Urol Res (2011) 39:339–343
DOI 10.1007/s00240-011-0362-1

ORIGINAL PAPER

Infrared spectroscopic analysis of 5,248 urinary stones from Chinese patients presenting with the first stone episode

Xizhao Sun · Luming Shen · Xiaoming Cong · Huaijun Zhu · Lei He · Jianlin Lu

Received: 30 September 2010 / Accepted: 7 January 2011 / Published online: 20 January 2011

Abstract A series of 5,248 urinary stones was analyzed by Fourier transform infrared spectroscopy between 1999 and 2008. This study evaluated the percentage of each stone type and the association with sex and age in Chinese stone formers presenting with the first stone episode. The overall sex ratio (male:female) was 2.34:1. Results showed that the preponderant type of stone was calcium oxalate, followed by carbapatite, anhydrous uric acid, struvite and cystine. Struvite stones in this study accounted for a relatively low rate compared to that reported by others. Of 5,248 stones, only 38.1% had one component, 42.5% consisted of two components, and 20.4% consisted of three components. Our results also showed the higher percentage of carbapatite stones in females than in males and the increment of anhydrous uric acid stones with age. In addition, the percentage of calcium oxalate stones decreased with increase in the percentage of carbapatite stones over the period.

Keywords Urinary calculi · Chemical composition · China · Fourier transform infrared

X. Sun (✉) · L. Shen (✉) · X. Cong · L. He · J. Lu
Department of Urology, The Affiliated Nanjing Drum Tower Hospital of Nanjing University Medical School, Zhongshan Road 321, Nanjing 210008, Jiangsu, China
e-mail: sunxizhaonj@163.com

L. Shen
e-mail: shenluming2009@163.com

X. Cong
e-mail: oneon2n@163.com

L. He
e-mail: lyghelei@163.com

J. Lu
e-mail: ljlxx01@163.com

H. Zhu
Department of Pharmacy, The Affiliated Nanjing Drum Tower Hospital of Nanjing University Medical School, Nanjing, Jiangsu, China
e-mail: sesisi@163.com

Introduction

Urolithiasis is a relatively common disease in both developed and underdeveloped countries, and its prevalence has been gradually increasing over several decades [1, 2]. Although shockwave lithotripsy (SWL), ureteroscopy (URS) and percutaneous nephrostolithotomy (PCNL) are all effective methods to remove urinary stones, recurrence rates are estimated at about 10% per year, totaling 50% over a 5- to 10-year period and 75% over 20 years [3]. For these reasons, prevention of stone formation is of great importance. Knowing the urinary stone composition is frequently a key factor in determining its most appropriate management.

Stone analysis is a routine test for patients with urolithiasis in Western countries, but not in China. To our knowledge, there has been no large-scale data about stone composition in China, the most populous country in the world. Hence, we evaluated the percentage of each stone type and the association with sex and age by analyzing 5,248 urinary stones from Chinese patients.

Materials and methods

From 1999 to 2008, a series of 5,248 stone samples was received at our center. All of these stones were from patients presenting with their first stone episode. The stones were obtained from spontaneous passage, SWL, URS, PCNL and open surgery. All stones were washed and dried. A small part (1 mg) of stone sample was mixed with potassium bromide (200 mg KBr), powdered and then pressed into a small tablet. Finally, the tablet was analyzed by Shimadzu Fourier Transform Infrared Spectrophotometer 8300 (manufactured by Shimadzu Corporation, Japan).

Statistical significance was determined using chi-squared test and Spearman's rank correlation coefficient, with a P value of <0.05 considered as significant.

Results

There were 3,678 males and 1,570 females (6 months to 88 years) with a peak age of 31–40 years for both males and females. The overall sex ratio (male:female) was 2.34:1 and it was highest in young children, as well as in very old patients, while lowest in teenagers.

The stones were classified according to their major components (Table 1). The preponderant type of stone was calcium oxalate monohydrate (COM), followed by carbapatite, calcium oxalate dihydrate (COD), anhydrous uric acid, struvite and cystine. The other types were less than 1% of the cases. COM and anhydrous uric acid stones occurred more frequently in males than in females ($P < 0.001$), whereas carbapatite and struvite stones were more prevalent in females than in males ($P < 0.001$).

Of 5,248 stones, only 38.1% of stones had one component, 42.5% consisted of two components, and 20.4% consisted of three components (Table 2). Calcium stones accounted for over half of the cases.

Table 1 The percentage of each stone type classified according to the major component of the stone for both genders

	Overall		Male		Female	
	n	%	*n*	%	*n*	%
COM	2,780	52.97	1,946	52.91	834	53.12
Carbapatite	1,159	22.08	761	20.69	398	25.35
COD	757	14.42	569	15.47	188	11.97
Anhydrous uric acid	318	6.06	253	6.88	65	4.14
Struvite	88	1.68	41	1.11	47	2.99
Cystine	59	1.12	39	1.06	20	1.27
Ammonium urate	33	0.63	27	0.73	6	0.38
Brushite	13	0.25	9	0.24	4	0.25
Sodium urate	10	0.19	10	0.27	0	0
Calcium carbonate	12	0.23	9	0.24	3	0.19
Uric acid dihydrate	3	0.06	2	0.05	1	0.06
Others	16	0.3	12	0.33	4	0.25
Overall	5,248	100	3,678	100	1,570	100

Figures 1 and 2 show the percentage distribution of each stone type according to sex and age in single-component stones and mixed stones, respectively. There were some significant associations of the percentage between the age groups above 20 years old. In single-component stones, COM and struvite stones in females both increased with age ($P < 0.05$). Carbapatite and anhydrous uric acid stones in males decreased and increased with age, respectively ($P < 0.001$). In mixed stones, COM and anhydrous uric acid stones in males increased with age ($P < 0.05$).

The percentage of calcium oxalate (CaOx) stones decreased with increase in the percentage of carbapatite stones from 1999 to 2008. However, no obvious changes occurred in the percentage of non-calcium stones including uric acid, struvite and cysteine stones over the same period.

Discussion

The percentage of each stone type in different countries and areas differs markedly due to different socio-economic conditions, lifestyle and diet habits. For instance, there are significant differences among recent results from Spain and northern India [4, 5]. However, our results were similar to those of northern India: high rate of calcium oxalate and low rate of struvite stones.

COM was the most abundant stone type in most of the studies, and its formation is related to the high oxalate/calcium ratio in urine [6]. We also observed the highest rate of COM stone. The predominant vegetarian diet in China may be one of the reasons for its high oxalate content, which is also mentioned in a study from northern India [5]. COD stones were more prevalent in males than in females, and this could be ascribed to significant differences in urinary concentration of calcium and citrate between males and females. Urinary calcium excretion was higher in males than in females, whereas urinary citrate as a crystal inhibitor was higher in females [7].

This study also confirmed the higher percentage of carbapatite (the major form of calcium phosphate) stones in females than in males. Pak [8] reported that patients with renal tubular acidosis and primary hyperparathyroidism were more likely to have carbapatite stones or mixed calcium oxalate–carbapatite stones. Thus, the higher percentage in females can be partially explained by their greater tendency to have the two metabolic disorders [9, 10]. The pure carbapatite stones decreased with age in males, which may be attributed to the decline in urinary phosphorus and calcium concentration with age [4].

The formation of anhydrous uric acid stones is mainly related to acidic urine [11]. The present study highlighted the male preponderance of anhydrous uric acid stones, especially in patients over 50 years. In Japan, Ito et al. [12]

Table 2 The distribution of stones composed of single or multiple components

Stones with single component		Stones with two components		Stones with three components	
Component	*n*	Component	*n*	Component	*n*
COM	1,007	COM/carbapatite	816	COM/COD/carbapatite	552
Carbapatite	367	COD/carbapatite	430	Carbapatite/COM/COD	267
Anhydrous uric acid	272	COM/COD	292	Carbapatite/COD/COM	89
COD	120	Carbapatite/COD	241	COD/COM/carbapatite	78
Struvite	88	Carbapatite/COM	195	COM/carbapatite/COD	44
Cystine	59	COD/COM	89	COD/carbapatite/COM	39
Ammonium urate	33	Anhydrous uric acid/COD	46	Others	2
Brushite	13	COM/anhydrous uric acid	40		
Calcium carbonate	12	COM/brushite	29		
Sodium urate	10	COD/anhydrous uric acid	1		
Uric acid dihydrate	3				
Others	14				
Overall	1,998		2,179		1,071

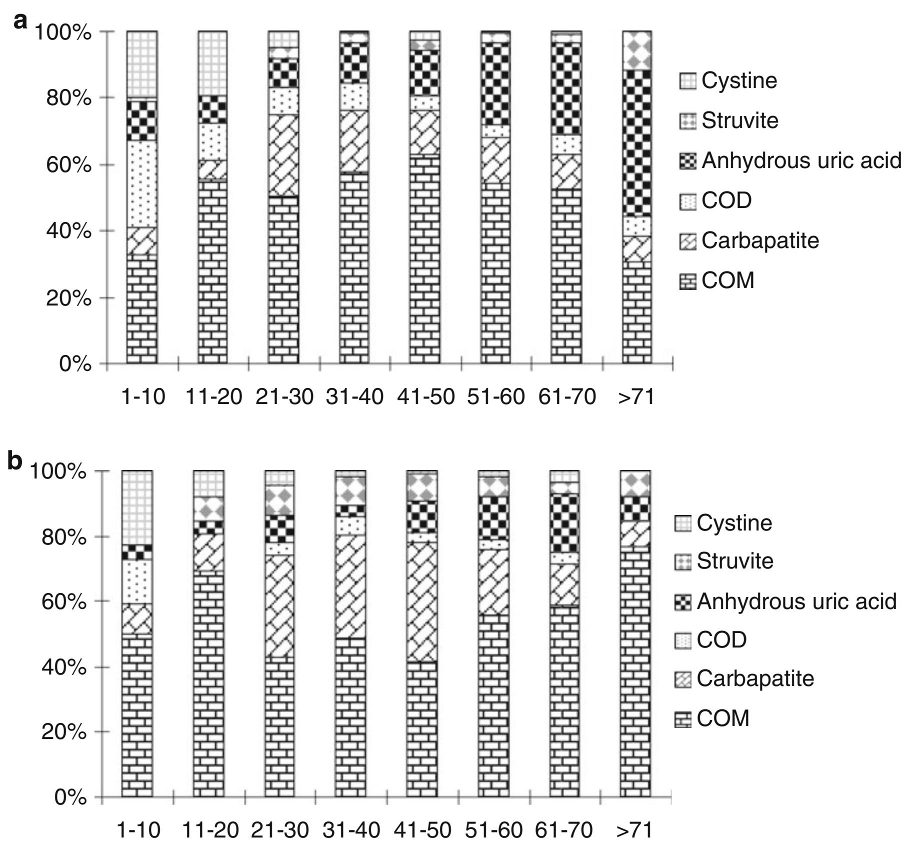

Fig. 1 Percentage distribution of each stone type according to sex and age in single-component stones. **a** Percentage distribution in males. **b** Percentage distribution in females

reported that the sex ratio of uric acid stones was 11:1, and the peak age group was 50–60 years. In view of the well-established pH dependence of uric acid nephrolithiasis, the rising rate of such stones with age may parallel a progressive defect in urine ammoniagenesis that manifests with aging [13], a main factor causing low urine pH in such stone formers [14, 15]. In addition, insulin resistance, the occurrence of which increases with age in both genders [16], may be a factor in acidic urine and uric acid stones in older patients [17].

Struvite stones are formed as a result of persistent infections caused by urease-producing bacteria [18].

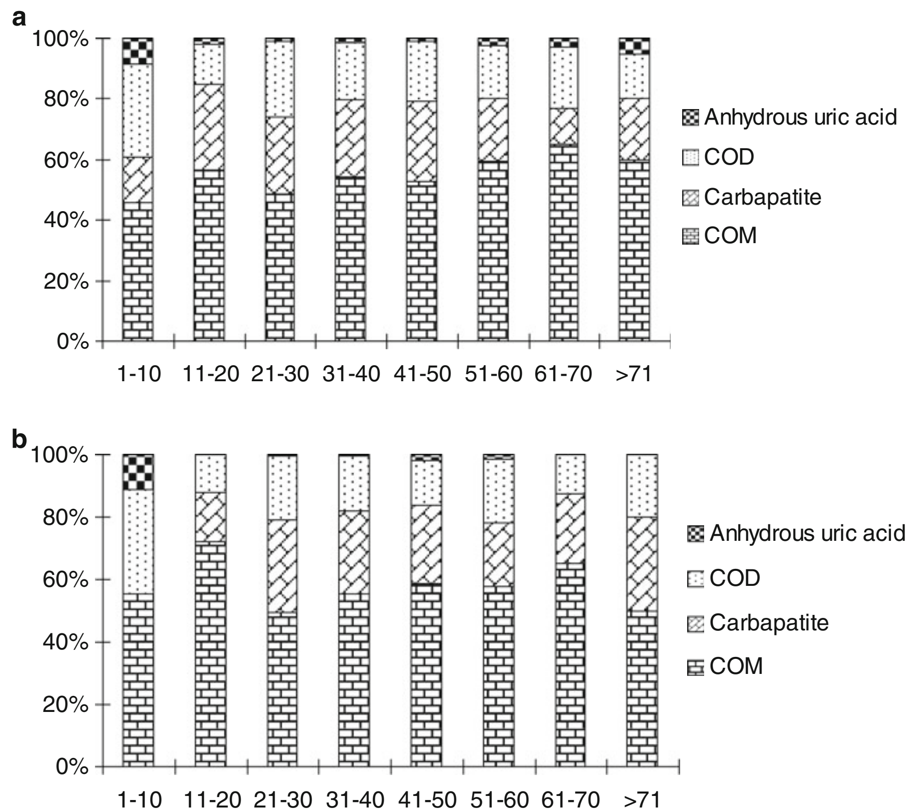

Fig. 2 Percentage distribution of each stone type according to sex and age in mixed stones. **a** Percentage distribution in males. **b** Percentage distribution in females

Historically, this stone type has been thought to account for 7–31% of urinary stones in the Western world [19]. Our study found a relatively lower rate of struvite stones (1.62%), similar to that reported in northern India [5]. Antibiotics abuse in China may be one major reason for this low rate of our study. In many countries, antibiotics are used for about one-third of hospitalized patients and two-thirds of the inpatient population in China. The rate of antibiotic use for outpatients in China was high as well.

Conclusions

Our results emphasize a high percentage of calcium oxalate stones and, in contrast, a low percentage of struvite stones in China. They also show the higher percentage of carbapatite stones in females than in males, and the increment of anhydrous uric acid stones with age in males. In addition, the percentage of calcium oxalate stones decreased with increase in the percentage of carbapatite stones over the period.

Acknowledgments The authors declare no competing interests. No other colleagues or institutions have been acknowledged.

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