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The Infrared Spectroscopic Analysis of Urinary Stone Composition in the Liuyang Region

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Abstract

To better understand the composition of urinary stones in the Liuyang region of Changsha, Hunan Province, and to provide insights for the prevention and treatment of urolithiasis in this area. We retrospectively collected and analyzed the infrared spectroscopic results of stone composition from 594 patients at Liuyang People's Hospital between January 1, 2024, and June 30, 2024. Among the 594 cases of urinary stones, 383 were male and 211 were female, revealing a statistically significant difference in gender distribution ($P < 0.05$), with a higher proportion of male patients compared to female patients. In terms of stone composition, 542 cases were classified as mixed-composition stones, while only 52 cases were identified as single-composition stones, indicating that mixed-composition stones were significantly more prevalent than single-composition stones ($P < 0.05$). The statistical analysis of the infrared spectroscopic composition of stones in patients from the Liuyang region provides an important reference for the prevention and treatment of urolithiasis in this population.

Keywords

Urinary stones; Infrared spectroscopic analysis; Prevention and treatment

Urolithiasis is a prevalent condition in China, with varying prevalence rates across different regions. Notably, there is a generally higher incidence in the southern regions compared to the north [1]. The clinical manifestations of urolithiasis are diverse and depend on factors such as the size, location, and mobility of the stones. Common symptoms include flank or abdominal pain, hematuria, and urinary symptoms such as frequency, urgency, and dysuria. When stones cause urinary obstruction, they can lead to severe complications, including hydronephrosis and renal function impairment. Additionally, the long-term presence of stones may irritate the local mucosa, resulting in chronic inflammation, polyp formation, and even carcinogenesis [2]. The occurrence of urinary stones is influenced by a combination of environmental, climatic, cultural, nutritional, and hereditary factors [3]. Preventive strategies for both newly developed and recurrent stones are essential to reduce the physical and financial burden on patients [4]. Hence, the prevention of urolithiasis is of paramount importance in medical practice, as it not only reduces the incidence of this common condition but also prevents the onset of severe complications that can significantly affect patients' quality of life and overall health. By implementing preventive measures, individuals can lower their risk of developing urinary stones, thereby minimizing the potential for acute pain, urinary tract infections, renal dysfunction, and even long-term consequences such as chronic inflammation and malignancy [5]. Identifying the composition of kidney stones is essential for determining the underlying cause of urolithiasis, which aids in developing personalized treatment and prevention strategies [6]. Currently, infrared spectroscopy is widely used for analyzing the composition of stones [7].

A Comprehensive Epidemiological and Chemical Compositional Study of 594 Urinary Stone Specimens Collected in Liuyang Region Between January 1st and June 30th, 2024, Employing Infrared Spectroscopy: Insights into

Regional Prevalence, Chemical Profiles, and Potential Etiologies for Tailored Preventive and Therapeutic Interventions.

1. Samples and Methods

Clinical data and stone analysis results of patients with urinary calculi who underwent infrared spectroscopy stone composition analysis at Liuyang People's Hospital from January 1, 2024, to June 30, 2024, were collected and analyzed. All patients with calculi in this study were from Liuyang and its surrounding areas. These stone samples were obtained through drug-assisted expulsion, surgery (open surgery, ureteroscopic lithotripsy, and percutaneous nephrolithotomy), or extracorporeal shock wave lithotripsy. A total of 594 patients underwent stone composition analysis, including 383 males and 211 females, with a male-to-female ratio of 1.82:1. The age range was 23-93 years, with a mean age of 54.4 years.

The "LIIR-20 Infrared Spectroscopy Automatic Stone Analysis System" (Fig. 1) produced by Lanmode (Tianjin) Scientific Instrument Co., Ltd. was used for stone composition analysis. The stones were washed clean with water, and a certain amount of KBr crystals were ground into a powder in an agate mortar and dried in an oven at 100°C for future use. The stone samples to be tested were naturally air-dried or dried under an infrared lamp for future use. Approximately 150 mg of dried KBr powder and about 1.5 mg of stone sample were weighed and mixed in the mortar. The mixture was ground thoroughly in the same direction (clockwise or counterclockwise) until no visible particles remained. The resulting powder was poured into a pressing mold (with the column core fitted over the short column and the bowl facing upwards) and smoothed as much as possible. The long column was slowly inserted into the column core and gently rotated to ensure an even distribution of the powder. The mold was then placed in a tablet press to form a pellet, which was quickly inserted into the instrument for testing. The computer automatically analyzed and reported the stone composition after generating and interpreting the spectrum.

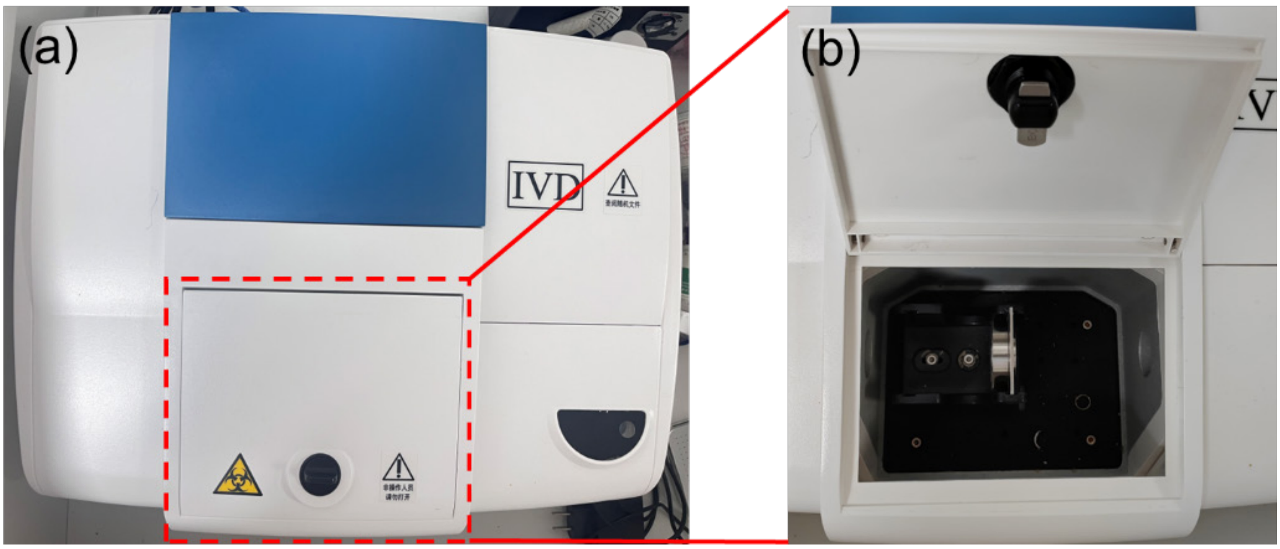

Figure 1. LIIR-20 Infrared Spectroscopy Automatic Stone Analysis System.
(a) Overall system diagram, (b) The Sample Cavity.

2. Results

Among the 594 cases of urinary calculi, 383 were male patients and 211 were female patients. There were 52 cases of pure stone composition and 542 cases of mixed stone composition. The chi-square test revealed that the proportion of male patients was significantly higher than that of female patients ($P < 0.05$), and mixed stones were significantly more prevalent than stones with a single composition ($P < 0.05$). The detailed number of stones by their respective compositions is presented in the table below.

Table 1. Results of Stone Composition Analysis

Single Component Stones (52 cases)		Two-Component Stones (435 cases)		Three-Component Stones (107 cases)	
Uric acid anhydrous	12	Calcium oxalate monohydrate, Calcium oxalate dihydrate	287	Calcium oxalate monohydrate, Calcium oxalate dihydrate, Carbonate apatite	95
Calcium oxalate dihydrate	11	Calcium oxalate dihydrate, Carbonate apatite	63	Calcium oxalate monohydrate, Calcium oxalate dihydrate, Uric acid anhydrous	7
Carbonate apatite	11	Calcium oxalate monohydrate, Carbonate apatite	61	Carbonate Apatite, Calcium hydrogen phosphate dihydrate, Calcium Oxalate Dihydrate	3
Calcium oxalate monohydrate	9	Calcium Oxalate Dihydrate, Uric acid anhydrous	10	Calcium oxalate dihydrate, Ammonium urate, Calcium oxalate monohydrate	2
Magnesium ammonium phosphate hexahydrate	4	Carbonate apatite, Magnesium ammonium phosphate hexahydrate	6		
Ammonium urate	3	Hydroxyapatite, Calcium oxalate dihydrate	3		
Calcium hydrogen phosphate dihydrate	1	Calcium oxalate dihydrate, Ammonium urate	2		
Xanthine	1	Calcium oxalate monohydrate, Uric acid anhydrous	2		
		Carbonate Apatite, Calcium hydrogen phosphate dihydrate	1		

3. Discussion

Here, we retrospectively analyzed the infrared spectroscopy test results of the composition of urinary calculi in the Liuyang area. There were more male patients in the Liuyang area, and most of the calculi were mixed in composition. The results showed the main chemical composition of calculi in this area and their possible formation mechanisms. This study is of great significance for understanding the epidemiological characteristics of calculi in this area and providing the basis for prevention and treatment.

Through our analysis, we have discovered that calcium oxalate stones account for a significantly high proportion of urinary calculi in the Liuyang region. The high incidence of calcium oxalate stones may be closely linked to the dietary habits of local residents, particularly the consumption of high-oxalate foods such as spinach and nuts. Additionally, the high concentration of calcium ions in the local water supply may further contribute to the formation of calcium oxalate stones [8]. It is recommended that patients undertake dietary interventions and improve water quality to reduce the risk of stone formation.

Furthermore, we have also observed a relatively high prevalence of carbonate apatite stones. The high proportion of carbonate apatite stones may be closely associated with elevated concentrations of calcium, phosphorus, and carbonate in urine. Another potential factor is metabolic abnormalities, such as primary hyperparathyroidism, which can disrupt the balance of calcium and phosphorus metabolism, thereby facilitating the formation of carbonate apatite stones [9]. An alkaline urine environment also favors the precipitation of carbonate apatite [10]. Consequently, it is advisable to adjust dietary habits (e.g., reducing phosphorus intake and increasing fluid intake) and undergo regular physical examinations to monitor urine and blood calcium and phosphorus levels, with the aim of reducing the incidence of carbonate apatite stones.

In the infrared spectroscopy analysis of urinary calculi in the Liuyang region, we have identified a diverse range of stone compositions, highlighting the complexity of stone formation in this area. This diversity may reflect the combined influence of multiple physiological, metabolic, and environmental factors. Further metabolic studies, dietary and environmental assessments, as well as in-depth investigations into different stone-forming mechanisms, are warranted. We eagerly anticipate the emergence of more research in these areas in the future.

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