

Infrared Spectroscopic Analysis of Urinary Tract Stones

Chien-Hsing Lu, Hsueh-Fu Lu, Wen-Chi Chen, Tracy Lee¹, Hsi-Chin Wu

Department of Urology, ¹Laboratory of Biochemistry, China Medical College Hospital; and School of Medicine, China Medical College, Taichung, Taiwan, R.O.C.

Background. Urinary tract stones are common urological disorders. However, there have been few studies of the stone composition in Central Taiwan. Infrared spectroscopy is a simple procedure used to analyze urinary stones. We conducted this study to evaluate the composition of urinary tract stones using infrared spectroscopy.

Methods. Most of the samples (89.8%) were obtained during endourological procedures and extracorporeal shock wave lithotripsies. The stone fragments were analyzed using a standard infrared procedure. The most common spectra were in the 4000–600 cm^{-1} region and a number of bands were identified.

Results. There were 1427 stone analyses done from August 15, 1993 through December 31, 1999 in this hospital. Of the patients who had stones removed, 16.8% had kidney stones, 5.5% had bladder stones, and 77.7% had ureteral stones. The results showed that 79.2% of stones were calcium oxalate related, 14% were infectious stones, 4.3% were uric acid related and 0.4% were cystine. The most frequently found microorganism in urine culture for infectious stones was *Proteus mirabilis*. Benign prostatic hyperplasia was the major disease associated with urinary bladder stones in men (80%). However, no associated disorders were found in female patients. Foreign bodies within stones were seen in two female patients and one of them was intrauterine device. Infectious stones were predominant in female patients which consisted 60% (120/200) of the stones.

Conclusions. A total of 79.2% stones were composed calcium oxalate. Infectious stones were predominantly found in female patients. Urinary bladder stones were frequently seen in older male patients with benign prostatic hyperplasia. Further study of patients with stones should focus on the calcium oxalate because it is the major composition. Women with urinary stones should be carefully examined due to the high possibility of urinary tract infection. (Mid Taiwan J Med 2000;5:73-8)

Key words

infrared spectroscopy, stone analysis, urolithiasis

INTRODUCTION

Urinary tract stones are relatively common occurrences in industrialized countries where they affect about 5% to 12% of the population

[1,2]. In addition, there has been increasing incidence of urinary tract stones during the past two decades in the countries with high socioeconomic standards [3]. An increasing trend of calcium oxalate stones is related to the increased consumption of animal proteins as well [3,4]. Since Taiwan is a developing country with increasingly better socioeconomic conditions, it is not surprising that

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Address reprint requests to: Wen-Chi Chen, Department of Urology, China Medical College Hospital, No 2, Yuh-Der Road, Taichung 404, Taiwan, R.O.C.

urinary tract stones have become one of the major urological diseases in Central Taiwan. The patients with stones include 40% of the population in the outpatient department as well as 60% of the population in the inpatient department of this hospital. However, there have been few studies which have reported the composition of stones that occurred in patients in Central Taiwan.

One of the ways to effectively treat stone recurrence in stone-forming patients is to know the stone composition. There have been many methods suggested for the analysis of the composition of urinary stones. Infrared (IR) spectroscopy is an effective and easy method for the examination of the composition of stones, and it was highly regarded in reports by Daudon et al and Donsimoni et al [5,6]. IR spectra are directly involved with the vibrations of the atoms or groups of atoms in a molecule. Vibrational frequencies are associated with functional groups and are used to identify the structural units present in a compound. This technique is specific, rapid and versatile and can be used with crystalline and amorphous substances. IR analysis has many advantages over classic chemical analyses whose results have often been incorrect or inclusive. IR also has advantages over other instrumental methods such as X-ray and electron diffraction which cannot be used to analyze samples of amorphous or poorly crystallized materials [7]. However, with the improvement of stone operations such as extracorporeal shockwave lithotripsy (ESWL), ureteroscopy, and variable intraluminal lithotriptors, the stones can only be obtained in fragments which prevented us from doing the analysis through stereomicroscopy before the procedure of IR. Thus, examination of the stones including the peripheral region and core region was impossible. The aim of this study was to investigate the distribution of stone composition using IR of stone fragments.

PATIENTS AND METHODS

The samples were obtained from several different sources of patient groups. Each stone was fragmented into a powdered format, compressed into a nearly transparent wafer with potassium bromide, and then examined using the BioRad IR-7 infrared spectroscope (Hercules, California). The standard procedure for the interpretation of the data obtained from IR spectra was based on the previous report by Oliver and Sweet and Hesse et al [8,9]. We retrospectively subdivided the patients into different groups according to age, gender, and stone composition. Those with compositions of struvite and apatite were considered to have infectious stones [10]. Patients were further reviewed for related diseases using medical history and laboratory data results.

RESULTS

A total of 1427 stones were analyzed using IR from August 15, 1993 through December 31, 1999. Surgical treatments, including 41 open surgeries (2.9%), 914 endourological procedures (64.1%), 367 ESWL (25.3%) and 105 patients (7.4%) who spontaneously passed their stones were included. Table 1 lists the original sites of the stones that were classified as kidney, ureter or urinary bladder. There were 969 men and 458 women in this study with the ratio of 2.1 : 1. The composition of the stones consisted of 79.2% (n = 1130, 815 were males and 315 were females) were calcium oxalate related (included calcium oxalate monohydrate, dihydrate, and mixed type), 14% (n = 200) were infectious stones, 4.3% (n = 61) had uric acid stones and four (0.4%) patients had cystine stones. Table 2 presents the data on the distribution of stone composition according to gender. The variations in the age distribution of the patients are shown in Fig. 1. The results of urine culture in patients with infectious stones showed *Proteus mirabilis* (4.0%), *Pseudomonas aeruginosa* (20%), *E. coli* (15%) and no growth (25%).

Table 1. Origins of urinary tract stones

	Kidney No. (%)	Ureter No. (%)	Bladder No. (%)	Total No. (%)
Male	180 (12.6)	769 (53.9)	65 (4.6)	1014 (71.4)
Female	60 (4.2)	340 (23.8)	13 (0.9)	413 (28.9)
Total	240 (16.8)	1109 (77.7)	78 (5.5)	1427 (100.0)

Table 2. Composition of urinary tract stones

Compositon	Male No. (%)	Female No. (%)	Total
COM	71 (5.0)	31 (2.2)	102
COD	24 (1.7)	12 (0.8)	36
COM+COD	81 (5.7)	18 (1.3)	99
COM+APA	193 (13.5)	104 (7.3)	297
COD+APA	137 (9.6)	54 (3.8)	191
COM+COD+APA	309 (21.7)	96 (6.7)	405
APA	69 (4.8)	73 (5.1)	142
Brushite	20 (1.4)	11 (0.8)	31
Struvite	11 (0.8)	47 (3.3)	58
Uric acid	28 (1.9)	20 (1.4)	48
Urate	5 (0.3)	0 (0.0)	5
COM+uric acid	6 (0.4)	2 (0.1)	8
Cystine	5 (0.3)	0 (0.0)	5
Total	959 (67.2)	468 (32.8)	1427

COM = calcium oxalate monohydrate; COD = calcium oxalate dihydrate; APA = apatite.

Of the 65 male patients with bladder stones, 52 were diagnosed with benign prostatic hyperplasia. Their stones were removed using endoscopic fragmentation during the procedure of transurethral resection of the prostate. There were two children (6 and 9 years old, respectively) with bladder stones but no definite etiology was found from the results of serial urological

surveys such as excretory urography, cystoscopy and ultrasonography. The compositions of the stones were apatite and calcium oxalate monohydrate. There were foreign bodies within the bladder stones of two adult females that were struvite and apatite in composition. One of the foreign bodies was an intrauterine device that has been reported elsewhere [11].

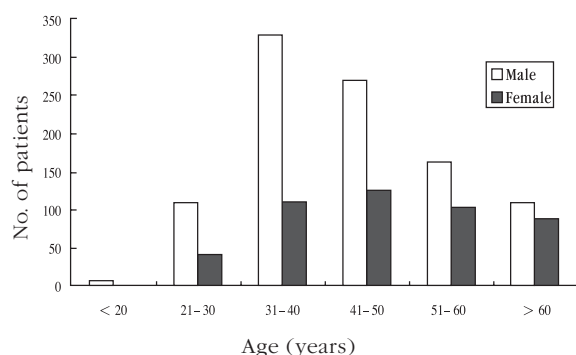


Fig. 1 Age and gender distribution of patients with urinary tract stones.

DISCUSSION

The results presented from the 1427 urinary stones analyzed using IR revealed that 1130 (79.2%) were calcium oxalate stones. This is consistent with the results of previous reports [5,6]. The age distribution in the groups was also consistent with the results of a previous report that most patients were between 31 to 50 years old [12]. The gender ratio varied according to the stone composition. Calcium oxalate stones were more

frequently found in men than in women with a ratio of 2.6:1, that is higher than the average ratio for the whole group in this study. Whereas, apatite and struvite were the most frequently encountered composition in middle-aged female patients, which could be due to a high incidence of urinary tract infection in this group. The findings revealed that a mixed composition of stone was predominant, and occurred in 1000 (70.1%) patients. One possible explanation is that most of the samples were obtained from lithotripsy fragments (89.8%), instead of intact stones.

Cystine stone disease is an autosomal recessive hereditary inborn error of metabolism in which patients excrete relative insoluble amino acid of cystine into the urine. The prevalence of cystine stone disease was observed in men but the cause is still poorly understood. The percentage of uric acid stones (4.3%) was relatively lower than that of other reports which varied from 7% to 13% [6]. This may be due to that most of our stones were obtained during endourological and ESWL procedures. Radiological targeting was required to localize the stones during treatment whereas uric acid is relatively invisible using radiological imagings.

Most of the bladder stones in the male group were due to bladder outlet obstruction, whereas factors responsible for bladder stones in children have not been determined. Scott reported that vesicle stones in children were predominant in communities with relatively lower socioeconomic status [13]. Although Taiwan is a developing country, it is evident that there is a relatively low incidence of children's bladder stones in this report. Foreign bodies per se within urinary bladder can be a risk factor for stone formation. A forgotten catheter or migrating intrauterine device should be carefully followed up for the long-term risk of stone formation. However, the possible causes of bladder stones in women and children should be investigated further.

Infectious stones occurred in 200 patients

(14%) in this report. This result is similar to the results in a report by Daudon et al [5]. However, in the male group infectious stone only occurred in 8% of the population (80/966). While over 40% (120/468) of female patients in this analysis had infectious stones. This may be related to the higher incidence of urinary tract infections in women. This reminds us that female patients should be more carefully examined before stone treatments such as, endourological procedures or ESWL are given. Urine routine and urine culture seem essential for the female patients because of the high risk of infection. Early detection and treatment for infectious stones in female patients is crucial to the successful management and of prevention complications.

It has been reported that the incidences of different types of stones have changed during the past 20 to 25 years; now more calcium stones and fewer infectious stones occur [14]. This result is compatible with our present study. Therefore, to search for the causes of the increased incidence of calcium stones becomes more important than before. Because of the age at onset of stone formation has also fallen [14], hereditary causes should be paid more attention to in future studies.

In conclusion, the major composition of kidney stones in Central Taiwan was calcium oxalate, and *Proteus* infection was be the major infectious microorganism in the infectious stone group. These data were consistent with those presented in other serial reports. Our future studies on the pathogenesis of stone formation will focus on the calcium oxalate groups.

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紅外線光譜的尿路結石分析

盧建興 呂學甫 陳汶吉 李翠綺¹ 吳錫金

中國醫藥學院附設醫院 泌尿部 檢驗部¹

背景 尿路結石是泌尿系統常見的疾病之一，但在中台灣結石成份分析的報告並不多。紅外線光譜儀是分析尿路結石成份的簡便儀器，本研究以此儀器分析本院病患的尿路結石。

方法 從1993年8月15日至1999年12月31日，共施行了1427個尿路結石分析，結石分佈以輸尿管佔最多為77.7%，而腎結石佔16.8%，膀胱結石則佔了5.5%。大部份結石的標本是從碎石手術得來(佔89.8%)，取得之結石碎片予以進行標準的紅外線光譜儀檢驗。

結果 草酸鈣類相關結石最多佔了79.2%，感染結石佔14%，尿酸相關結石佔4.3%，而胱氨酸只佔了0.4%。從感染結石病人的尿液培養中發現變形桿菌是最多的細菌。男性病患的膀胱結石主要合併的疾病是良性前列腺增生症(80%)，而女性病患則無明顯相關疾病，60%的感染結石發生在女性病患。

結論 紅外線光譜儀可以檢驗很多不同來源的尿路結石碎片，草酸鈣結石是最主要的尿路結石成份。感染結石較常發生於女性病患，膀胱結石常見於前列腺增生症的病人。結石病人的進一步研究應著眼於草酸鈣結石病人，因為此類結石最多，有尿路結石的婦女應小心檢查其患尿路感染的高可能性。(中台灣醫誌 2000;5:73-8)

關鍵詞

紅外線光譜儀，結石分析，尿路結石

聯絡作者：陳汶吉

地址：404 台中市北區育德路2號

中國醫藥學院附設醫院 泌尿部

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