Original Article

Spectrum of urinary stone composition in Northwestern Rajasthan using Fourier transform infrared spectroscopy

Amilal Bhat*, Vikash Singh, Mahakshit Bhat[1], Vinay Kumar[2], Akshita Bhat[3]

Department of Urology, Dr. S.N. Medical College, Jodhpur, [1]Department of Urology, M.G. Medical College, Jaipur, Departments of [2]Urology and [3]Sugery, S.P. Medical College, Bikaner, Rajasthan, India

*E-mail: amilalbhat@redifmail.com

ABSTRACT

Introduction: The aim of this study was to evaluate the chemical composition of urinary stones and pattern of changes according to the patient's age in Northwestern Rajasthan using Fourier transform infrared (FTIR) spectroscopy.

Materials and Methods: A prospective study of 1005 urolithiasis patients was carried out in two tertiary care centers from September 2012 to September 2016. Chemical composition of urinary stones was analyzed using FTIR spectroscopy, and a subgroup study based on the patient's age was done (8–12 years – Group A, 13–18 years – Group B, and >18 years – Group C).

Results: Out of 1005 patients, 59 were in Group A, 104 in Group B, and 842 in Group C. Male predominance was found in all age groups. Mixed composition stones were much more common than pure one (74.83% vs. 25.17%). Overall, combination of calcium oxalate monohydrate with dihydrate was the most common composition (58.0%). Calcium oxalate was the predominant chemical composition in 91.54% of stones, followed by uric acid in 4.28%, struvite in 2.29%, calcium phosphate in 1.49%, and cystine in 0.4%. The proportion of calcium oxalate stone was increasing while that of struvite, uric acid, and cystine stone was decreasing with age. Most of the vesical calculi in pediatric age group (Group A; 8–12 years) patients were made up of combination of struvite, calcium phosphate, and uric acid. A total of 85.11% of staghorn calculi were of oxalates.

Conclusion: In Northwestern Rajasthan, calcium oxalate is the most common composition of urinary stones in all age groups. Mixed stones are more common than pure ones. The incidence of calcium oxalate stone increases while that of struvite, uric acid, and cystine stone decreases with age.

INTRODUCTION

Urolithiasis is a common cause of morbidity and absenteeism from work worldwide. In India, varied stone compositions are found in different regions, but the exact data are lacking because of paucity of large population-based prospective studies.[1] Approximately 80% of adults with urolithiasis have stones that consist predominantly of calcium oxalate and/or calcium phosphate. Struvite stones (magnesium ammonium phosphate) represent 10%–15%, uric acid stones, 5%–10%, whereas cystine stones are rare, 1%–2%.[2,3] In childrens, the composition of urinary stones is somewhat different than that of adults and also continuously changing from the past.[4] In India, Northwest region is the "stone belt" that includes some part of Maharashtra, Gujarat, Punjab, Haryana, Delhi, and Rajasthan.[5,6] The recurrence rate of stones is unacceptably high at 10% after the 1st year of stone presentation, 35% at 5 years, and 50% at 10 years.[7] Urinary stone analysis assists with identification of the possible causes of renal stone formation and when combined with blood, and urine analysis helps in identification of treatable risk factors to decrease recurrence.

Methods used for renal stone analysis include Fourier transform infrared (FTIR) spectroscopy, X-ray diffraction

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crystallography, coherent-scatter analysis, scanning electron microscopy with energy dispersion, thermogravimetry, polarizing microscopy, and wet chemical analysis.[2,8] Among all these methods, FTIR is a sensitive, reliable, accurate, rapid, and specific method.[2,8] A study was therefore done to perform chemical analysis of stones to know the stone pattern in different age group patients presenting to our hospital.

MATERIALS AND METHODS

This was a prospective study conducted on 1005 urolithiasis patients from two tertiary care centers in India, between September 2012 and September 2016. The geography, lifestyle, and dietary habits of the population served by these two centers are comparable. Basic demographic data were collected from the patients, and informed as well as written consent was obtained. To analyze the variability in stone composition in pediatrics and adults, patients were divided into three age groups; 8–12 years (Group A), 13–18 years (Group B), and >18 years (Group C).

The stones recovered from surgery were washed with distilled water to remove blood and tissue remains attached, completely dried with filter paper, and then cut for microscopic structural analysis. To prepare the renal stones for analysis, they were grinded to a fine consistency (using a mortar and pestle) and then dried in a hot air oven for 24 h at 100°C. Then to make pellet, 0.003 mg of the dried powder was mixed with 0.097 mg of potassium bromide powder. This mixture was transferred to the mini hand press to form a pellet which was then transferred onto the spectrophotometer pellet holder for analysis.

FTIR spectroscopy was performed using a Perkin-Elmer Fourier Transformer Infrared Spectrophotometer, with a wave number range from 7800 to 350 cm^{-1}. The instrument had a high sensitivity with a signal/noise ratio of 30,000:1. The spectrum obtained was then compared to the 1668 spectra in the NICODOM-IR kidney stone library.

Pure stones in our study were defined as stone composed of ≥90% of the reported composition. Mixed stones were made up of more than one composition, but none of the compositions was ≥90% of the total. The stone component was considered as predominant one if it exceeded 50% of the total composition of the calculus.

RESULTS

Total 1005 patients with urinary stones were analyzed during September 2012–September 2016. Out of these, 714 were male and 291 were female with the ratio of 2.45:1. There were 59 patients in Group A, 104 in Group B, and 842 patients in Group C. The patient's age ranged from 8 to 72 years. The mean age, male to female ratio, and other demographic parameters are described in Table 1. Urinary stones were more common in males in all age groups, and this male dominance was increasing with age [Table 1].

Out of 1005 stones analyzed, 664 were renal, 219 were ureteric, and 122 were urinary bladder stones. Stones with mixed composition were much more common than pure one (74.83% vs. 25.17%) [Table 2]. Overall the most common composition was the combination of calcium oxalate monohydrate and dihydrate (58.0%) [Figure 1a and b]. Calcium oxalate as predominant chemical composition was present in 91.54% of the stones, followed by uric acid in 4.28%, struvite in 2.29%, calcium phosphate in 1.49%, and cystine in 0.4%. Renal, ureteric, and urinary bladder stones were predominantly calcium oxalate-containing stones in 96.1%, 94.1%, and 62.3%, respectively.

On subgroup analysis according to the age, we have found that renal stones were more common in adults whereas vesical calculus was more common in pediatric patients [Table 1]. Furthermore, the proportion of calcium oxalate stone was increasing while that of uric acid, struvite, and cystine was decreasing with age in all parts of the urinary tract [Table 2]. Calcium oxalate was the most frequent composition in renal and ureteric stones in all age groups, but this was not true for vesical calculus. In Group

Table 1: Demographic characteristics of patients

Demographic variable	Age			Total
	8-12 years Group A	13-18 years Group B	>18 years Group C	
Sex distribution (%)				
Male	35 (59.3)	71 (68.3)	608 (72.2)	714 (71.0)
Female	24 (40.7)	33 (31.7)	234 (27.8)	291 (29.0)
Male:female ratio	1.5:1	2.15:1	2.60:1	2.45:1
Age (mean, years)				
Male	10.3	16.4	35.8	32.6
Female	10.6	15.8	39.6	34.5
Location of stone (%)				
Renal	28 (47.5)	64 (61.6)	572 (67.9)	664 (66.1)
Ureteric	13 (22.0)	20 (19.2)	186 (22.1)	219 (21.8)
Vesical	18 (30.5)	20 (19.2)	84 (10.0)	122 (12.1)

Table 2: Distribution of stone composition according to age

Stone composition	Pure/mixed	Age			All age groups (*n*=1005), number of cases (%)
		8-12 years Group A (*n*=59), number of cases (%)	13-18 years Group B (*n*=104), number of cases (%)	>18 years Group C (*n*=842), number of cases (%)	
Calcium oxalate monohydrate	Pure	10 (17)	15 (14.4)	152 (18.1)	177 (17.61)
Calcium oxalate dihydrate	Pure	2 (3.4)	4 (3.8)	42 (5.0)	48 (4.78)
Calcium oxalate monohydrate + calcium oxalate dihydrate	Mixed	17 (28.8)	53 (51)	513 (60.9)	583 (58.0)
Calcium oxalate + uric acid	Mixed	5 (8.5)	6 (5.8)	57 (6.8)	68 (6.77)
Calcium oxalate + calcium phosphate	Mixed	5 (8.5)	10 (9.6)	43 (5.1)	58 (5.77)
Uric acid	Pure	8 (13.6)	4 (3.8)	7 (0.8)	19 (1.89)
Calcium oxalate + calcium phosphate + uric acid	Mixed	3 (5.1)	3 (2.9)	15 (1.8)	21 (2.09)
Struvite	Pure	2 (3.4)	1 (0.96)	2 (0.2)	5 (0.50)
Struvite + calcium phosphate	Mixed	4 (6.8)	7 (6.7)	11 (1.3)	22 (2.19)
Cystine	Pure	3 (5.1)	1 (0.96)	Nil (0.0)	4 (0.40)
Total		59 (100)	104 (100)	842 (100)	1005 (100)

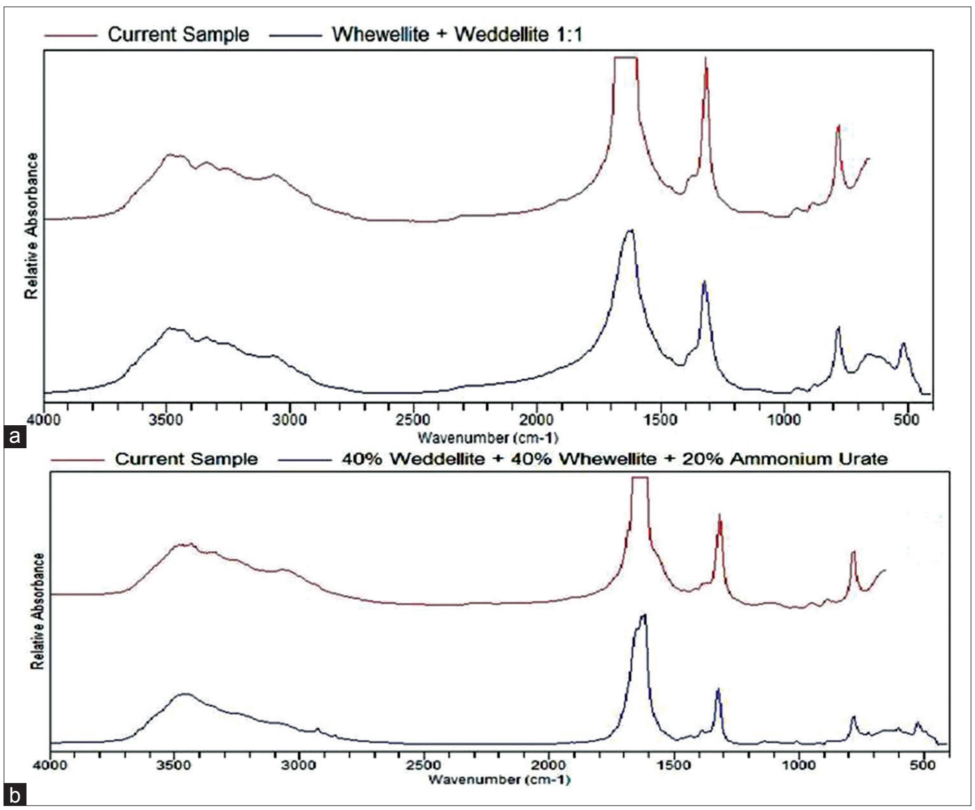

Figure 1: (a) Fourier transform infrared spectrum profile of a mixed calcium oxalate stone showing major peaks. (b) Fourier transform infrared spectrum profile of a mixed calcium oxalate with uric acid stone showing major peaks

C, calcium oxalate was the most frequent composition whereas only 33.3% vesical calculi in Group A patients had calcium oxalate as predominant chemical composition while rest were composed of varying amount of struvite, calcium phosphate, and uric acid.

A total of 85.11% (143 out of 168) of staghorn calculi were of oxalates followed by varied composition of calcium oxalate, phosphate, struvite, and uric acid (12.51%). Staghorn stones of pure struvite composition were present only in 2.38%.

DISCUSSION

Northwest Rajasthan is one of the stone belt regions of India.[5] Stone analysis will give a rough idea about the etiology that will help in formulating preventive measures. Both European as well as American urological societies also recommend for stone analysis at least once.[9,10]

Currently, multiple modalities are available for stone analysis.[2] However, we have chosen FTIR spectroscopy because of quick examination, moderate cost, the ability to test a small sample, semiautomatic evaluation and its ability to identify organic components or noncrystalline substances [Table 3].[2,8]

Urinary calculus disease usually occurs in working age group and leads to an economic burden on the society. Jindal *et al.* in their study showed a mean age of 38 years for urolithiasis.[11] In our study, the mean age was 32.6 years for males and 34.5 years for females. Bangash *et al.* reported the mean age of 43.9 years, with insignificant sex difference.[12] Males were found to have more stone disease in our study than females with the ratio of 2.45:1, and this male dominance was increasing with age (Group A 1.5:1, Group B 2.15:1, and Group A 2.6:1). This was consistent with most of the other studies.[12-14]

Urinary stone composition varies across the world and calcium oxalate stones are found to be the most predominant composition.[1,15-18] Pediatric patients show different stone profile than adults. Very scanty data of pediatric stone composition are available in Indian literature. Ansari *et al.* analyzed 1050 urinary stones recovered from patients in Northern India and found that calcium oxalate was the most predominant component present in 93.04% of the cases followed by struvite in 1.42%.[1] Similar results have been reported from different parts of India.[5,11,16] Gabrielsen *et al.* while analyzing the data of 5245 stones belonged to 1–18 years old patients of the United States reported calcium oxalate as the most common stone composition.[19] We have also found calcium oxalate as the most common composition and was present predominantly in 91.54% of stones followed by uric acid in 4.28%, struvite in 2.29%, calcium phosphate in 1.49%, and cystine in 0.4%. This pattern of calcium oxalate as predominant composition was seen in all age groups (Group A 57.6%, Group B 81.7%, and Group C 95.1%) [Table 4].

The high incidence of calcium oxalate stones in our region may be because of its hot climate, oxalate-rich diet, and decreased fluid intake.[20,21] On subgroup analysis based on the patient's age, we observed that the proportion of calcium oxalate stone was increasing whereas that of uric acid, struvite, and cystine was decreasing with age, and this trend was similar for all whether it was renal, ureteric, or vesical calculus. Gabrielsen *et al.* reported similar trends while evaluating the stone composition in pediatric patients in a large retrospective study.[19] Other studies also showed peak incidence of calcium oxalate stones between the age of 30 and 50 years.[22,23]

Table 3: Stone analysis techniques - pros and cons

Technique	Advantages	Disadvantages
Fourier transform infrared spectroscopy	High sensitivity – can examine small amount of sample Fast result Cost effective Does not need highly qualified technician Semiautomatic evaluation and able to identify organic components or noncrystalline substances Can also recognize even small fractions of multiple components as percentage more precisely and accurately as compared to other techniques	Lengthy and time-consuming preparation Because of overlapping absorption bands, sometimes there is difficulty in detection of small amounts of components in some complex stones
Chemical analysis	Cost-effective Simple to perform	Needs large sample size Time taking Gives information about individual ions and radicals rather than a specific compound
X-ray diffraction	Analysis is quantitative Can be applied on small sample size Measurement is automatic Easy Exact differentiation of all crystalline components is possible	Cannot detect amorphous or noncrystalline components Costly
Scanning electron microscopy	Possibility to visualize the components, their shape, internal structure, location inside the stone, and relation between the crystals and the organic matrix	Costly Needs qualified technicians
Thermogravimetry	Simple Fast	Closely related compounds are difficult to differentiate Needs large amount of sample

Table 4: Distribution of stones having calcium oxalate as predominant composition

Location	Age			All age groups (*n*=1005), *n*/total (%)
	8-12 years Group A (*n*=59), *n*/total (%)	13-18 years Group B (*n*=104), *n*/total (%)	>18 years Group C (*n*=842), *n*/total (%)	
Renal	20/28 (71.4)	58/64 (90.6)	560/572 (97.9)	638/664 (96.1)
Ureteric	8/13 (61.5)	17/20 (85.0)	181/186 (97.3)	206/219 (94.1)
Vesical	6/18 (33.3)	10/20 (50.0)	60/84 (71.4)	76/122 (62.3)
Any location	34/59 (57.6)	85/104 (81.7)	801/842 (95.1)	920/1005 (91.5)

Pure uric acid stone was present in 13.65% of patients in Group A in contrast to only in 0.8% of patients in Group C. Urinary uric acid excretion rates decrease with age in pediatric patients and might impact on stone formation.[24] Struvite stones are the best marker of urinary tract infection. The incidence of struvite and calcium phosphate stones is decreasing because of early detection and vigorous treatment of urinary tract infection with antibiotics nowadays. Due to more chances of urinary tract infection in uncircumcised males and young females, these stones were more common in Group A than in Group C. Alaya *et al*. and Daudon *et al*. also found decreasing frequency of struvite and calcium phosphate stones with age.[14,23] The fact that no cystine stones were detected in Group C may be because the formation of cystine stone is genetically determined and most patients present in childhood.

In the past, struvite was the main component of staghorn calculus, but now, calcium oxalate predominates in staghorn stones.[1,16,25,26] In the present study, 143 out of 168 (85.11%) staghorn calculi were made up of oxalates followed by mixed composition in 12.51% as the second most common composition. Rest of 2.38% staghorns were made up of struvite. Again, the frequent use of antibiotics for urinary tract infection appears the reason of this changing trend.

The composition of vesical calculus usually differs between pediatric and adult patients. Vesical calculus in children is usually related to poor nutrition or urinary tract infection while in adults and old age patients, it is mostly because of bladder outlet obstruction. In our patients, calcium oxalate was the most common composition in vesical calculus in adults, but in pediatric patients of 8–12 years age, mixed stones containing struvite, calcium phosphate, and uric acid were the most common composition [Table 4].

CONCLUSION

The present study concludes that in Northwestern Rajasthan, calcium oxalate is the most frequent composition of urinary stones in all age groups. The incidence of calcium oxalate stone increases while that of struvite, uric acid, and cystine stone decreases with age. Further studies are needed to evaluate the mechanism behind these differences to decrease the incidence, prevalence, and recurrences of urinary stone disease.

REFERENCES

1. Ansari MS, Gupta NP, Hemal AK, Dogra PN, Seth A, Aron M, *et al*. Spectrum of stone composition: Structural analysis of 1050 upper urinary tract calculi from Northern India. Int J Urol 2005;12:12-6.
2. Singh I. Renal geology (quantitative renal stone analysis) by 'Fourier transform infrared spectroscopy'. Int Urol Nephrol 2008;40:595-602.
3. Moe OW. Kidney stones: Pathophysiology and medical management. Lancet 2006;367:333-44.
4. Coward RJ, Peters CJ, Duffy PG, Corry D, Kellett MJ, Choong S, *et al*. Epidemiology of paediatric renal stone disease in the UK. Arch Dis Child 2003;88:962-5.
5. Kabra SG, Gaur SV, Sharma SS, Patni MK, Benarji P. Urolithiasis incidence of urinary calculi in South Eastern Rajasthan. Report of 1144 cases. Indian J Surg 1972;34:261-9.
6. Haldiya KR, Bhandari NS, Singh Madhu B, Beniwal VK, Lakshmi Narayana J. Chemical composition of urinary calculi in desert region of Rajasthan, India. J Human Ecol 1999;10:69-72.
7. Kasidas GP, Samuell CT, Weir TB. Renal stone analysis: Why and how? Ann Clin Biochem 2004;41(Pt 2):91-7.
8. Basiri A, Taheri M, Taheri F. What is the state of the stone analysis techniques in urolithiasis? Urol J 2012;9:445-54.
9. Türk C, Knoll T, Petrik A, Sarica K, Skolarikos A, Straub M, *et al*. EAU Guidelines on Urolithiasis, Limited Update; 2016. p. 12.
10. Pearle MS, Goldfarb DS, Assimos DG, Curhan G, Denu-Ciocca CJ, Matlaga BR, *et al*. Medical management of kidney stones: AUA guideline. J Urol 2014;192:316-24.
11. Jindal T, Mandal SN, Sonar P, Kamal MR, Ghosh N, Karmakar D. Analysis of urinary stone composition in Eastern India by X-ray diffraction crystallography. Adv Biomed Res 2014;3:203.
12. Bangash K, Shigri F, Jamal A, Anwar K. Spectrum of renal stones composition; chemical analysis of renal stones. Int J Pathol 2011;9:63-6.
13. Marshall V, White RH, De Saintonge MC, Tresidder GC, Blandy JP. The natural history of renal and ureteric calculi. Br J Urol 1975;47:117-24.
14. Alaya A, Nouri A, Belgith M, Saad H, Jouini R, Najjar MF. Changes in urinary stone composition in the Tunisian population: A retrospective study of 1,301 cases. Ann Lab Med 2012;32:177-83.
15. Singh I, Gupta NP, Hemal AK, Dogra PN, Ansari MS, Seth A, *et al*. Impact of power index, hydroureteronephrosis, stone size, and composition on the efficacy of *in situ* boosted ESWL for primary proximal ureteral calculi. Urology 2001;58:16-22.
16. Ahlawat R, Goel MC, Elhence A. Upper urinary tract stone analysis using X-ray diffraction: Results from a tertiary referral centre in Northern India. Natl Med J India 1996;9:10-2.
17. Daudon M, Donsimoni R, Hennequin C, Fellahi S, Le Moel G, Paris M, *et al*. Sex- and age-related composition of 10 617 calculi analyzed by infrared spectroscopy. Urol Res 1995;23:319-26.
18. Choo-Kang E. Chemical composition of urinary tract stones at the University Hospital of the West Indies. West Indian Med J 2008;57:427-30.
19. Gabrielsen JS, Laciak RJ, Frank EL, McFadden M, Bates CS, Oottamasathien S, *et al*. Pediatric urinary stone composition in the United States. J Urol 2012;187:2182-7.
20. Pendse AK, Singh PP. The etiology of urolithiasis in Udaipur (Western part of India). Urol Res 1986;14:59-62.
21. Singh PP, Pendse AK, Rathore V, Dashora PK. Urinary biochemical profile of patients with ureteric calculi in Jodhpur region (North Western India). Urol Res 1988;16:105-10.
22. Costa-Bauzá A, Ramis M, Montesinos V, Grases F, Conte A, Pizá P, *et al*. Type of renal calculi: Variation with age and sex. World J Urol 2007;25:415-21.
23. Daudon M, Doré JC, Jungers P, Lacour B. Changes in stone composition according to age and gender of patients: A multivariate epidemiological approach. Urol Res 2004;32:241-7.
24. Stapleton FB, Linshaw MA, Hassanein K, Gruskin AB. Uric acid excretion in normal children. J Pediatr 1978;92:911-4.
25. Wall I, Hellgren E, Larsson L, Tiselius HG. Biochemical risk factors in patients with renal staghorn stone disease. Urology 1986;28:377-80.
26. Stamatelou KK, Francis ME, Jones CA, Nyberg LM, Curhan GC. Time trends in reported prevalence of kidney stones in the United States: 1976-1994. Kidney Int 2003;63:1817-23.

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