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Analysis on Chemical Composition of Urinary Calculi and Evaluation on Metabolic Disturbance in 1080 Uyghur, Kazakh and Han Nationality Patients of Xinjiang

Muhammad Rizwan Farooqi[1], Hamulati Tusong[1], Kaisaier Aji[1] and Wang Yu Jie[1*]

[1]Department of Urology, The First Affiliated Hospital of Xinjiang Medical University, Urumqi, Xinjiang, China

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***Corresponding Author:**
Wang Yu Jie
Department of Urology, The First Affiliated Hospital of Xinjiang Medical University, Urumqi, Xinjiang, China
wangyj-mr@vip.sina.com

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ABSTRACT

Urinary stones pose a significant health concern globally. The incidence rates vary and are influenced by diverse factors. Despite advancements in the treatment modalities, increasing rate of urinary stones necessitates the development of stone prevention strategies and understanding of metabolic risk factors. **Objective:** To determine the relationship between chemical composition of urinary calculi and evaluation on metabolic disturbance in 1080 Uyghur, Kazakh and Han patients of Xinjiang. **Methods:** The stone composition of 1080 patients and analysis of 24-h urine and serum biochemistry results of 775 cases was evaluated by infrared spectroscopic analysis and automatic biochemical machine respectively **Results:** Among 644 cases of urinary stones, calcium oxalate stones (409 cases) and mixed type stones (436 cases) were predominant. Metabolic disturbances were found in 643 cases (82.97%) out of 775 patients, showing various urinary abnormalities like hyperuricosuria, hyperoxaluria, hyper-phosphaturia, hyper-cystinuria, hypercalciuria, hypomagnesuria, hypocitraturia, and reduced urine volume (<2000ml in 407 cases). **Conclusions:** Urinary calculi have intimate connection with metabolic evaluation. Metabolic evaluation and composition of urinary calculi have great significance in treatment and prevention of urinary calculi.

INTRODUCTION

Urinary system stones are a prevalent condition within urological diseases, ranking first or second in the spectrum of urological diseases, especially among inpatients in urology departments [1]. Epidemiological data from Western countries indicate that 5-10% of individuals experience urinary system stones at least once in their lifetime [2], with the incidence in Europe ranging from 100 to 400 cases per 100,000 people [3]. As China's economy advances, social development accelerates, and living standards rise, dietary habits undergo significant changes, leading to an overall increase in the incidence of urinary system stones, estimated at 3% to 8%. The Southern regions of China, with higher economic development, exhibit even higher incidence rates of 5-10% [4]. Xinjiang, a region in China and a high-risk area for urinary system stones, experiences an annual incidence rate of 200 to 500 cases per 100,000 people, with approximately 43% of cases requiring hospitalization [5]. Urinary system stone incidence is influenced by various factors such as patient gender, age, ethnicity, occupation, water quality, climate, geographical location, body mass index (BMI), lifestyle, and water intake [5]. Depending on the location of stone formation, different degrees of damage can occur, ranging from obstruction to severe impairment of kidney function,

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potentially requiring lifelong dialysis. Despite advancements in the treatment of urinary system stones, such as extracorporeal shock wave lithotripsy, percutaneous nephrolithotomy, ureteroscopy, holmium laser lithotripsy, pneumatic ballistic lithotripsy, and laparoscopic stone removal, the incidence of urinary system stones is on the rise [6]. Stone prevention has become a focal point of concern for urologists. In recent years, with in-depth research on the causes of urinary system stones, urologists have increasingly emphasized the metabolic risk factors associated with stone formation [7]. There have been reports on the composition of stones in Uyghur patients in the southern part of Xinjiang, but there is a lack of comparative studies on the stone compositions and metabolic characteristics of various ethnic groups in Xinjiang [8, 9]. This study focuses on 1080 patients with urinary system stones treated in our hospital from 2009 to 2012, analyzing their stone compositions using infrared spectroscopy. Additionally, we conducted a comprehensive analysis of serum biochemical indicators and 24-hour urine electrolyte components in 775 of these patients using an automatic biochemical analyzer. By determining the stone compositions and metabolic characteristics of patients with urinary system stones and conducting comparative analyses among different ethnic groups, this study aims to provide relevant guidance for analyzing the causes of urinary system stones in the region and offer important clues for stone prevention and preventing stone recurrence.

METHODS

It is a retrospective cross-sectional study conducted in the Urology Department of Xinjiang Hospital from March 2018 - December 2021. Specimens from a total of 1080 patients with urinary system stones who were treated in this duration of approximately three years were included, comprising 571 specimens from Uyghur patients, 45 from Kazakh patients, and 464 from Han Chinese patients. Specimens from 775 patients who underwent complete serum biochemical and urine electrolyte tests upon admission were selected for further analysis. Patients diagnosed with urinary system stones but did not receive treatment to obtain stone specimens. Patients diagnosed with urinary system stones but did not receive treatment to obtain stone specimens and those with incomplete biochemical or urine electrolyte test results were excluded from the study. For analysis and determination of stone composition, The IR Prestige-21 Fourier Transform Infrared Spectrometer, a press machine, ZW-5A temperature-controlled drying oven, molecular sieve drying apparatus (Chengdu Scientific Instrument Company, China), agate mortar (Beijing Chengke Scientific Equipment Company, China), ammonium magnesium phosphate hexahydrate, potassium bromide, L-cysteine, calcium oxalate, and other reagents (Shanghai Martin Reagent Co., Ltd., China) were used. The reagents were thoroughly ground in an agate mortar, placed in a temperature-controlled drying oven for sufficient drying, and then transferred to the molecular sieve drying apparatus. The stone specimen's surface residues were rinsed 2-3 times with distilled water, allowed to air dry naturally (room temperature: 20-29°C). After complete drying, the prepared potassium bromide powder and the stone specimen were mixed thoroughly and ground in the agate mortar. The mixture was then placed in the temperature-controlled drying oven for drying, not exceeding 5 minutes (prolonged exposure to high temperatures may cause crystal dehydration, significantly affecting the analysis results). After removal, it was ground for about a minute and then pressed into a pellet (thickness not exceeding 0.5 millimeters) using a press machine. The prepared pellet was quickly placed into the Fourier Transform Infrared Spectrometer [10]. Comparative analysis with the spectral library using computer processing yielded the stone's composition. All selected patients underwent fasting blood collection upon admission for serum biochemical analysis. A 24-hour urine sample was collected, and 10ml of the well-mixed urine was sent to the laboratory in a specialized container for electrolyte analysis. Biochemical and urine electrolyte results were obtained using our hospital's automated biochemical analyzer. Statistical analysis included patient age, gender, stone distribution location, stone composition results, ion concentrations (calcium, magnesium, phosphorus, potassium) in urine, and serum biochemical ion concentrations. Data were statistically analyzed using SPSS 21.0 software. Group differences were compared using the chi-square test for categorical data and the t-test for grouped continuous data. A significance level of $P<0.05$ was considered statistically significant.

RESULTS

This study included a total of 1080 cases of urinary system stone specimens, with a gender distribution of 737 males (68.24%) and 343 females (31.76%), spanning an age range from 2 months to 93 years. Among the male cases, Uyghurs accounted for 381 (35.28%), Kazakhs 28 (2.59%), and Han Chinese 328 (30.37%). In the female cases, Uyghurs represented 190 (17.61%), Kazakhs 17 (1.57%), and Han Chinese 136 (12.59%). The overall age distribution included: ≤10 years (241 cases, 22.31%), ≤20 years (110 cases, 10.18%), ≤30 years (152 cases, 14.07%), ≤40 years (186 cases, 17.22%), ≤50 years (182 cases, 16.85%), ≤60 years (104 cases, 9.62%), ≤70 years (71 cases, 6.76%), ≤80 years (29 cases, 2.69%), ≤90 years (4 cases, 0.37%), ≤95 years (1 case,

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0.09%) as demonstrated in table 1.

Table 1: Gender and Age-wise Distribution Among Uyghur, Han Chinese, and Kazakh Patients [N (%)]

Variables	Ethnicity			
	Uyghur	Han Chinese	Kazakh	Total
Gender-wise distribution of patients (%)				
Male	381 (35.28)	28 (2.59)	328 (30.37)	737 (68.24)
Female	190 (17.61)	17 (1.57)	136 (12.59)	343 (31.76)
Age-wise distribution of patients (%)				
≤10	214 (19.87)	23 (2.12)	4 (0.37)	241 (22.31)
11-20	90 (8.33)	20 (1.85)	0 (0)	110 (10.18)
21-30	106 (9.81)	30 (2.77)	16 (1.48)	152 (14.07)
31-40	70 (6.48)	101 (9.35)	15 (1.39)	186 (17.22)
41-50	53 (4.90)	126 (11.67)	3 (0.27)	182 (16.85)
51-51	20 (1.85)	83 (7.68)	1 (0.09)	104 (9.62)
61-70	12 (1.11)	53 (4.91)	6 (0.55)	71 (6.76)
71-80	6 (0.55)	23 (2.13)	0 (0)	29 (2.69)
81-90	0 (0)	5 (0.46)	0 (0)	5 (0.46)
Total	571 (52.87)	464 (42.96)	45 (4.17)	1080 (100)

The distribution of stones based on location included: renal stones 860 cases (79.63%), left renal stones 671 cases (21.13%), right renal stones 169 cases (15.31%); ureteral stones 164 cases (15.19%), left ureteral stones 152 cases (14.07%), right ureteral stones 12 cases (1.29%); bladder stones 51 cases (4.72%), urethral stones 5 cases (0.46%) as shown in table 2.

Table 2: Stone Distribution in Uyghur, Han Chinese, and Kazakh Patients [N (%)]

Site	Ethnicity			
	Uyghur	Han Chinese	Kazakh	Total
Kidney	498 (46.11)	323 (29.91)	39 (3.63)	860 (79.63)
Ureter	46 (4.44)	115 (10.65)	3 (0.27)	164 (15.19)
Bladder	22 (2.60)	26 (2.31)	3 (0.27)	51 (4.72)
Urethra	5 (0.46)	0 (0)	0 (0)	5 (0.46)
Total	571 (52.87)	464 (42.96)	45 (4.17)	1080 (100)

In serum biochemistry, only a few items considered related to the etiology of urinary stones, such as Mg2+, Ca2+, P5+, UA, were selected for statistical comparison analysis [11]. The results are as follows: There were no statistically significant differences in blood Mg2+ and Ca2+ between Uyghurs and Han Chinese, Uyghurs and Kazakhs, and Kazakhs and Han Chinese. There was a statistically significant difference in blood P5+ between Uyghurs and Han Chinese (P<0.05), no significant difference between Uyghurs and Kazakhs (P>0.05), and a significant difference between Kazakhs and Han Chinese (P<0.05). The specific results are detailed in the following table 3.

Table 3: Serum Biochemistry Comparison in Uyghur, Han Chinese, and Kazakh [mmol/L]

Site	Ethnicity		
	Uyghur	Kazakh	Han Chinese
Ca^{2+}	2.25±0.34	2.21±0.09	2.24±0.04
Mg^{2+}	1.07±0.13	1.05±0.19	1.03±0.16
UA	282.23±98.34	279.42±97.45	294.2±71.34
P^{5+}	1.34±0.40	1.22±0.38	0.88±0.34

Uyghurs had statistically significant differences (P<0.05) with Han Chinese in urine specific gravity (SG) and 24-hour urine uric acid (UA), with Uyghurs higher than Han Chinese. Uyghurs also had mean values of urine K+, Na+, and UA above the normal range, while urine pH and urine volume were lower than Han Chinese. There were no statistically significant differences (P>0.05) in urine specific gravity (SG) and 24-hour urine uric acid (UA) between Uyghurs and Kazakhs, but there were significant differences (P<0.05) between Kazakhs and Han Chinese, with Kazakhs higher than Han Chinese. Kazakhs also had mean values of urine K+, Na+, and UA above the normal range, while urine pH and urine volume were lower than Han Chinese. According to the standards for urine metabolism abnormalities, 644 patients (83.09%) showed metabolic abnormalities, including 158 cases (24.5%) of hypercalciuria, 234 cases (36.8%) of hyperuricosuria, 265 cases (41.12%) of hyper-phosphaturia, 230 cases (35.7%) of hypomagnesuria, and 330 cases (51.2%) of low urine volume. Detailed results of urine electrolytes, 24-hour urine volume comparison, urine specific gravity and pH are shown in table 4.

Table 4: Comparison of Urine Electrolytes, 24-Hour Urine Volume [mmol/24h], Urine Specific Gravity and pH in Uyghur, Han Chinese, and Kazakh

Variables	Ethnicity		
	Uyghur	Kazakh	Han Chinese
Urine Electrolytes and 24-Hour Urine Volume [mmol/24h]			
K^{+}	156.56±144.40	147.33±130.34	59.32±43.56
Na^{+}	218.65±143.35	221±140.78	178.45±90.50
Ca^{2+}	6.78±5.01	5.99±4.02	5.09±2.99
HPO_4^{2-}	23.98±12.09	22.67±11.01	17.99±7.09
Mg^{2+}	5.78±4.01	4.78±3.68	5.45±4.01
Cr	17.25±11.89	16.67±12.01	13.01±5.89
UA	7.08±11.07	6.88±10.02	2.89±1.09
24h Urine Volume	1879±824	1935±713	2231±709
24-Hour Urine Analysis Results (%)			
Hypercalciuria	75 (11.65)	11 (1.71)	72 (11.18)
Hyperuricosuria	123 (19.1)	9 (1.39)	111 (17.24)
Hyperphosphaturia	109 (16.92)	8 (1.24)	138 (21.42)
Hypomagnesuria	99 (15.37)	12 (1.86)	119 (18.48)
Urine Specific Gravity and pH Results			
Urine pH	5.98±0.47	5.78±0.41	6.08±0.89
Urine Specific Gravity (SG)	1.026±0.08	1.020±0.06	1.016±0.04

DISCUSSION

This descriptive study observed and analyzed the urinary system stones, a common disease in the urological spectrum, ranking first or second in the spectrum of urological surgical diseases and holding the top position among inpatients in urology [12, 13]. The formation of

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urinary stones is complex, with mechanisms not fully explained to date [14]. Summarized stone-forming factors include individual factors, external factors, urological factors, and urine stone-forming factors [15]. Individual factors involve race, genetic factors, and dietary habits, while urological factors encompass damage, obstruction, infection, foreign bodies, etc [16]. External factors include natural and social environments, economic status, dietary culture, and geographic location. Urine factors involve components leading to urine oversaturation, inhibition, retention, and promotion. Epidemiological data from European and American countries show that 5% to 10% of people experience urinary stones at least once in their lifetime, with the incidence in Europe ranging from 100 to 400 per 100,000 people [17]. As China's economy and society develop, the overall incidence of urinary stones has increased by about 3% to 8%. In the southern regions, where economic levels are higher, the incidence is 5% to 10%, while Xinjiang is one of the high-incidence areas in China and even Asia, with an annual incidence of 200 to 500 per 100,000 people [18, 19]. The composition and incidence of urinary stones are related not only to patient gender, age, race, occupation, climate, water quality, and geographical location but also to personal factors such as body mass index, lifestyle, and water intake [20]. Urinary stones can occur regardless of age, gender, or race [21]. In the study, among 1080 patients, 737 were male (68.24%) and 343 were female (31.76%). The highest incidence was in Uyghurs (52.87%), followed by Han (42.96%) and Kazakhs (4.17%). The incidence was higher in males than females. Uyghur patients showed a higher incidence at younger ages, while Han patients had a higher incidence at older ages. Kidneys were the most common site for stone formation (79.63%), followed by ureters (15.19%), bladder (4.72%), and urethra (0.46%). The study highlighted Xinjiang's unique status as a high-incidence area. Differences in serum calcium (Ca2+) and magnesium (Mg2+) were not statistically significant, but phosphorus (P5+) levels were higher in Uyghurs compared to Han, suggesting a potential metabolic difference. Uyghurs had lower urine pH and volume compared to Han. Uyghurs had higher levels of K+, Na+, and uric acid (UA) in urine. Uyghurs and Kazakhs had statistically significant differences in urine specific gravity (SG) and electrolyte levels compared to Han. The study used infrared spectroscopy to analyze stone composition, categorizing them into pure and mixed types. Calcium oxalate stones were the most common. Uyghurs had a higher incidence of stones with uric acid components, possibly linked to their dietary habits.

CONCLUSIONS

The study provides insights into the complexity of urinary stone formation, emphasizing the impact of demographic, genetic, environmental, and lifestyle factors on stone composition and incidence.

Authors Contribution

Conceptualization: MRF
Methodology: HT
Formal analysis: KA
Writing-review and editing: MRF, WYJ, HT, KA
All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

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