3% in adults. Bladder calculi in children are predominantly calcium oxalate, ammonium hydrogen urate and uric acid [17]. Metabolic studies from the region and data from SIUT (Table 2) show that the major risk factors are low urinary volume (20–30%), hyperuricosuria (20–60%), hyperoxaluria (50–60%), hypomagnesuria (20–30%) and hypocitraturia (30–40%). Hypercalciuria is encountered in 7–10% of the patients [19,20]. Most studies in stone-formers show normal blood calcium levels and hyperuricaemia in 10–20% cases [20]. These results suggest that dietary and environmental factors are more important in this region, as oxalate-rich and calcium-poor diets prevail with the low intake of proteins. Furthermore, chronic diarrhoea and malabsorption in the tropics could be a major causative factor for hyperoxaluria [21].

Diet constitutes a major component of the environmental factors for urolithiasis. In contrast to western

Table 1 Epidemiology and composition of renal calculi in selected countries

| Variable | Pakistan | India | Bangladesh | Thailand | Saudi Arabia | Japan |
|--------------------------------------|----------|---------|------------|----------|--------------|---------|
| Reference | [4,9] | [10,11] | [12] | [10,13] | [14] | [15,16] |
| Prevalence rate, % | 12 | 15 | 4 | 10 | 20 | 7 |
| Bladder stone (% of stone burden) | 10 | 15 | 20 | 17 | 3 | 0.3 |
| Composition, % | | | | | | |
| Calcium oxalate | 65 | 74 | 87 | 69 | 66 | 88 |
| Uric acid and urate | 20 | 3 | 1 | 6 | 20 | 8 |
| Struvite | 12 | 22 | 9 | 12 | 2 | 3 |
| Others | 1 | 1 | 3 | 13 | 12 | 1 |

Table 2 Metabolic studies in adult stone-formers and controls at SIUT

| Variable | Stone-formers (376), n (%) | Controls, n (%) | P (chi-square) |
|---------------------------------|----------------------------|-----------------|----------------|
| Number of patients | 376 | 168 | |
| Urine | | | |
| Urinary volume, <1000 mL/24 h | 76 (20) | 28 (16) | NS |
| Hypercalcaemia, >250 mg/24 h | 30 (8) | 8 (4.7) | NS |
| Hyperuricosuria, >700 mg/24 h | 38 (10) | 0 | <0.001 |
| Hyperoxaluria, >40 mg/24 h | 195 (51.8) | 38 (22) | <0.001 |
| Hyperphosphaturia, >800 mg/24 h | 45 (11.9) | 16 (9.5) | NS |
| Urinary sodium, >200 mmol/24 h | 45 (11.9) | 0 | <0.001 |
| Hypocitraturia, <300 mg/24 h | 214 (57) | 60 (35) | <0.001 |
| Hypomagnesuria, <60 mg/24 h | 126 (33.7) | 8 (4.7) | <0.001 |
| Normal | 48 (12.7) | 98 (58) | <0.001 |
| Blood | | | |
| Hypercalcaemia, >10.5 | 7.4 | 5.0 | NS |
| Hyperuricaemia, >6.5 | 12.9 | 0 | <0.001 |
| Hypokalaemia, K <3.5 | 35.0 | 5.0 | <0.001 |

countries, where a high calcium and protein diet are major risk factors, in developing countries dietary deficiencies play an important role [2]. Dietary habits show wide variations between countries [22]. In Pakistan and India, and in data from SIUT (Table 3) on dietary studies, there is a low protein and calcium diet with an increased consumption of oxalate-rich foods and a low intake of fluids [20].

Patient evaluation

The advent of minimally invasive techniques for treating urinary stones has shifted the focus away from patient evaluation. However, reported recurrence rates of 50% have re-emphasized the importance of identifying causal factors and developing preventive strategies [23]. That an appropriate focused evaluation can identify a cause in 97% of the patients suggests that evaluation is essential. However, this is not always practical and economically feasible in the countries of the region, but it can be facilitated by developing selected tertiary-care centres, where patients can be referred after their initial screening by history, dietary habits, urine analysis,

plain abdominal X-ray and/or ultrasonography at district level. Metabolic studies and stone analysis should be undertaken at specialized centres. This strategy will reduce the overall investment and provide a high-quality evaluation for most high-risk stone-formers.

Imaging

The plain abdominal film is the first imaging test in evaluating patients; $\approx 90\%$ of renal calculi are sufficiently radio-opaque to be detected. Most of these are calcium oxalate or calcium oxalate and phosphate mixtures. Struvite or matrix calculi are less opaque, while pure uric acid and cystine stones are not detectable by a plain film.

Ultrasonography is a simple technique, with the mobile and portable machines currently available being ideally suited for developing countries with vast and populated rural areas. Compared with radiography, ultrasonography has a detection limit of 75% [24]; in patients with renal colic, ultrasonography complements radiography and is useful for detecting hydronephrosis or dilatation of the pelvicalyceal system. It can also be

Table 3 Food frequencies (% of low, medium and high) in adult stone-formers and controls at SIUT

| Component | Stone-formers (100) | | | Controls (30) | | |
|--------------|---------------------|--------|------|---------------|--------|------|
| | Low | Medium | High | Low | Medium | High |
| Fluid intake | 47 | 47 | 06 | 07 | 40 | 53 |
| Protein | 27 | 53 | 20 | 17 | 77 | 06 |
| Calcium | 60 | 33 | 06 | 33 | 63 | 04 |
| Oxalate | 22 | 40 | 38 | 20 | 60 | 20 |
| Sodium | 07 | 73 | 20 | 10 | 66 | 24 |
| Fibre | 47 | 47 | 06 | 33 | 23 | 44 |
| Fat | 0 | 60 | 40 | 03 | 53 | 40 |

used for serial surveillance of recurrent stone-formers, especially those with infections, to evaluate renal size and parenchymal thickening.

IVU is the standard investigation for evaluating obstruction in patients with suspected calculous disease. CT is a new approach for evaluating suspected renal/ureteric colic; CT detects mild hydronephrosis and ureteric calculi, and is superior to radiography and ultrasonography. Not only oxalate and phosphate stones, but also struvite, cystine and uric acid calculi are identified.

Dietary and metabolic risk factors in patients with nephrolithiasis

The protein intake is low in countries of the region, causing ammonium acid-urate stone formation. There is also a low intake of fluids in this population; a quarter of the recurrent stone-formers and 10% of the others have low urinary volumes (<1000 mL/24 h) [20] (Table 2). Chronic dehydration attributable to the hot climate, diarrhoea and working in farming contribute to hypovolaemia. Stone-formers eat a low-fibre diet in this population, mainly because they tend to consume refined wheat flour and rice as staple foods. Excess sodium in the diet produces a variety of metabolic changes which can contribute to lithiasis, e.g. increased urinary pH, calcium and cystine excretion, and reduction of urinary citrate.

The diet of the population indicates a low calcium intake, as shown by hypercalcaemia in only 5–10% and hypercalciuria in 10% of the population. This low calcium intake is a major contributory factor to hyperoxaluria. Hyperuricosuria is associated with uric acid and calcium oxalate stones in 10–30% of the cases. Other risk-factors are a low urinary pH (<5.5), reduced urine volume (<1 L/day) and chronic diarrhoea. The lack of data on the oxalate content of foods of the region makes analysis of the dietary contribution difficult. Oxalate intake was moderate to high in the stone-formers managed at the SIUT. Hyperoxaluria appears to be a major risk factor in the region, attributable mainly

to an oxalate-rich diet, inflammatory bowel disease and intestinal fat malabsorption. Hypocitraturia also appears to be a major problem, mainly from the reduced intake of citrus fruits, the low-calcium diet and diarrhoea. Many stone-formers (more than half) and normal subjects (30%) have hypocitraturia (with a urinary citrate of <300 mg/day constituting hypocitraturia). The prevalent hypomagnesaemia in the stone-formers is a risk factor for stone formation; >30% of the stone-formers show low excretion of magnesium. Cystine stones constitute <1% of the stones in this region.

Evaluation plan

The evaluation plan comprises three phases. Visit 1 comprises: (a) a medical and dietary history; (b) urine analysis, including nitrates; (c) urine culture; (d) serum calcium/uric acid/phosphate/potassium, and a plain abdominal film/ultrasonography at primary district level centres; (e) 24-h urinary metabolic studies; (f) stone analysis (if passed), referred to specialized centres.

Visit 2 comprises the evaluation and analysis of the results of dietary and metabolic studies, and the treatment of patients with infections after assessing antibiotic sensitivity of the infecting organism. The stone-formers are classified into the following groups: group A, uncomplicated stone-formers with dietary risk factors; group B, uncomplicated stone-formers with metabolic risk factors; and group C, complex and infection stones and nondietary hyperoxalurias.

Visit 3 comprises: (a) an evaluation of patients with hypercalcaemia by parathyroid hormone levels; (b) patients with hyperoxaluria not related to diet investigated further for gastrointestinal disorders; and (c) the follow-up of patients with infection.

Management of renal calculi

Improved technology has revolutionized the management of stones; the advent of ESWL, fibre-optic, semi-rigid and flexible ureteroscopes, and narrow-calibre endoscopes, have expanded minimally invasive options in addition to prevailing open surgical procedures.

Recently ESWL has become the treatment of choice for most renal calculi, whereby 70–80% of patients can be treated with monotherapy [25]. Solitary or multiple stones with an overall diameter of up to 2.5 cm are ideal for ESWL. There are only a few absolute contraindications and these include pregnancy, renal artery aneurysm, infundibular stenosis, outlet tract obstruction, uncontrollable bleeding diathesis and untreated UTI. Complications are few, the commonest being renal colic, steinstrasse, urosepsis, haematuria, and intrarenal and perinephric haematoma.

We have treated 9040 stones by ESWL; to reduce obstructive complications we place JJ stents for stones of >1.5 cm, in a solitary kidney with stone, in obstructed kidneys and in patients from remote areas, as a prophylaxis against obstruction.

Percutaneous nephrolithotomy (PCNL) is a popular and rapidly increasing method for managing renal calculi, now used routinely for complex urinary stones. Both morphological and functional studies show that PCNL has little deleterious effect on renal function, not only in normal kidneys but also in patients with pre-existing renal insufficiency [26]. The technique has continued to develop, with improvements in endoscopic instruments, intracorporeal lithotripsy (including ultrasound), pneumatic devices, the holmium-YAG laser and flexible nephroscopes. Improvement in the control of infection and postoperative analgesic care have also contributed. Stone-free rates may often be >90% [27]. The indications for PCNL include hard renal calculi of >2 cm, stones in the lower-pole calyx or within calyceal diverticula, staghorn calculi, or as a salvage procedure after failed ESWL. Cystine stones and stones in a kidney with an anatomical abnormality are other indications. The only absolute contraindication for PCNL is irreversible coagulopathy.

Open surgery for renal stone disease has decreased considerably because of the adoption of noninvasive and minimally invasive techniques. The commonest current and acceptable indications for open surgery include complex stones in kidneys with a dilated collecting system, failure of percutaneous, endourological or ESWL, and stones in a kidney with anatomical abnormalities, e.g. PUJ obstruction, infundibular stenosis, ureteric strictures and concomitant open surgery [28]. In the last 10 years, we have treated 11 329 renal stones, 84% by ESWL and PCNL and the rest by open surgery (Table 4).

Management of ureteric calculi

Of ureteric calculi up to 5 mm in diameter in the lower ureter, 98% will pass spontaneously [29]. The management of other ureteric calculi depends on

the size and location. In proximal ureteric calculi, ESWL should be the first line of treatment for stones of <1 cm in diameter. If ESWL fails, the stone should be removed percutaneously [8]. Ureteroscopy and ESWL are the available options for distal ureteric calculi; ESWL is minimally invasive and can be used with no anaesthesia, but the re-treatment rate is high. Failure of ESWL may require ancillary procedures. Ureterorenoscopy (URS) gives higher stone-free rates but requires anaesthesia, and being more invasive has the added risk of urosepsis and ureteric trauma. In our experience the pneumatic lithoclast was cheaper, more user-friendly and had a higher success rate than the Alexandrite laser [6]. 'Blind' extraction using a Dormia basket should be discouraged because of its inherent complications.

Open surgery is the last option used when all the other methods have failed or where these methods are contraindicated, e.g. large stones, ureteric stones in small children, and with associated renal dysfunction. At the SIUT we have treated 3088 ureteric stones in the last 10 years (Table 5).

Management of urinary tract calculi in patients with renal failure

This is a challenge which requires a concerted team effort by urologist, nephrologist, radiologist and chemical pathologist. Many of these patients present in a critical condition with obstruction, sepsis, renal dysfunction, and fluid and electrolyte imbalance. They may therefore require immediate renal replacement therapy. Their subsequent management will thus require a combination of treatments, e.g. percutaneous nephrostomy, JJ stenting, peritoneal and/or haemodialysis [4]. Definitive surgical procedures after stabilization are PCNL [26], URS lithoclast, ESWL and open surgery. Those patients who do not recover should then be considered for renal replacement therapy in the form of transplantation [4]. In the last 3 years we have treated 478 patients in renal failure; many required a combination of these initial procedures (Table 6).

Table 4 The treatments for renal stones at the SIUT in 11 329 patients

| <i>Treatment</i> | <i>Number (%)</i> | <i>Stone size, cm mean (range)</i> | <i>Stone-free at 6 months, %</i> | <i>Overall complication rate, %</i> |
|------------------|-------------------|------------------------------------|----------------------------------|-------------------------------------|
| ESWL | 9040 (79.7) | | | 8 |
| | 5115 (60) | 0.5–2 | 98 | |
| | 2896 (32) | 2.1–3.0 | 43 | |
| | 729 (8) | > 3.1 | 34 | |
| PCNL | 412 (4.5) | 5.8 (3–7.8) | 90 | 7 |
| Open surgery | 1877 (16.5) | 4.5 (3–8.0) | 98 | 12 |

Table 5 The treatment of ureteric stones at the SIUT in 3088 patients

| | Site of ureteric stones | | |
|----------------------------------|-------------------------|------------|-------------|
| | Upper | Middle | Lower |
| Number (%) | 969 (31.4) | 460 (14.9) | 1659 (53.7) |
| Procedure | | | |
| ESWL | 751 (77.6) | NA | 501 (30.2) |
| Ureterscopy + Lithoclast | 104 (10.7) | 369 (80.2) | 1117 (67.3) |
| Open surgery | 114 (11.7) | 91 (19.8) | 41 (2.5) |
| Stone-free rate, % (one session) | | | |
| ESWL | 46.0 | NA | 80.0 |
| Ureterscopy + Lithoclast | 79.1 | 92.0 | 96.0 |
| Open surgery | 100 | 100 | 100 |

NA, not available.

Management of bladder calculi in adults

Bladder calculi in adults constitute 4% of all urolithiasis at our centre. With the advent of new techniques, the options available have increased from open cystolithotomy and blind litholapaxy to endoscopic mechanical litholapaxy, lithotripsy and intracorporeal disintegration devices [30]. Endoscopic mechanical lithotripsy using the lithotrite works well for stones of 2–2.5 cm in diameter. Haematuria and bladder perforation are rare complications. For hard stones we combine the lithoclast and mechanical lithotrite. Percutaneous cystolithotripsy was used for those patients who had associated stricture of the urethra and had a suprapubic catheter *in situ*. We have treated 670 bladder calculi at SIUT, with minimal complications. Of the 670 calculi, 185 (27.6%) were treated by open surgery, 288 (42.9%) by litholapaxy, 180 (26.8%) by ESWL and the rest by per-urethral or percutaneous cystolithotomy. The stone-free rates were 100% for open surgery, 98.6% for litholapaxy and 50% for ESWL; the complication rates were 5.9% for open surgery and \approx 2% for litholapaxy and ESWL.

Paediatric urolithiasis

Urolithiasis in children, unlike in western countries, is an endemic problem in developing countries [31]. Technological advances in minimally invasive procedures and endourology have equally benefited paediatric stone-formers; ESWL, URS and PCNL can all be used safely to manage the stone burden. ESWL can be successful in 80% of stone-formers, with an 86% stone-free rate [32]. Clinically significant residual stones pose a problem and this is where medical management becomes essential. However, there is no effect on renal function. PCNL has become a well-established technique in children; stone-free rates for PCNL monotherapy are \approx 90% [33]. The long-term renal damage is minimal and PCNL can

Table 6 The management of stones causing obstructive renal failure, in 478 patients at the SIUT

| Management | Number (%) |
|--|------------|
| Initial | |
| Percutaneous nephrostomy | 242 (50.6) |
| JJ stenting | 114 (23.8) |
| Percutaneous nephrostomy + JJ stenting | 25 (5.2) |
| Haemodialysis | 223 (46.6) |
| Peritoneal dialysis | 17 (3.5) |
| Definitive | |
| Open surgery | 334 (69.8) |
| Percutaneous nephrolithotomy | 40 (8.3) |
| Ureterorenoscopy | 54 (11.2) |
| Lithotripsy (ESWL) | 45 (9.4) |
| Outcome | |
| Improvement in renal function | 308 (64.4) |
| Maintenance dialysis | 34 (7.1) |
| Deaths | 25 (5.2) |
| Lost to follow-up | 43 (8.9) |
| Transplantation | 68 (14.2) |

be safely combined with ESWL for a larger stone burden. URS, with the availability of mini-scopes, has become a safe and popular procedure, and accepted as the first line of treatment for distal ureteric stones, especially in small children. The risk of ureteric stricture and damage to ureteric orifice, leading to VUR, is very rarely reported [34]. In our centre we have treated 1440 children with urolithiasis in the last 14 years. Up to 1995, open surgery was the mainstay of treatment, but thereafter lithotripsy, PCNL and URS were introduced in a dedicated paediatric stone clinic (Table 7).

Dietary management

Dietary modifications could play an important part in the management of stone disease in the region; keeping in perspective the social and cultural environment of the stone-formers, the following modifications should be advised in the long term.

- High fluid intake: a minimum of 10–12 glasses of water (250 mL each).
- Oxalate restriction: restrict the use of spinach, okra, green vegetables, tea, and green and black pepper.
- Fat-rich foods: reduce the consumption of oily or fat-rich food, especially animal-fat products.
- Sodium: avoid the use of salt shakers and salty food.
- Increase citrus fruits: promote the consumption of lemon juice, orange juice, and especially potassium-rich products.
- Increase the fibre intake, e.g. bran bread.
- Increase calcium intake by having at least two cups of milk/milk products per day.

Table 7 The management of paediatric urolithiasis at the SIUT (1440 patients)

| Procedure | Site of stone, n (%) | | |
|--------------------------------|----------------------|------------|-----------|
| | Renal | Ureteric | Bladder |
| Number (%) | 795 (55.2) | 198 (13.8) | 447 (31) |
| ESWL (0.5–2.0 cm) | 177 (22.2) | 85 (43) | 63 (14.0) |
| Stone-free at 3 months, % | 84 | 54 | 48 |
| PCNL (2.5–5.0 cm) | 62 (7.8) | NA | NA |
| Stone-free rate at 3 months, % | 68 | – | – |
| Ureterscopy and Lithoclast | NA | 37 (18.6) | 77 (17.2) |
| Stone-free rate, % | NA | 90 | 93.1 |
| Open surgery | 556 (70) | 76 (38) | 307 (68) |
| Stone-free rate, % | 98.2 | 100 | 100 |

Medical treatment

Medical treatment should be based on assessing 24-h urinary metabolic abnormalities. Drug treatment is advised after a high fluid intake (> 3 L/day) and dietary modifications in the long-term fail to correct abnormalities or prevent recurrence. In cases of hypercalciuria with normal parathyroid hormone levels, the treatment is thiazide diuretics and potassium citrate, with a reduction of sodium in the diet [35]. Patients with hyperoxaluria not related to diet should be investigated for underlying bowel disease. Therapy should include a reduction in oxalate-rich diet, with pyridoxine supplements and lemon juice. For severe hypocitraturia investigations should be directed to detect gastrointestinal disorders and renal tubular acidosis. Here the mainstay of treatment is lemon juice or potassium citrate. Hyperuricosuria with hyperuricaemia is treated by allopurinol 300 mg/day and potassium citrate or orange juice as an alternative [36]. Most patients with stone disease present with more than one risk factor; in our studies, 10% presented with several metabolic or environmental risk factors. Medical therapy thus requires a combination, depending on the individual patient profile and the type of stone formation.

Conclusion

Although stone disease has been known since the dawn of civilisation, the exact causes and its complete prevention remain an enigma. In tropical countries there are estimated to be more than 1 million stone-formers. With the introduction of minimally invasive techniques and accurate diagnostic procedures, the management of stone disease, especially in developed countries, has been revolutionized. However, with limited

resources and a large stone burden, the dilemma is whether to invest in these methods or in research directed towards preventing and identifying the causes of the problem. This is where the developed nations should help in opening specialized centres for collaborative work. Research should focus on dietary and medical therapy, as these play a vital role in obtaining remission from stone disease in 90% of the patients. Furthermore, the reporting of stone disease and risk factors should have a uniform terminology to facilitate understanding by all professionals.

In the context of tropical countries, the remaining question is where to find the ideal solution:

- In minimally invasive facilities, especially in public hospitals, with maximum use to benefit the most patients.
- In the formation of specialized stone clinics attached to dedicated centres, to manage referred cases from rural and urban areas. These clinics should provide for the evaluation and treatment of patients.
- In prospective studies to study and identify risk factors for the region.
- In awareness programmes for the public on the prevention of stone disease, and teaching sessions for primary physicians for early diagnosis and appropriate treatment. These will play a vital role in preventing stone disease and associated renal failure.

Hopefully, with a better understanding of the risk factors prevalent in our region, an improvement in metabolic evaluation and the introduction of minimally invasive techniques, we will approach the ideal management of stone disease in the region.

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References

- 1 UNDP. *Profile of Human Poverty in Human Development. Report 1997*. Oxford: Oxford University Press, 1997: 137–228
- 2 Husain M, Lal M, Ali B *et al*. Urolithiasis in Sindh. A single center experience with a review of 10,000 cases. *J Nephrol Urol Transplant* 1998; 1: 10–3
- 3 Gupta NP, Kochar GS, Wadhwa SN, Singh SM. Management of patients with renal and ureteric calculi presenting with chronic renal insufficiency. *Br J Urol* 1985; 57: 130–2
- 4 Husain M, Lal M, Ali B *et al*. Management of urinary calculi associated with renal failure. *J Pak Med Assoc* 1995; 45: 205–8

- 5 Aegukkatajit S, Nagaphant A, Nuhung R *et al.* Epidemiological study of urinary stones based on operative theater data at regional hospitals and general hospitals of public health region-5, Thailand. *J Med Assoc Thai* 1994; **77**: 484-7
- 6 Naqvi SAA, Khaliq M, Zafar MN, Rizvi SAH. Treatment of ureteric stones. Comparison of laser and pneumatic lithotripsy. *Br J Urol* 1994; **74**: 694-8
- 7 McCarrison RA. Lecture on the causation of stone in India. *Br Med J* 1931; **4**: 1009-15
- 8 Preminger GM. Minimally invasive management of urinary tract calculi: What have we learned? In Rogers AL, Hibert BE, Hess B, Khan SR, Preminger GM, eds. *Urolithiasis 2000*. Vol. 11. Cape Town: University of Cape Town, 2000: 858-68
- 9 Talati J, Khan H, Drago A *et al.* Epidemiology of urolithiasis in Pakistan. In Talati J, Suttan RAL, Moazam F, Ahmed M, eds. *The Management of Lithiasis*. Dordrecht, the Netherlands: Kluwer Academic Publishers, 1997: 21-33
- 10 Robertson WG. Title? In Husain I, ed. *Urolithiasis. Epidemiology and Pathogenesis in Tropical Urology and Renal Disease*. London: Churchill Livingstone, 1984: 143-64
- 11 Jayadevan S, Marickar YMF, Pillai RN. Incidence and prevalence of urolithiasis in Kerala. In Rodgers AL, Hibbert BE, Hess B, Khan SR, Preminger GM, eds. *Urolithiasis 2000*. Vol. 2. Cape Town: University of Cape Town, 2000: 392-4
- 12 Rashid HU, Fatima N, Ahmed S *et al.* Clinical characteristics of renal stone disease in Bangladesh. *Bangladesh Renal J* 1997; **16**: 5-6
- 13 Yanagawa M, Kawamura J, Onishi T *et al.* Incidence of urolithiasis in northeast Thailand. *Int J Urol* 1997; **6**: 537-40
- 14 Abomelha MS, Al-Khader AA, Arnold J. Urolithiasis in Saudi Arabia. *Urology* 1990; **35**: 31-4
- 15 Yoshida O, Terai A, Ohkawa T, Okada Y. Nutritional trend of the incidence of urolithiasis in Japan from 1965 to 1995. *Kidney Int* 1999; **56**: 1899-904
- 16 Yamaguchi K, Okhawa M, Orito M *et al.* A clinical survey of urinary calculi in terms of stone composition. *Japan Kidney Int* 1988; **30**: 375-83
- 17 Thind SK, Sidhu H, Nath R *et al.* Chronological variation in chemical composition of urinary calculi between 1965- and 68 and 1982-86 in north western India. *Trop Geog Med* 1988; **40**: 338-41
- 18 Aegukkatajit S. Reduction of urinary stone in children from north eastern Thailand. *J Med Assoc Thai* 1999; **12**: 1230-3
- 19 Sribooulue P, Prassongwattana V, Tungsanga K *et al.* Blood and urinary aggregation and inhibition composition in controls and renal stone patients from north eastern Thailand. *Nephron* 1991; **59**: 591-6
- 20 Khamesra HL, Barjatiya MK, Srehlata A. Urinary stone risk factors in north-west India population. In Rodgers AL, Hibbert BE, Hess B, Khan SR, Preminger GM, eds. *Urolithiasis 2000*. Cape Town: University of Cape Town, 2000: 343-5
- 21 Haghghi P, Wolf PL. Tropical spruce and subclinical enteropathy: a vision for the nineties. *Crit Rev Clin Laboratory Sci* 1997; **34**: 313-41
- 22 Hesse A, Sieven R. Current aspects of epidemiology and nutrition in urinary stone disease. *World J Urol* 1997; **5**: 165-71
- 23 Seftel A, Resnick MI. Metabolic evaluation of urolithiasis. *Urol Clin North Am* 1990; **17**: 159-69
- 24 Aegukkatajit S, Promsing C, Lovorapong S. Study of urinary stone in Buri Ram province by portable ultrasound. *J Med Assoc Thai* 1995; **78**: 305-9
- 25 Lal M, Hussain M, Hashmi A *et al.* ESWL monotherapy of renal calculi. *J Nephrol Urol Transplant* 2000; **1**: 13-7
- 26 Agrawal MS, Aron M, Asopa HS. Endourological renal salvage in patients with calculus nephropathy and advanced uraemia. *BJU Int* 1999; **84**: 252-6
- 27 Segura JW. The role of percutaneous surgery in renal and ureteral stone removal. *J Urol* 1989; **141**: 780-1
- 28 Paik ML, Wainsten MA, Spirnak JP *et al.* Current indications for open stone surgery in the treatment of renal and ureteral calculi. *J Urol* 1998; **159**: 374-9
- 29 Segura JW, Preminger GM, Assimos DG *et al.* Ureteral stones clinical guidelines panel summary report on the management of ureteral calculi. *J Urol* 1997; **158**: 1915-21
- 30 Bhandari M, Ahlawat R. Management of bladder and urethral calculi. In Whitfield HN, Hendry WF, Kirby RS, Duckett JW, eds. *Textbook of Genitourinary Surgery*, 2nd edn, Vol. 1. Oxford: Blackwell Science Ltd, 1998
- 31 Badawy H, Salama A, Eissa M *et al.* Percutaneous management of renal calculi: Experience with percutaneous nephrolithotomy in 60 children. *J Urol* 1999; **162**: 1710-3
- 32 Elsobky E, Sheir KZ, Madbouly K *et al.* Extracorporeal shock wave lithotripsy in children: experience using two second-generation lithotripters. *BJU Int* 2000; **86**: 851-6
- 33 Choong S, Whitfield H, Duffy P *et al.* The management of paediatric urolithiasis. *BJU Int* 2000; **86**: 857-60
- 34 Krautschick A, Alken P *et al.* Treatment update on pediatric urolithiasis. *J Urol* 1997; **15**: 195-202
- 35 Pak CYC, Resnik MI. Medical therapy and new approaches to management of urolithiasis. *Urol Clin North Am* 2000; **27**: 243-53
- 36 Wabner CL, Pak CYC. Effect of orange juice consumption on urinary stone risk factors. *J Urol* 1993; **149**: 1405-8

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Abbreviations: SIUT, Sindh Institute of Urology and Transplantation; PCNL, percutaneous nephrolithotomy; URS, ureterorenoscopy.