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Research article

Evaluation of Chemical Composition of Urinary Calculi *in vivo* Based on Gray Scale Ultrasound

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ABSTRACT

Objective: The purpose of this study was to preliminarily predict the chemical composition of urinary calculi using ultrasound *in vivo*.

Methods: A retrospective analysis was performed on the data of 267 patients with urinary calculi, including Non-Contrast Computed Tomography (NCCT) and ultrasound imaging data obtained before intervention, as well as the chemical composition after intervention. Statistical analysis was performed on the Hounsfield Unit (HU) value of the calculi, the grayscale value of the calculi, and the grayscale value of the posterior acoustic shadow of the calculi on ultrasound.

Results: The chemical composition analysis indicated that there were four types of mixed calculi; the main components were Calcium Oxalate Monohydrate (COM) calculi, Calcium Oxalate Dihydrate (COD) calculi, Carbonate Apatite (CA) calculi and anhydrous Uric Acid (UA0) calculi. The HU value discriminated between calcium-containing calculi and UA0 calculi, with a cut-off value of 644.00, a sensitivity of 88.00% and a specificity of 95.04%, and $P<0.001$. The grayscale value of the calculi on ultrasound discriminated between calcium-containing calculi and UA0 calculi with a cut-off value of 200.29, a sensitivity of 38.84% and a specificity of 96.00%, $P<0.001$. The grayscale value of the posterior acoustic shadow of the calculi on ultrasound discriminated between CA calculi and UA0 calculi with a cut-off value of 31.48, a sensitivity of 58.33% and a specificity of 84.00%, and $P=0.011$.

Conclusion: Ultrasound can preliminarily distinguish the chemical composition of urinary calculi and provide certain information for clinicians to choose treatment plans.

Keywords: Urinary calculi; Chemical composition; NCCT; HU value; Ultrasound; Grayscale value

Abbreviations: NCCT: Non-Contrast Computed Tomography; HU: Hounsfield Unit; COM: Calcium Oxalate Monohydrate Calculi; COD: Calcium Oxalate Dihydrate Calculi; CA: Carbonate Apatite Calculi; UA0: Anhydrous Uric Acid Calculi; DECT: Dual-Energy Computer Tomography; ROI: Region of Interest; ANOVA: One-Way Analysis of Variance; LSD: The Least Significant Difference; ROC: Receiver Operating Characteristics; ESWL: Extracorporeal Shock Wave Lithotripsy; SD: Standard Difference; BMI: Body Mass Index; AUC: Area Under the Curve; CI: Confidence Interval

INTRODUCTION

Urolithiasis is a common, painful and unbearable urinary system disease, which is also a risk factor for cardiovascular disease and chronic kidney disease [1]. Urolithiasis has become a major medical problem worldwide. Its high incidence and recurrence rates lead to many health problems and an increased socio-economic burden, which has attracted increasing attention [2].

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Recent epidemiological data indicate that urolithiasis affects approximately 12% of the population during their lifetime and its prevalence and morbidity are steadily increasing worldwide. In the United States, the prevalence of urolithiasis increased from 3.2% in 1980 to 8.8% in 2010. In Asia, the prevalence of urolithiasis ranged from 5% to 19.1%. In China, the prevalence of urolithiasis has increased from 4% to 6.4% in the last 30 years due to social development, lifestyle and dietary changes. In other words, 1 in 17 adults in China suffers from urolithiasis. Several studies have shown that the recurrence rate of urolithiasis in cured patients increases every year after the initial stone event. The estimated recurrence rate is 6%-17% within one year, 30%-50% within five years, and 60%-80% throughout life [3].

With such a high prevalence and recurrence rate of urolithiasis, it is crucial to choose an appropriate method of investigation. Currently, the recognized gold standard for diagnosing urinary calculi is Non-Contrast Computed Tomography (NCCT), which is used not only for morphological and anatomical evaluation, especially the application of Dual-Energy Computed Tomography (DECT) in recent years. By measuring the inherent atomic number differences, different calculi compositions show different attenuation characteristics at different energy or kilovoltage levels. This property predicts the chemical composition of the calculi and distinguishes uric acid-containing calculi and calcium-containing calculi. The advantage of DECT in identifying the calculi composition helps in the management patients with uric acid calculi, which can be treated by alkalizing the urine to avoid surgery. At the same time, the problem of radiation dose should not be ignored, as the prevalence and recurrence rate of urolithiasis continues to increase, and patients may be affected by the biological effects of ionizing radiation. Gray scale ultrasound is the preferred method for obtaining high-resolution images of non-ionizing radiation, which is economical, widely available and convenient. It can dynamically evaluate the morphology, size, quantity, anatomical information and degree of obstruction of urinary calculi in real time [4].

Recent studies have shown that the sensitivity and specificity of gray scale ultrasound in the diagnosis of urolithiasis are 45%-99% and 88%-94%, respectively. A meta-analysis of prospective studies showed that the sensitivity of low-dose CT in the diagnosis of urolithiasis was 93.1% (95% confidence interval: 91.5%-94.4%), and the specificity was 96.6% (95%confidence interval: 95.1%-97.7%). The sensitivity and specificity of gray scale ultrasound in the diagnosis urolithiasis are not inferior to those of NCCT. A strong echo with posterior acoustic shadow characterizes the diagnosis of urolithiasis by gray scale ultrasound. During of clinical ultrasound examination, the degree of strong echo of the calculi and the degree of echo of the posterior acoustic shadow are often different. Previous studies have shown that the size of the calculi, tissue medium, reverberation, distance from the probe and probe frequency can affect the degree of echo of the calculi and the posterior acoustic shadow. However, whether they are affected by chemical composition is not well understood. Therefore, the purpose of this study was to quantitatively analyze the degree of the echo of urinary calculi and the posterior acoustic shadow, and to attempt to explore the feasibility of grayscale ultrasound in evaluating the chemical composition of urinary calculi in vivo [5].

MATERIALS AND METHODS

Subjects

This study retrospectively evaluated the data of patients (age ≥ 18 years old) who underwent transurethral ureteroscopic lithotripsy or percutaneous nephrolithotomy in the Department of Urology of Tianjin Medical University Second Hospital from September 2018 to January 2020. Inclusion criteria: Ultrasound examination and NCCT examination were performed before surgical treatment, and the calculi with HU value determined by NCCT were taken as the target calculi. Calculi composition results were obtained after lithotomy. Exclusion criteria: Patients were treated with chemodissolution before the surgery. The ethics committee of Tianjin Medical University Second Hospital approved our study design. Written informed consent from participants was not required because the study was retrospective, and patient-recorded information was anonymized and de-identified before analysis [6].

Methods

Prior to surgery, all patients underwent a preoperative urinary examination by ultrasound examination and NCCT examination. Ultrasound was performed using the DC-8S ultrasound scanner (Mindry, convex array probe, 3.5 MHz) with a focus depth of 15 cm and the focus placed on the lower edge of the target calculi. NCCT was performed using a GE Light Speed Pro 64-row helical CT (General Electrics, Health Care, Waukesha, Wisconsin, USA), with a voltage of 120 kV and a current of 240 mA. The slice thickness and slice spacing were each 5 mm each, and the scan ranged from the bilateral upper pole to the pubic symphysis. All images were acquired using the Picture Archiving and Communication System (PACS) and stored for subsequent evaluation by two radiologists blinded to the chemical composition of the calculi during a consensus reading session [7].

Obtaining the HU value of target calculi: For target calculi, a Region Of Interest (ROI) overlying the entire calculi on the slice was obtained for each plane for tissue and bone windows at 120 kV. The HU value of target calculi is presented for the central ROI of the plane passing through the maximum transverse diameter. Each target calculi was measured three times, and the average value was taken as the HU value of the target calculi [8].

Measurement of information associated with target calculi in gray scale ultrasound: We used the ImageJ 1.47V software (National Institute of Health, Bethesda, USA) software to circle the extent of the calculi along the boundary of the target calculi, which was the ROI, and the software automatically calculated the grayscale value. Then, the area of the posterior acoustic shadow of the target calculi was determined, and ImageJ 1.47V software was used to obtain the length, width and grayscale value of the posterior acoustic shadow of the target calculi. The sonogram of each target calculi was saved in at least two different sections to show the approximate shape and the extent of the calculi and to provide a relatively objective grayscale value. The grayscale value of each target calculi and the grayscale value of the posterior acoustic shadow were measured three times and the average value was recorded [9].

Statistical analysis

Each quantitative indicator was presented as mean ± standard deviation (mean ± SD). Continuous variables were compared statistically using one-way Analysis of Variance (ANOVA) and non-parametric tests. After ANOVA, the Least Significant Difference (LSD) post hoc test was used to compare groups. The Kruskal-Wallis-Dunn test was used for non-parametric distributions. Receiver Operating Characteristics (ROC) analysis was used to calculate the cut-off HU value and grayscale value for each group to differentiate the different groups of calculi. Spearman correlation was used to test the relationship between calculi characteristics. Data were analyzed using SPSS 20.0 (SPSS, Chicago, Illinois, USA) and MedCalc 18.2 (MedCalc, Ostend, Belgium). P<0.05 was considered statistically significant [10].

RESULTS

A total of 267 patients (174 males/93 females) were included in the study, with a mean age of 52.2 ± 12.38 years. Chemical composition analysis by infrared spectroscopy revealed four types of mixed composition calculi. All mixed composition calculi had a primary composition calculi type contributing to at least two thirds (>66%) of the calculi, and the primary composition calculi also defined the group. The number of calculi in each group was as follows: Calcium Oxalate Monohydrate calculi (COM, n=197), calcium oxalate dihydrate calculi (COD, n=21), anhydrous uric acid calculi (UA0, n=25), carbonate apatite (CA, n=24). Table 1 shows the patient and calculi characteristics according to calculi composition [11].

Table 1: Demographics and clinical outcomes according to urinary calculi composition.

n or mean ± SD						
Variable	**Total cohort**	**COD**	**CA**	**UA0**	**COM**	**P-value**
Cases	267	21	24	25	197	
Age (years)	52.27 ± 12.38	53.05 ± 11.36	43.83 ± 11.72	57.88 ± 13.67	52.50 ± 11.90	0.001[a]
Male/Female	174/93	45547	45579	18/7	137/60	0.005[a]
BMI (kg/m^2)	25.78 ± 3.44	25.38 ± 3.39	25.61 ± 3.12	26.10 ± 2.69	25.84 ± 3.58	0.968[a]
Right/Left side						0.738[a]
Right side	119	11	11	9	88	
Left side	148	10	13	16	109	
Location						0.273[a]
Kidney	130	11	19	14	86	
Upper ureter	104	10	2	6	86	
Middle ureter	18	0	0	3	15	
Lower ureter	15	0	3	2	10	
Ipsilateral hydronephrosis						0.544[b]
None	56	5	5	11	35	
Mild	88	3	9	3	73	
Moderate	111	12	8	9	82	
Severe	12	1	2	2	7	

Calculi size on NCCT (cm)	1.96 ± 1.32	1.75 ± 0.90	2.96 ± 2.33	2.69 ± 1.47	1.77 ± 1.06	<0.001[b]
HU value	1069.62 ± 316.49	1167.24 ± 235.39	1001.75 ± 267.89	589.48 ± 285.93	1128.41 ± 278.19	<0.001[a]
Calculi size on ultrasound (cm)	2.13 ± 1.23	1.97 ± 1.00	2.87 ± 2.23	2.61 ± 1.60	2.00 ± 0.96	0.189[b]
Grayscale value of calculi on ultrasound	183.76 ± 34.45	189.51 ± 35.38	190.42 ± 36.23	164.16 ± 26.23	184.83 ± 34.43	0.020[a]
Grayscale value of posterior acoustic shadow on ultrasound	42.08 ± 25.59	37.62 ± 19.17	32.80 ± 17.82	48.65 ± 25.59	42.85 ± 26.75	0.131[a]
Width of posterior acoustic shadow on ultrasound (cm)	1.54 ± 0.99	1.46 ± 0.81	2.04 ± 1.50	1.79 ± 1.28	1.46 ± 0.87	0.328[b]
Length of posterior acoustic shadow on ultrasound (cm)	4.79 ± 2.09	5.35 ± 1.85	5.92 ± 1.37	4.66 ± 2.05	4.60 ± 2.14	0.032[b]

Note: a: Based on one-way ANOVA, b: Based on non-parametric tests, SD: Standard Difference; COD: Calcium Oxalate Dihydrate; CA: Carbonate Apatite; UA0: Anhydrous Uric Acid; COM: Calcium Oxalate Monohydrate; BMI: Body Mass Index; NCCT: Non-Contrast Computed Tomography; HU: Hounsfield Units.

The results showed significant differences in age, sex, calculi size, HU value on NCCT, the grayscale value of the calculi on ultrasound and the length of the posterior acoustic shadow on ultrasound among the four groups (P<0.05). There was a significant difference in the grayscale value of the posterior acoustic shadow between the UA0 group and the CA group (P<0.05, Table 2) [12].

Table 2: Differences in demographics and clinical outcomes of four types of urinary calculi.

P-value						
Variable	**COM *vs.* COD**	**COM *vs.* CA**	**COM *vs.* UA0**	**COD *vs.* CA**	**COD *vs.* UA0**	**CA *vs.* UA0**
Age (years)	0.844[a]	0.001[a]	0.037[a]	0.011[a]	0.177[a]	<0.001[a]
Sex	0.014[a]	0.006[a]	0.805[a]	0.932[a]	0.037[a]	0.024[a]
BMI (kg/m^2)	0.668[a]	0.727[a]	0.807[a]	0.910[a]	0.717[a]	0.815[a]
Right/Left side	0.502[a]	0.914[a]	0.414[a]	0.661[a]	0.269[a]	0.492[a]
Location	0.172[a]	0.122[a]	0.886[a]	0.945[a]	0.338[a]	0.287[a]
Ipsilateral hydronephrosis	0.544[b]					
Calculi size on NCCT (cm)	0.817[b]	0.002[b]	<0.001[b]	0.041[b]	0.014[b]	0.679[b]
HU value	0.539[a]	0.034[a]	<0.001[a]	0.045[a]	<0.001[a]	<0.001[a]
Calculi size on ultrasound (cm)	0.189[b]					

Grayscale value of calculi on ultrasound	0.549[a]	0.447[a]	0.005[a]	0.928[a]	0.012[a]	0.007[a]
Grayscale value of posterior acoustic shadow on ultrasound	0.372[a]	0.069[a]	0.284[a]	0.527[a]	0.144[a]	0.030[a]
Width of posterior acoustic shadow on ultrasound (cm)	0.328[b]					
Length of posterior acoustic shadow on ultrasound (cm)	0.320[b]	0.005[b]	0.703[b]	0.212[b]	0.296[b]	0.017[b]

Note: a: Based on one-way ANOVA, b: Based on non-parametric tests, COM: Calcium Oxalate Monohydrate; COD: Calcium Oxalate Dihydrate; CA: Carbonate Apatite; UA0: Anhydrous Uric Acid; BMI: Body Mass Index; NCCT: Non-Contrast Computed Tomography; HU: Hounsfield Units.

ROC analysis showed a significant difference between the UA0 group and calcium-containing calculi, including the COM group, COD group and CA group. For the HU value, the area Under the Curve (AUC) was 0.907, $P<0.001$, and the cut-off value was 644.00 HU. For the grayscale value of the calculi on ultrasound, the AUC was 0.705, $P<0.001$, and the cut-off value was 200.29. The results of the ROC analysis of the HU value, the grayscale value of the calculi and the grayscale value of the posterior acoustic shadow on ultrasound were then used to discriminate between the calcium-containing subgroup of calculi and UA0 (Table 3) [13].

Table 3: Results of ROC curve analysis to differentiate the various calculi groups by using HU value, the grayscale value of calculi, and the grayscale value of posterior acoustic shadow.

Calculi groups differentiated						
		UA0 *vs.* calcium-containing calculi (COM, COD, CA)	**COD *vs.* CA**	**COD *vs.* UA0**	**CA *vs.* UA0**	**COM *vs.* UA0**
HU value	AUC	0.907	0.73	0.903	0.848	0.915
	Cut-off value (HU)	644	1063	644	644	644
	Sensitivity (%)	88	85.71	95.24	91.67	88
	Specificity (%)	95.04	66.67	88	88	95.43
	95% CI	0.866-0939	0.577-0.851	0.779-0.970	0.717-0.935	0.870-0.948
	P-value	<0.001	0.004	<0.001	<0.001	<0.001
Grayscale value of calculi on ultrasound	AUC	0.705	-	0.735	0.707	0.701
	Cut-off value	200.29	-	200.29	187	200.29
	Sensitivity (%)	38.84	-	52.38	58.33	96
	Specificity (%)	96	-	96	80	37.56
	95% CI	0.646-0759		0.584-0.854	0.559-0.828	0.636-0.760
	P-value	<0.001	-	0.003	0.007	0.001
Grayscale value of posterior acoustic shadow on ultrasound	AUC	-	-	-	0.699	-
	Cut-off value	-	-	-	31.48	-
	Sensitivity (%)	-	-	-	58.33	-
	Specificity (%)	-	-	-	84	-
	95% CI				0.551-0.822	
	P-value	-	-	-	0.011	-

Note: ROC: Receiver Operating Characteristics; UA0: Anhydrous Uric Acid; COM: Calcium Oxalate Monohydrate; COD: Calcium Oxalate Dihydrate; CA: Carbonate Apatite; HU: Hounsfield Units; AUC: Area Under the Curve; CI: Confidence Interval.

Spearman correlation analysis was used to analyze the relationship between calculi characteristics. The results showed that the calculi size on ultrasound was positively correlated with the width of the posterior acoustic shadow on ultrasound, and the correlation coefficient was 0.755, P<0.001. The HU value was positively correlated with the grayscale value of the calculi on ultrasound, and the correlation coefficient was 0.121, P<0.05 [14].

DISCUSSION

The high prevalence and recurrence rate of urolithiasis has attracted increasing attention. A complete understanding of calculi information before treatment helps to select a reasonable and practical treatment plan and improve the treatment success rate, such as the composition type, size and location of calculi. The composition of calculi has different physical and solid characteristics that directly affect the success of treatment. Calcium oxalate calculi are the most common composition of urolithiasis. It has a dense structure, hard texture, smooth surface or mulberry shape, and the treatment effect of Extracorporeal Shock Wave Lithotripsy (ESWL) is poor. Carbonate apatite is an infectious calculi that should be removed as much as possible during surgery. Urinary tract infections and acidic urine should be controlled after surgery to prevent recurrence and rapid growth of calculi. Uric acid calculi are soft and can be treated with medication. Therefore, it is both an advantage and a trend to know the composition of the calculi before treatment [15].

There are currently many studies on the use of NCCT to predict the composition of urinary calculi. Torricelli et al. found that the HU value of cystine calculi was 648 ± 122 HU and that of calcium oxalate calculi was 1099 ± 239 HU, which successfully discriminated calcium oxalate calculi from cystine calculi. Pareek et al. found that a HU value ≤ 500 HU and urinary pH ≤ 5.5 could be used to differentiate uric acid calculi from calcium-containing calculi. Similarly, the HU value of calcium-containing calculi in adults was higher than that of uric acid calculi and cystine calculi. Lee et al. showed that the HU value of uric acid calculi, phosphate calculi and calcium oxalate calculi were 513 HU ± 197 HU, 1660 HU ± 292 HU and 1684 HU ± 290 HU, respectively, which successfully differentiated uric acid calculi from calcium-containing calculi. In our study, we distinguished the composition of the subgroup calculi, and the results showed that the cut-off value of calcium oxalate dihydrate calculi for distinguishing carbonate apatite calculi and anhydrous uric acid calculi were 1063.00HU and 644.00 HU, respectively. The cut-off value of anhydrous uric acid calculi to differentiate between carbonate apatite and calcium oxalate monohydrate calculi was 644.00 HU, respectively. In conclusion, a HU value ≤ 644.00 could be used to distinguish calcium-containing calculi from anhydrous uric acid calculi. Our results are consistent with previous studies, showing that the HU value of calcium-containing calculi is higher than that of anhydrous uric acid calculi, and that the HU value of NCCT can be used to differentiate calcium-containing calculi from anhydrous uric acid calculi [16].

Although NCCT has become the gold standard for the diagnosis of urolithiasis, ultrasound is widely used for the diagnosis of urolithiasis in routine clinical practice because it is economical, convenient and safe. Recent studies have reported that the sensitivity and specificity of ultrasound in the diagnosis of urolithiasis are 90%-93% and 95%-100%, respectively. The accuracy and information provided by ultrasound in the diagnosis of urolithiasis is similar to that of NCCT. Our study showed that the grayscale value of the strong echo of calcium-containing calculi was higher than that of anhydrous uric acid calculi. The cut-off value of calcium-containing calculi and anhydrous uric acid calculi was 200.29, *i.e.* the grayscale value of the strong echo of calculi on ultrasound was ≤ 200.29, which can preliminarily distinguish calcium-containing calculi from anhydrous uric acid calculi. The results were similar to those of the NCCT in predicting calculi composition [17].

The posterior acoustic shadow of urinary calculi varies in degree of the ultrasonic manifestation is different, and the influence of the different chemical compositions of urinary calculi on the posterior acoustic shadow has been widely discussed. King et al. showed that the chemical composition of the calculi had no apparent effect on the posterior acoustic shadow. At the same time, the rough texture of the tissue may affect the posterior acoustic shadow behind the small calculi. Rubin et al. showed that surface topography, such as the roughness and radian of the calculi, could affect the clarity of the posterior acoustic shadow. The posterior acoustic shadow of the calculi with a rough surface and small radian is clear. In contrast, the posterior acoustic shadow of calculi with a smooth surface and a large radian is flat. However, some scholars have pointed out that the more calcium in the tissue, the more pronounced the sound attenuation *i.e.,* the lower the degree of the posterior acoustic shadow echo and the lower the grayscale value. According to our results, the grayscale values of the posterior acoustic shadow in the CA group were lower than in the UA0 group and more obvious than in the UA0 group, indicating a relationship between the chemical composition of the calculi and the degree of echo of the posterior acoustic shadow, which may be related to the difference in the number of calcium elements and elements of different substances. The CA group is high in calcium and has greater ultrasound attenuation, lower echo and more apparent posterior acoustic shadow. In contrast, the UA0 group contains no calcium elements, has a relatively lower acoustic attenuation, a higher echo, a lighter acoustic shadow and a higher grayscale value. The results of calculi composition analysis using energy spectral CT showed that substance with high atomic numbers mainly produce photoelectric absorption effects. Carbonate apatite contains high-order chemical elements with strong X-ray attenuation. In contrast, uric acid contains low-order chemical elements with low X-ray attenuation, suggesting a correlation between acoustic attenuation and the order of chemical elements. This is similar to our findings that calcium-containing calculi are significantly more posteriorly attenuated than non-calcium-containing calculi, with lower posterior acoustic echoes and grayscale values [18].

This study also found a relationship between the HU value of the calculi and the grayscale value of the strong echo of the calculi. It is suggested that the echo of calculi on ultrasound is more substantial, its HU value may be more significant, and its calcium content is greater. The more the posterior attenuation is, the less the echo of the posterior acoustic shadow is. Conversely, the ultrasound echo of calculi is reduced. Their HU value can be lower, with less calcium or non-calcium content, and the posterior acoustic shadow is lighter. The results of this study still have some implications for the treatment of urolithiasis. For example, uric acid calculi that are negative without radiolucency can be identified by ultrasound. The grayscale value of the strong echo and the posterior acoustic shadow determined the characteristics of calculi. Uric acid calculi can be dissolved clinically by alkalinizing urine with drugs to avoid ESWL or surgical treatment. In addition, the treatment of urolithiasis is not only concerned with the chemical composition of the calculi; the size of the calculi is also a critical factor in determining the treatment plan for urolithiasis. To improve the accuracy of ultrasound calculi size measurement, the width of the posterior acoustic shadow is used as an additional measure, especially for calculi size ≤ 5 mm. Most calculi without posterior acoustic shadow were ≤ 5 mm, and these had the highest likelihood of spontaneous calculi discharge. Therefore, the accurate measurement of calculi size using the posterior acoustic shadow is also important for the management of urolithiasis [19].

In this study, the sensitivity and specificity of using HU value to differentiate calcium-containing calculi from anhydrous uric acid calculi were 85.87%-95.24% and 66.67%-95.43%, respectively. The sensitivity and specificity were 38.84%-96.00% and 37.56%-96%, respectively, for distinguishing calcium-containing calculi from anhydrous uric acid calculi using the grayscale value of the calculi and the posterior acoustic shadow on ultrasound. Although the sensitivity of ultrasound to predict urinary calculi composition is lower than that of NCCT, this may be due to the small number of patients in the subgroup of this study. In addition, the ROIs of the strong echo of the calculi and the posterior acoustic shadow are artificially defined. The determination of the possible boundary may need to be more accurate to influence the study results. However, this study quantified the characteristics of calculi on ultrasound. It made a preliminary prediction of the composition of calculi, which provided an empirical basis for future research, with the hope that ultrasound may be a valuable tool for predicting the composition of urinary calculi and providing more information for the choice of treatment and follow-up of urolithiasis [20,21].

CONCLUSION

In this study, calcium-containing calculi were distinguished from anhydrous uric acid calculi by measuring the grayscale value of the strong echo and the posterior acoustic shadow of urinary calculi on ultrasound. Ultrasound can provide some information to predict the chemical composition of urinary calculi and help clinicians choose the appropriate treatment plans.

AUTHOR CONTRIBUTIONS

Jing Li designed the study, Ningning Liu and Xiaoyi Wang collected and analysed the data, Ningning Liu wrote the manuscript, and Haijie Xie revised the manuscript. Jing Li and Haijie Xie are the co-corresponding authors. We extend our sincere gratitude to our department chair for the support. We also thank our physicians, engineers, nurses, and other department staff. All authors read and approved the final manuscript.

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CONFLICT OF INTEREST

The authors declare that they have no competing interests.

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