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Original Article

Urinary calculi composition and its correlation with sex, age, calculi site, urine pH and underlying diseases: a retrospective study

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Abstract: Objective: To investigate the composition of urinary calculi and its correlation with sex, age, calculi site, urine pH, and underlying diseases. Methods: The clinical data of 300 patients with urinary calculi admitted to Meizhou People's Hospital from January 2022 to October 2024 were retrospectively analyzed. The composition of urinary calculi and its correlation with sex, age, calculi site, urine pH, and underlying diseases were examined. Logistic regression analysis was performed to identify factors influencing calculi composition. Results: Significant differences in calculi composition were observed across sex, age, calculi site, and urine pH (all P<0.05). Gender was an independent risk factor for the formation of dahllite (Dah) calculi (adjusted odds ratio [OR] = 3.70, 95% confidence interval [CI]: 2.10-6.51, P<0.01). Age, calculi site, and urine pH were independent risk factors for the formation of uric acid (UA) calculi (adjusted OR = 1.04, 95% CI: 1.01-1.06, P<0.01; adjusted OR = 3.03, 95% CI: 1.81-7.38, P = 0.01; adjusted OR = 1.56, 95% CI: 1.17-2.09, P<0.01). Urine pH was also an independent risk factor for the formation of six ammonium magnesium phosphate calculi (adjusted OR = 2.31, 95% CI: 1.42-3.80, P = 0.01). Conclusion: Sex, age, calculi site, and urine pH are significantly associated with the composition of urinary calculi.

Keywords: Urinary calculi, composition, sex, age, urine pH

Introduction

Urinary calculi are among the most common diseases seen in urology, characterized by a high incidence and recurrence rate [1]. These calculi can occur in the kidneys, ureters, bladder, or urethra [2] and may lead to urinary tract obstruction, infection, tissue damage, kidney function decline, or even systemic complications, which in severe cases can be life-threatening [3, 4]. The composition of urinary calculi is diverse, including calcium oxalate (CaOx), calcium oxalate monohydrate (COM), calcium oxalate dihydrate (COD), calcium phosphate (CaP), dahllite (Dah), dicalcium phosphate dihydrate (DCPD), calcite (Cal), uric acid (UA), uricite (Ur), sodium urate monohydrate (SUM), ammonium urate (AUU), ammonium magnesium phosphate (AMP), magnesium ammonium phosphate monohydrate (AMPM), six ammonium magnesium phosphate (SAMP) and cystine (Cys) [5]. CaOx calculi are the most prevalent type, accounting for 68.7%-90% of all urinary calculi [6]. Reduced urinary output and excessive renal excretion of calcium, oxalates, or urates increase the risk of CaOx calculi formation [7]. Citrate and other organic substances (e.g., nephrocalcin and osteopontin) inhibit calculi formation by forming complexes with oxalates [8].

Dah calculi are primarily associated with excessive solute intake and external environmental factors that disturb urine pH [9]. UA calculi account for 10%-20% of urinary calculi and are the second most common type in developed countries, following CaOx calculi. Insulin resistance, metabolic syndrome, low urine pH, and low urine volume are significant contributors to UA calculi formation [10]. SAMP, which com-

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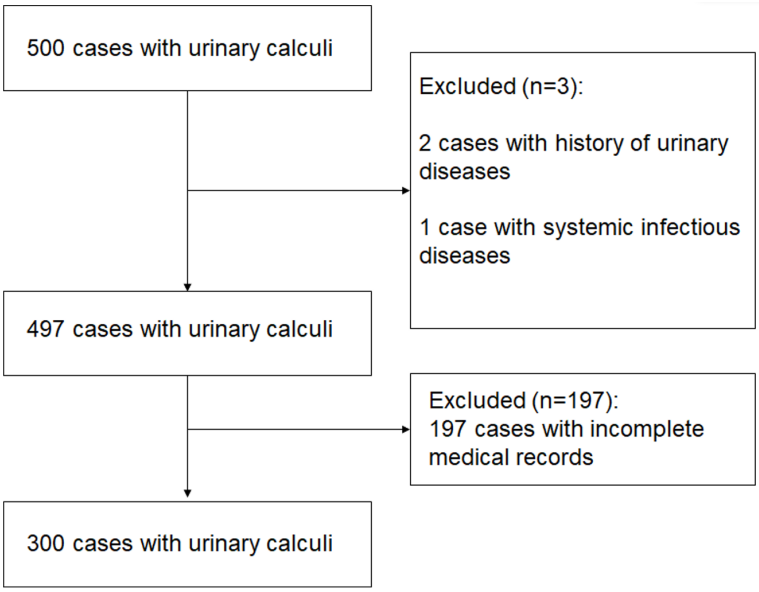

Figure 1. Flow diagram detailing the selection of patients included in the retrospective analysis.

prise 10%-15% of urinary calculi, are infection-related calculi caused by recurrent or persistent urinary tract infections. These calculi can form antler-like structures within 4-6 weeks, and are a primary component of staghorn calculi [11].

The chemical composition and structural complexity of urinary calculi present significant challenges in understanding their formation mechanisms and developing prevention strategies [12]. Analyzing calculi composition provides clinicians with essential insights into the underlying causes of calculi formation, enabling tailored treatment plans [13]. Urinary calculi formation is a multifactorial process with mechanisms that remain incompletely understood [14]. Studies suggest a strong association between calculi formation and metabolic disturbances, as abnormal metabolism is a risk factor [15]. The incidence and metabolic characteristics of urinary calculi vary by race, diet, and lifestyle [16]. In addition, patient-specific factors such as age, sex, calculi location, and urine pH play critical roles in calculi formation [17].

Liu et al. demonstrated through Mendelian randomization that sedentary lifestyles, obesity, smoking, and type 2 diabetes mediate the causal relationship between educational level and kidney calculi [18]. Zhang et al. identified diabetes and hypertension as predictive factors for upper urinary tract calculi [19]. Despite these findings, the relationship between urinary calculi composition and sex, age, calculi site, urine pH and underlying diseases remains unclear. This study aims to analyze urinary calculi composition and its correlations with sex, age, calculi site, urine pH, and underlying diseases, providing a foundation for improved prevention and treatment strategies.

Materials and methods

Patients

This study was approved by the ethics committee of Meizhou People's Hospital (approval number: 2024-C-180; approval date: October 28, 2024) and employed a retrospective cohort study design. The clinical data of 300 patients with urinary calculi, admitted to Meizhou People's Hospital from January 2022 to October 2024, were retrospectively analyzed. After excluding 2 cases with a history of urinary diseases, 1 case with systemic infectious diseases, and 197 cases with incomplete data, a total of 300 patients were included in the final analysis. The screening flowchart is presented in **Figure 1**.

The average age of the patients was 55.90 ± 25.43 years. The average diameter of the calculi was 2.23 ± 0.21 cm. Urolithiasis specimens were collected via percutaneous nephrolithotomy or ureteroscopic lithotripsy. Patient medical records were retrieved using a predefined data collection sheet.

Inclusion criteria: (1) Diagnosis of urinary calculi based on imaging examinations (e.g., lumbar acid levels, hematuria, renal colic, and B-ultrasound findings of calculi ≥0.3 mm in the upper or lower urinary tract). (2) Treated at Meizhou People's Hospital. (3) No history of urinary diseases or surgeries. (4) Age ≥ 18 years. (5) Complete medical records. (6) Underwent urinary calculi composition analysis.

Exclusion criteria: (1) Inability to cooperate with the study. (2) Presence of mental disorders. (3) Systemic infectious diseases. (4) Withdrawal from the study for personal reasons. (5) Use of medications affecting urine pH.

Data collection

The composition analysis of urinary calculi from 300 patients was performed using the LIIR20 automatic infrared spectrum analysis system (Lambda Scientific Instrument Co., Ltd., Tianjin, China), as previously described [20]. The procedure was as follows: 1. The calculi samples were cleaned with water. 2. The specimens were dried in a drying oven for 20 minutes, placed in sterile containers, and stored at 20-22°C. 3. Before composition analysis, the calculi specimens were finely ground into particles smaller than 2 μm. The ground powder was then compressed. 4. The prepared sample was analyzed using the LIIR20 system to determine the calculi composition.

Based on the results of the composition analysis [21], the calculi were classified into the following groups: 1. Simple CaOx calculi group: Calculi containing only CaOx (including COM and COD. 2. Mixed CaOx calculi group: Mixed calculi with CaOx as the main component. 3. Dah calculi group: Dah as the primary component. 4. UA calculi group: Calculi primarily composed of UA or AUU. 5. SAMP calculi group: Calculi primarily composed of SAMP. 6. Other calculi group: Calculi composed of components not included in the above groups.

On the morning following admission, clean midstream urine samples were collected from patients and analyzed. Urine with a pH <5.5 was classified as acidic, while urine with a pH ≥5.5 was considered neutral or alkaline.

Outcome measures

The differences in calculi composition based on sex, age, calculi site, urine pH, and underlying diseases (e.g., hypertension, diabetes) were analyzed.

Statistical analysis

Data were analyzed using GraphPad Prism 10 software. Measurement data (e.g., age, calculi diameter, body mass index [BMI], weight, and disease duration) were expressed as mean ± standard deviation. Categorical data were presented as n (%), and comparisons were performed using the χ^2 test. Logistic regression analysis was used to identify factors influencing calculi composition. A *P*-value <0.05 was considered statistically significant.

Results

General data

Among the 300 patients included in the study, the mean age was 55.90 ± 14.36 years (range: 20-84 years). The cohort comprised 161 males and 139 females. Additional patient details are presented in **Table 1**.

Distribution of calculi components

As shown in **Figure 2**, the distribution of calculi components among the 300 patients was as follows: Simple CaOx calculi: 53.00% (159/300); Mixed CaOx calculi: 22.00% (66/300); Dah calculi: 5.00% (15/300); UA calculi: 12.67% (38/300); SAMP calculi: 6.67% (20/300); Other calculi: 0.66% (2/300).

Comparison of sex in patients with different types of calculi

The proportion of simple CaOx calculi was significantly lower in female patients compared to male patients, whereas the proportion of Dah calculi was higher in female patients than in male patients (P<0.05, **Table 2**).

Age distribution of patients with different types of calculi

As shown in **Table 3**, patients were categorized into three age groups: young (20-44 years), middle-aged (45-59 years), and elderly (≥60 years). The young group included 57 cases, the middle-aged group 133 cases, and the elderly group 110 cases. The proportion of simple CaOx calculi was higher in the young and middle-aged groups compared to the elderly group (P<0.05). Conversely, the proportion of UA calculi was lower in the young and middle-aged groups than in the elderly group (P<0.05).

Comparison of calculi site in patients with different types of calculi

As shown in **Table 4**, the proportion of simple CaOx calculi was significantly higher in the

Table 1. General data of patients

Index	Number/(x±s)	Percentage (%)
Gender		
Male	161	53.67
Female	139	46.33
Age (years)		
20-44	57	19.00
45-59	133	44.33
≥60	110	36.67
Calculi site		
Upper urinary tract	271	90.33
Lower urinary tract	29	9.67
Urine pH value		
<5.5	51	17.00
≥5.5	249	83.00
Hypertension		
Yes	97	32.33
No	203	67.67
Diabetes		
Yes	51	17.00
No	249	83.00
BMI (kg/m^2)	22.56 ± 2.24	
Weight (kg)	62.65 ± 7.95	
Duration of the disease (years)	3.82 ± 0.41	
Treatment history		
Percutaneous nephrolithotomy	158	52.67
Ureteroscopic lithotripsy	142	47.33

Note: BMI: body mass index.

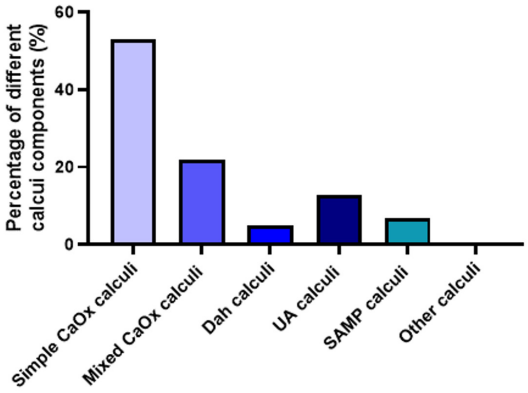

Figure 2. Distribution of calculi components. CaOx: calcium oxalate; Dah: dahllite; UA: uric acid; SAMP: six ammonium magnesium phosphate.

upper urinary tract compared to the lower urinary tract (P<0.05). Conversely, the proportion of UA calculi was lower in the upper urinary tract than in the lower urinary tract (P<0.05).

Comparison of urine pH in patients with different types of calculi

As shown in **Table 5**, the proportion of simple CaOx calculi and SAMP calculi in acidic urine was significantly lower than in neutral or alkaline urine. In contrast, the proportion of UA calculi in acidic urine was significantly higher than in neutral or alkaline urine (P<0.05).

Comparison of underlying diseases in patients with different types of calculi

As shown in **Table 6**, there was no significant difference in calculi composition between patients with and without hypertension (P>0.05). Similarly, no significant difference was observed in calculi composition between patients with and without diabetes (P>0.05, **Table 7**).

Multivariate Logistic regression analysis of factors influencing calculi composition

In this study, simple CaOx calculi were used as the reference group. Variables with statistical significance in univariate analysis (sex, age, calculi site, and urine pH) were included in the logistic regression analysis (all P<0.05). The results (**Table 8**) indicated the following: 1. Sex was an independent risk factor for the formation of Dah calculi (adjusted odds ratio [OR] = 3.70, 95% confidence interval [CI]: 2.10-6.51, P<0.01). 2. Age, calculi site, and urine pH were independent risk factors for the formation of UA calculi (adjusted OR = 1.04, 95% CI: 1.01-1.06, P<0.01; adjusted OR = 1.03, 95% CI: 1.81-7.38, P = 0.01; adjusted OR = 1.56, 95% CI: 1.17-2.09, P<0.01). 3. Urine pH was an independent risk factor for the formation of SAMP calculi (adjusted OR = 2.31, 95% CI: 1.42-3.80, P = 0.01).

Discussion

The incidence of urinary calculi varies significantly by sex, with a male-to-female ratio of 1.16:1 in this study, consistent with previous reports [22]. Male patients are more prone to

Table 2. Gender distribution of patients with different types of calculi

Variable		Cases	Calculi components											
			Simple CaOx calculi		Mixed CaOx calculi		Dah calculi		UA calculi		SAMP calculi		Other calculi	
			Case	%	Case	%	Case	%	Case	%	Case	%	Case	%
Gender	Male	161	98	60.87	30	18.63	4	2.48	22	13.66	7	4.36	0	0.00
	Female	139	61	43.88	36	25.90	11	7.91	16	11.51	13	9.35	2	1.45
χ^2				8.64		2.30		4.63		0.31		3.00		2.33
P				0.00		0.13		0.03		0.58		0.08		0.13

Note: CaOx: calcium oxalate; Dah: dahllite; UA: uric acid; SAMP: six ammonium magnesium phosphate.

Table 3. Age distribution of patients with different types of calculi

Groups	Cases	Young group		Middle-aged group		Old-aged group		χ^2	P
		Case	%	Case	%	Case	%		
Simple CaOx calculi	159	39	68.42	71	53.38	49	44.55	8.61	0.01
Mixed CaOx calculi	66	7	12.28	36	27.07	23	20.91	5.21	0.07
Dah calculi	15	3	5.26	5	3.76	7	6.36	0.87	0.65
UA calculi	38	1	1.75	10	7.52	27	24.54	23.35	<0.01
SAMP calculi	20	5	8.77	11	8.27	4	3.64	2.58	0.28
Other calculi	2	2	3.52	0	0.00	0	0.00	8.58	0.01

Note: CaOx: calcium oxalate; Dah: dahllite; UA: uric acid; SAMP: six ammonium magnesium phosphate.

Table 4. Calculi site distribution of patients with different types of calculi

Variable		Cases	Calculi components											
			Simple CaOx calculi		Mixed CaOx calculi		Dah calculi		UA calculi		SAMP calculi		Other calculi	
			Case	%	Case	%	Case	%	Case	%	Case	%	Case	%
Calculi site	Upper urinary tract	271	149	54.98	61	22.51	14	5.17	28	10.33	17	6.27	2	0.74
	Lower urinary tract	29	10	34.48	5	17.24	1	3.45	10	34.48	3	10.35	0	0.00
χ^2				4.42		0.42		0.16		13.81		0.70		0.22
P				0.04		0.52		0.69		<0.01		0.40		0.64

Note: CaOx: calcium oxalate; Dah: dahllite; UA: uric acid; SAMP: six ammonium magnesium phosphate.

Table 5. Urine pH distribution of patients with different types of calculi

Variable		Cases	Calculi components											
			Simple CaOx calculi		Mixed CaOx calculi		Dah calculi		UA calculi		SAMP calculi		Other calculi	
			Case	%	Case	%	Case	%	Case	%	Case	%	Case	%
Urine pH	Acid urine	51	14	27.45	14	27.45	3	5.88	20	39.22	0	0.00	0	0.00
	Neutral or alkaline urine	249	145	58.23	52	20.88	12	4.82	18	7.23	20	8.03	2	0.81
χ^2				16.10		1.06		0.10		39.15		4.39		0.41
P				<0.01		0.30		0.75		<0.01		0.04		0.52

Note: CaOx: calcium oxalate; Dah: dahllite; UA: uric acid; SAMP: six ammonium magnesium phosphate.

Table 6. Distribution of hypertension in patients with different types of calculi

Variable		Cases	Calculi components											
			Simple CaOx calculi		Mixed CaOx calculi		Dah calculi		UA calculi		SAMP calculi		Other calculi	
			Case	%	Case	%	Case	%	Case	%	Case	%	Case	%
Hypertension	Yes	97	53	54.64	25	25.77	2	2.06	10	10.31	7	7.22	0	0.00
	No	203	106	52.22	41	20.20	13	6.40	28	13.79	13	6.40	2	0.99
χ^2				0.15		1.19		2.61		0.72		0.07		0.96
P				0.69		0.28		0.11		0.40		0.79		0.33

Note: CaOx: calcium oxalate; Dah: dahllite; UA: uric acid; SAMP: six ammonium magnesium phosphate.

Table 7. Distribution of diabetes in patients with different types of calculi

Variable		Cases	Calculi components											
			Simple CaOx calculi		Mixed CaOx calculi		Dah calculi		UA calculi		SAMP calculi		Other calculi	
			Case	%	Case	%	Case	%	Case	%	Case	%	Case	%
Diabetes	Yes	51	31	60.78	11	21.57	1	1.96	6	11.76	2	3.93	0	0.00
	No	249	128	51.41	55	22.09	14	5.62	32	12.85	18	7.23	2	0.80
χ^2				1.50		0.01		1.20		0.05		0.74		0.41
P				0.22		0.93		0.27		0.83		0.39		0.52

Note: CaOx: calcium oxalate; Dah: dahllite; UA: uric acid; SAMP: six ammonium magnesium phosphate.

Table 8. Multivariate Logistic regression analysis of factors influencing calculi composition

Calculi components		β value	Wald χ^2 value	Adjusted OR value (95% CI)	*P* value
Dah calculi	Gender (male vs female)	1.30	20.80	3.70 (2.10-6.51)	<0.01
UA calculi	Age (years)	0.04	9.22	1.04 (1.01-1.06)	<0.01
	Calculi site (upper urinary tract vs lower urinary tract)	0.03	6.36	1.03 (1.81-7.38)	0.01
	Urine pH	0.45	8.96	1.56 (1.17-2.09)	<0.01
SAMP calculi	Urine pH	0.82	11.72	2.31 (1.42-3.80)	0.01

Note: Dah: dahllite; UA: uric acid; SAMP: six ammonium magnesium phosphate.

urinary calculi, potentially due to factors such as greater engagement in physical labor and higher alcohol consumption, which can lead to excessive fluid loss, reduced urine output, and an increased risk of calculi formation [23]. In contrast, female patients benefit from higher estrogen levels, which promote citrate excretion. Increased urinary citrate reduces calcium salt saturation, thereby inhibiting calculi formation [21].

Our study also found that the proportion of simple CaOx calculi was lower in female patients than in males, while the proportion of Dah calculi was higher in females, consistent with prior findings [24, 25]. The main reasons for these sex-related differences in calculi composition include: 1. Elevated androgen levels in males, which increase serum oxalate levels and promote CaOx calculi formation [26]. 2. Higher estrogen levels in females, which enhance citrate excretion and inhibit CaOx calculi formation [27]. 3. The anatomical characteristics of the female urethra, which is shorter and straighter with an opening near the vagina, increase the risk of local and retrograde infections. This can elevate urinary pH and support the growth of urease-producing microorganisms, ultimately contributing to Dah calculi formation [28]. Moreover, our study identified sex as an independent risk factor for Dah calculi formation.

Age is another important factor influencing urinary calculi formation. Studies suggest that endogenous α-insulin trimolecular condensation inhibitors, which significantly inhibit calculi formation, decrease with age. This reduction leads to an increased incidence of calculi in older populations [23]. The highest calculi detection rate in this study occurred in the 45-59 age group, aligning with findings from a national survey in 2020 [25].

The proportion of UA calculi in the elderly group was higher than in the young and middle-aged groups, consistent with previous studies [29]. This may be due to decreased renal ammonia production and increased urine acidification in older individuals, which promote the supersaturation of UA in urine [30]. Additionally, metabolic disorders such as obesity, insulin resistance, and diabetes, which increase with age, contribute to reduced urine pH and a higher risk of UA calculi formation [31]. Conversely, the proportion of simple CaOx calculi was higher in the young and middle-aged groups compared to the elderly group. This is likely related to reduced urinary calcium excretion in younger individuals. Our findings also indicated that age is an independent risk factor for the formation of UA calculi.

The incidence of urinary calculi is significantly higher in the upper urinary tract compared to the lower urinary tract [32]. Upper urinary tract calculi primarily occur in the kidneys, while lower urinary tract calculi mainly form in the bladder [33]. Upper urinary tract calculi are usually caused by Randall's plaque formation in the kidneys, whereas lower urinary tract calculi often result from retrograde urinary tract infections and urethral obstruction [34]. In our study, 271 patients had upper urinary tract calculi, and 29 had lower urinary tract calculi, consistent with epidemiological trends [35]. We found that the proportion of simple CaOx calculi was higher in the upper urinary tract than in the lower urinary tract, while the proportion of UA calculi was lower in the upper urinary tract compared to the lower urinary tract. Bladder calculi are mainly caused by nutrient deficiency, lower urinary tract obstruction, and infection; thus, UA calculi are more common in the bladder [36]. Furthermore, our study demonstrated that the calculi site is an influential factor in the formation of UA calculi.

Urine pH significantly influences the formation of urinary calculi [37]. Studies have shown that urine pH affects the formation of UA calculi, CaOx calculi and SAMP calculi [38]. When urine pH is <5.5, the solubility of uric acid decreases markedly, increasing the likelihood of supersaturation and crystallization, which elevates the risk of uric acid calculi [39]. Our results indicated that the proportion of simple CaOx calculi and SAMP calculi in acidic urine was lower than in neutral or alkaline urine, while the proportion of UA calculi in acidic urine was higher. Additionally, our study confirmed that urine pH is an influential factor in the formation of UA and SAMP calculi.

Common metabolic diseases such as essential hypertension and diabetes can lead to increased levels of calcium, oxalic acid, and uric acid in the urine, thereby increasing urine acidity and reducing citrate content, which increases the risk of urinary calculi [40]. However, our study found no significant difference in calculi composition between patients with and without hypertension. Similarly, no difference was observed between diabetic and non-diabetic patients.

Dietary adjustment is crucial for preventing calculi formation [41]. Strict control of calcium, oxalate, fructose, salt, and protein intake, along with ensuring adequate fluid intake to produce at least 2-2.5 liters of urine per day, can effectively reduce the concentration of calcium, magnesium, uric acid, and other calculi-promoting substances in the urine [42]. Therefore, patients can prevent calculi formation by adjusting their diet and increasing water intake.

Our study has some limitations. First, as a retrospective single-center study, we did not perform 24-hour urine electrolyte analysis in patients with calculi, limiting our understanding of their urinary electrolyte status. Additionally, we did not follow up with patients for postoperative recurrence of calculi. Moreover, we did not conduct a detailed analysis of factors closely related to calculi formation, such as metabolic syndrome. Since all calculi samples were surgically removed, there may have been patients with asymptomatic calculi or spontaneous passage of calculi who were not included, potentially introducing bias. Furthermore, in the analysis of calculi composition, only some calculi were randomly selected for analysis, which may have caused deviations in the results. In conclusion, sex, age, calculi site, and urine pH are closely associated with the composition of urinary calculi. Analysis of calculi components can guide etiological investigation, treatment, and prevention strategies for urinary calculi.

Disclosure of conflict of interest

None.

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