

Characteristics of Blood Tests in norovirus-associated Benign Convulsions with Mild Gastroenteritis in Children

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Abstract

Purpose: Benign convulsions with mild gastroenteritis (CWG) is a common condition in children in Asia, and the prognosis is generally good. However, the diagnosis of CWG is an exclusive diagnosis and attention should be paid to the exclusion of potential intracranial diseases. This study analyzed the clinical features of norovirus associated CWG to provide evidence for reducing unnecessary tests.

Methods: Medical records of children admitted to the Department of Emergency of Guangzhou Women and Children's Medical Center with Stool etiology was positive for norovirus between January 2019 and January 2020 were divided into CWG group and simple gastroenteritis group, and were reviewed and analyzed.

Results: A total of 89 norovirus cases were enrolled. Age of onset, male/female ratio of CWG group and simple gastroenteritis group were 49 cases, mean 20.84 ± 5.83 months and 27:22, 40 cases, mean 19.00 ± 13.48 months and, 26:14 respectively. Serum uric acid levels in CWG and acute gastroenteritis groups increased in 43 (87.8%) and 9 (22.5%) cases, respectively. The average serum uric acid level in the CWG group was significantly higher than that in the acute gastroenteritis group ($564.36 \pm 125.28 \mu\text{mol/L}$ vs $338.42 \pm 141.03 \mu\text{mol/L}$ [mean \pm standard deviation], $p < 0.0001$). The potential of hydrogen (pH), bicarbonate (HCO_3^-), BE bases excess (BE), blood glucose, Serum sodium and white blood cell (WBC) of CWG group were also lower than those of simple gastroenteritis group, the differences were statistically significant, while there were no significant differences in transaminase, residual myocardial enzymes, electrolytes and C-reactive protein (CRP), etc.

Conclusion: Children with norovirus diarrhea with recurrent convulsions, increased serum uric acid, more obvious acidosis should pay high attention to the possibility of Norovirus related CWG, lumbar puncture and Cranial imaging are unnecessary and should not be recommended.

1. Introduction

Benign convulsions associated with mild gastroenteritis (CWG) were first reported by Morooka in 1982 [1] and have been subsequently reported mainly in East Asia, with only few recent reports from Europe and the USA. CWG mainly occurs in previously healthy children with diarrhoea, excluding intracranial infection and other neurological diseases and generally has good prognosis. Cranial imaging and electroencephalogram examinations are usually normal, while cerebrospinal fluid tests generally is normal. However, CWG diagnosis is an exclusive diagnosis. Recent studies have shown that convulsions occur repeatedly after infection with norovirus [2,3], which has aroused concern for healthcare professionals and families, especially in community hospitals. Repeated convulsions with or without low-grade fevers are often misdiagnosed as complex febrile convulsions, viral encephalitis, toxic encephalopathy, or epilepsy. Lumbar puncture and cranial imaging examinations and electroencephalography are often required to further rule out other intracranial diseases. However, there is still a lack of knowledge on the clinically effective indicators for the anticipation of CWG. This study

analyzed the clinical features of norovirus associated CWG to provide evidence for reducing unnecessary tests.

2. Materials And Methods

2.1. Materials

Clinical data of children infected with norovirus admitted to the the Department of Emergency of Guangzhou Women and Children's Medical Center between January 2019 and January 2020 were retrospectively collected and divided into two groups: the CwG group and acute gastroenteritis group. Clinical data of children diagnosed with febrile seizures at the same time were also included in our study to rule out post-convulsive effects[4]. Clinical and related laboratory data of enrolled children were analysed retrospectively.

2.2. Inclusion and exclusion criteria

2.2.1. The inclusion and exclusion criteria for CwG

The inclusion criteria for CwG were as follows[5][6]: (1) previously healthy infants aged 6 months to 3 years; (2) mild gastroenteritis with convulsions, none to mild dehydration, and no apparent acid-base balance or electrolyte disorder; (3) none to low-grade fever (body temperature < 38.0°C) during convulsions; (4) no epileptiform discharge on the interparoxysmal electroencephalogram, no apparent abnormality in the skull when assessed by computerized tomography/magnetic resonance imaging, and normal blood glucose, blood calcium, blood magnesium, and cerebrospinal fluid levels; and (5) stool samples positive for norovirus by reverse transcription polymerase chain reaction (RT-PCR). The exclusion criteria were as follows: (1) intracranial infection, encephalopathy, or cerebral trauma related to convulsions; (2) mental or neurological defects; and (3) intestinal bacterial infection (such as a positive stool culture). For patients who were hospitalized more than once during our study period, only data from the first diagnosis was included.

2.2.2. Diagnostic criteria for febrile seizures

According to the latest guidelines[7], febrile seizures are those that occur in a child 6 months to 5 years of age and are accompanied by a fever ($\geq 100.4^{\circ}\text{F}$ [38°C]), without any central nervous system infection or other encephalopathies. They may be classified as simple or complex. Complex seizures last ≥ 15 minutes and are associated with focal neurologic findings or recur within 24 hours; however, they exclude moderate to severe dehydration and severe electrolyte imbalances.

2.2.3 The inclusion and exclusion criteria for acute gastroenteritis

The inclusion criteria for simple gastroenteritis were as follows: children with gastrointestinal symptoms caused by acute gastroenteritis, no serious dehydration and acidosis, no electrolyte imbalance, and no low blood sugar levels. We excluded intracranial space-occupying lesions and other diseases that cause

vomiting, diarrhoea, and other gastrointestinal symptoms from this study. We also excluded patients with serious complications and moderate-to-severe dehydration, defined by the World Health Organization as a fluid deficit of > 5% of body weight [8], See Table 1 for details .

2.2.4. Clinical and laboratory data

Clinical data on the age at onset, sex, timing and frequency of diarrhoea and seizures, and past medical history, such as for epilepsy and congenital central nervous system disease were collected. Laboratory findings, including C-reactive protein [CRP]; Lac lactate; neutrophil elastase [NE]; white blood cell [WBC]; creatine kinase myocardial band [CKMB]; uric acid, sodium, potassium, chloride, calcium, magnesium, glucose, potential of hydrogen [PH], bicarbonate (HCO_3^-), bases excess [BE] blood urea nitrogen, and creatinine levels were reviewed to exclude patients with an electrolyte imbalance or hypoglycaemia, which may also cause seizures. Other tests include a cranial MRI, a cranial CT, and an electroencephalogram. Laboratory tests were performed at the time of visiting the emergency room (after at least one seizure) in most cases.

2.3. Methods

Faecal samples were tested for norovirus by RT-PCR using a norovirus RNA Detection Kit (Guangdong Huayin Medicine Science, Co. Ltd. Guangzhou, China). An elevated serum uric acid level was defined as > 420 $\mu\text{mol/L}$, which was determined by colorimetry (Uric Acid Test Kit (manufacturer: Roche Diagnostics GmbH; Production address: Sandhofer Strasse 16, 68305 Mannheim, Germany). All statistical analyses were performed using the IBM SPSS version 21.0. Age was expressed as median and range, continuous variables (seizure frequency and clinical laboratory indicators, such as serum uric acid, myocardial enzymes, creatinine, blood glucose, HCO_3^- , calcium, sodium, and potassium levels) as mean \pm standard deviation and categorical variables as N (%). For homogeneity of variance, a t-test was used to compare the two groups, while the Mann–Whitney U test was used for comparison between non-normally distributed data groups. Statistical significance was set at $P < 0.05$. Spearman's rank-order correlation was used for correlation analysis. A receiver operating characteristic (ROC) analysis was performed to calculate the area under the curve (AUC) for ROC and the serum uric acid cut-off value that optimally distinguished CwG from acute gastroenteritis patients. The optimal threshold value corresponded to the best sum of sensitivity and specificity.

3. Ethics

This study was conducted in accordance with the Declaration of Helsinki of the World Medical Association. It was approved by the ethics committee of the Guangzhou Women and Children's Medical Center. Informed consent was obtained from the children's guardians or close relatives beforehand.

4. Results

4.1. General data

A total of 132 norovirus positive cases between January 2019 and January 2020 were initially enrolled, Among them, 43 cases did not meet the inclusion criteria due to diagnosis of epilepsy, intracranial infection, intracranial space occupation or complicated with other serious diseases. Only 89 of these cases met the inclusion criteria. Of the 89 cases, 49 patients met the inclusion criteria for CwG (27 boys and 22 girls; The age of onset ranged between 11 and 36 months (mean 20.84 ± 5.83 months), while 40 cases met the inclusion criteria for acute gastroenteritis (26 boys and 14 girls; The age of onset ranged between 2 and 53 months (mean 19.00 ± 13.48 months). Furthermore, 32 cases (19 boys and 13 girls; The age of onset ranged between 8 and 48 months (mean 23.53 ± 11.29 months) of febrile seizures observed during the same study period were included in our study.

4.2. Clinical manifestations

In the CwG group, 48 cases (98.0%) had generalized tonic-clonic seizures and convulsions following gastrointestinal symptoms. There were 42 cases (85.7%) that had seizures \geq two times (including three cases with seizures \geq 10 times); the mean frequency of seizures prior to admission was (2.85 ± 1.90) episode, The mean time interval between the first convulsion and blood drawing on admission was (1.83 ± 0.75) d. The total mean frequency of seizures was 3.82 ± 2.43 episodes during the course of the disease. Most cases (95.9%) had seizures that lasted for $<$ 5 min, although no patient had a single convulsion lasting $>$ 15 min. Patients neither had a previous history of convulsions, nor a diagnosis and family history of epilepsy. Nineteen patients (38.8%) underwent an electroencephalogram examination, only one case showed an abnormal result (because of increased slow waves on the background, which became normal in a later reexamination). Thirteen patients underwent a cerebrospinal fluid examination, all of which showed normal results. Twenty-eight patients (57.1%) underwent an MRI examination and 5 patients (10.2%) underwent CT examination. The results were all normal. The follow-up period ranged from 12–14 months. Of the 43 (87.8%) children who completed the follow-up, 1 (2.3%) had recurrent convulsions (due to gastroenteritis following rotavirus infection). On the final evaluation, neurological examination and psychomotor development were normal in all 43 of the 49 children, including the patient who had recurrent convulsions.

The symptoms of gastroenteritis in the CwG group were acute in onset, mainly presenting with diarrhoea and vomiting. Vomiting frequency was 1 to $>$ 10 times a day. Diarrhoea frequency was 3 to $>$ 10 times a day, with a watery consistency. The course of the disease was approximately 5–7 days, with no high-grade fever (when convulsions occurred). Gastrointestinal symptoms of the acute gastroenteritis group were all acute in onset, mainly presenting as diarrhoea, with a frequency of one to five times a day and a watery consistency; some cases were accompanied with vomiting one to five times a day. The course of disease was 1–5 days; some cases were accompanied by a high-grade fever, although most cases were complicated by symptoms of respiratory infection. No serious complications and no moderate to severe dehydration were noted in either group. Furthermore, there was no serious acid-base imbalance or electrolyte disorder.

In the febrile seizure group, there were 10 cases of complex convulsions and 22 of simple convulsions; the mean frequency of seizures was 1.41 ± 0.67 . All patients had convulsions before admission. The mean time between the first convulsion and admission for blood drawing was (0.76 ± 0.66) d. The duration of each convulsion was < 5 min in 29 patients (90.6%), and the duration of a single convulsion in all children was < 15 min. Among these patients, seven (21.9%) had a history of febrile seizures, while two (6.3%) had a family history of febrile seizures.

4.3. Blood test laboratory results

The serum uric acid levels, PH , HCO_3 , BE, blood glucose, Serum sodium and WBC of the CWG group were lower than those of the simple gastroenteritis group, with statistically significant differences, as shown in Table 2. Serum uric acid levels were elevated in all groups, with 43 (87.8%), 9 (22.5%), and 3 (9.4%) cases in the CWG, acute gastroenteritis, and febrile convulsion groups, respectively. The average serum uric acid level in the CWG group was significantly higher than that in the acute gastroenteritis group (564.36 ± 125.28 vs 338.42 ± 141.03 $\mu\text{mol/L}$, $p < 0.0001$) (Table 2, Figure 1). The serum uric acid level in the CWG group was little correlated with the number of seizures ($R^2 = 0.0353$, $p = 0.1961$) (Figure 2). There was no increase in serum uric acid levels in the febrile seizure group, and the average serum uric acid level was 287.18 ± 89.96 $\mu\text{mol/L}$. The ROC revealed that the optimal serum uric acid cut-off value for distinguishing between CWG and acute gastroenteritis was 444 $\mu\text{mol/L}$, with a sensitivity of 85.7%, a specificity of 85.0%, and an AUC of 88.0% (Figure 3). This serum uric acid level may be useful for predicting CWG.

Other blood test laboratory data in all children showed no significant abnormal findings for transaminase, myocardial enzymes, urea nitrogen, creatinine, blood ammonia, serum potassium, and serum calcium levels. The comparison between clinical characteristics and important laboratory indicators among the two groups is shown in Table 2.

5. Discussion

This study showed that children in the CWG group had Lower serum sodium, higher serum uric acid levels and metabolic acidosis was more obvious, than acute gastroenteritis group, as shown in Table 2. In addition, the serum uric acid level in the CWG group remained significantly higher than that in the acute gastroenteritis group. Uric acid is the end product of purine metabolism; the concentration of uric acid in the blood depends on the balance between uric acid production and excretion. Approximately two-third of uric acid in the human body is excreted by the kidney, while one-third by the intestinal tract. In addition, uric acid intestinal excretion occurs with the help of transporters and intestinal probiotics[9]. Studies have shown that blocking the transport of uric acid into the intestinal tract leads to an increase in serum uric acid concentration and concurrent improvement of intestinal barrier homeostasis, which reduces serum uric acid levels[10], proving that the intestinal tract plays a critical role in serum uric acid regulation. Furthermore, the intestinal flora is vital to purine and uric acid metabolism. This study showed that the gastrointestinal symptoms were more prominent in the CWG

group than in the acute gastroenteritis group, and the course of the disease was long, while metabolic acidosis was apparent. These results suggest that children with norovirus-associated CwG have significant gastrointestinal symptoms, which may be due to a high viral load and a serious damage to the intestinal barrier that ultimately affects serum uric acid metabolism. Whether seizures are caused by elevated serum uric acid levels or direct virus invasion remains debatable; thus, further studies are warranted.

Based on our results, the serum uric acid level in the CwG group remained significantly higher than that in the acute gastroenteritis group, ($p < 0.0001$) (Figure 1, Table 2). Similar to previous studies[11-12], the optimal serum uric acid cut-off value for distinguishing between CwG and acute gastroenteritis was 444 $\mu\text{mol/L}$, with a sensitivity of 85.7%, a specificity of 85.0%, and an AUC of 88.0% (Figure 3). Suggest possible an elevated serum uric acid level may be an effective clinical biochemical indicator for the anticipation of CwG. The possibility of norovirus-associated CWG should be noted especially in children with gastrointestinal symptoms and norovirus-positive seizures with repeated convulsions when serum uric acid is elevated in these children. It can provide evidence support for further reducing cranial imaging examination, electroencephalogram and invasive lumbar puncture examination, and make corresponding anti-aspiration measures, precautions and explanations to reduce unnecessary anxiety. But, the increase in serum uric acid levels in the CwG group was little correlated with the number of seizures ($R^2 = 0.0353$, $p = 0.1961$) (Figure 2), there was no statistical significance.

Previous studies consider uric acid as a metabolite. However, recent studies have found that uric acid is not only associated with gout but also with cardiovascular diseases and complications of preeclampsia in pregnancy and neurological diseases[13-15]. Other studies have shown that uric acid metabolites may improve nervous system activity and act as mediators of inflammation[16]. The function of serum uric acid needs to be further explored. Recently, there have been studies exploring the relationship between serum uric acid levels and seizures [17-18]. A mouse model study[17] showed that elevated serum uric acid levels could cause seizures in mice. In addition, it[18] has been shown that elevated serum uric acid levels are associated with seizures secondary to stroke. Previous studies also support our findings that the serum uric acid level in the CwG group is significantly higher than that in the acute gastroenteritis group[11-12]. In this study, with all children infected with norovirus, the serum uric acid level in the CwG group remained significantly higher than that in the acute gastroenteritis group. This suggests a high possibility of correlation between serum uric acid levels and seizures and explores the mechanism of seizures in children with CwG.

In conclusion, we study shows that children with norovirus diarrhea with recurrent convulsions, increased uric acid, more obvious metabolic acidosis should pay high attention to the possibility of Norovirus related CWG. Lumbar puncture and Cranial imaging are unnecessary and should not be recommended. Serum uric acid level may be a useful clinical blood test indicator to predict norovirus associated CWG and may provide a new research direction for the pathogenesis of norovirus associated CWG convulsion.

Disadvantages: This study was a retrospective analysis with a small sample size and was a single-center study; The dynamic changes of uric acid were not examined. The form of convulsions was described by family members and eyewitness doctors. The specific times of vomiting and diarrhea during the course of the disease cannot be counted. This is a shortcoming, and the conclusion needs to be further confirmed by a large sample multi-center prospective study.

Declarations

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Authors' contributions

Daoju Jiang and Kaili Shi completed data collection and manuscript writing.

Suyun Li completed statistical table 2. Guangming Liu completed the production of Figure 1 and Figure 2. Zheng Liu completed the production of Figure 3. Jun Shen and Peiqing Li completed the revision of the manuscript.

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Availability of data and materials

All data generated or analysed during this study are included in this published article [and its supplementary information files].

Ethics approval and consent to participate

This study was conducted in accordance with the Declaration of Helsinki of the World Medical Association. It was approved by the ethics committee of the Guangzhou Women and Children's Medical Center. Informed consent was obtained from the children's guardians or close relatives beforehand.

Consent for publication

Not applicable.

Competing interests

Daoju Jiang ,Kaili Shi,Suyun Li ,Guangming Liu ,Zheng Liu, Jun Shen , Peiqing Li . All other authors declare no conflict of interest.

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Tables

Table 1. WHO guideline for the assessment of dehydration^[8]

Decide	No dehydration	Mild dehydration (If the patient has two or more signs in below column)	Severe dehydration (If the patient has two or more signs in below column)
Condition	Well and alert	Restless or irritable	Lethargic or unconscious
Eyes	Norma	Sunken	Sunken
Thirst	Drinks normally, not thirsty	Drinks eagerly, thirsty	Drinks poorly, or not able to drink
Skin pinch	Recovers rapidly	Recovers slowly	Recovers very slowly
Fluid deficit as percentage of body weight (%)	<5	5–10	>10

Table 2: Comparison of clinical characteristics of norovirus associated CWG and norovirus simple gastroenteritis groups

	CWG group	Simple gastroenteritis group	P-value
Total (N)	49	40	
Age of onset (months)	20.84±5.83	19.00±13.48	0.3907
Male,n (%)	27(55.1%)	26(65.0%)	0.3440
Blood test laboratory results			
PH	7.34±0.06	7.39±0.05	<0.0001*
HCO ₃ ⁻ (mmol/L)	18.63±3.69	20.87±3.52	0.0045*
BE(mmol/L)	-6.09±3.45	-3.27±3.39	<0.0001*
K ⁺ (mmol/L)	4.03±0.53	4.09±0.50	0.585
Na ⁺ (mmol/L)	133.06±2.99	134.58±4.11	0.0468*
Ca ²⁺ (mmol/L)	1.19±0.07	1.20±0.06	0.4701
Mg ²⁺ (mmol/L)	1.23±0.79	1.22±0.56	0.9464
Glucose(mmol/L)	4.52±1.20	5.23±1.10	0.0046*
CKMB(U/L)	45.45±16.03	45.17±32.74	0.9581
Serum uric acid(umol/L)	564.36±125.28	338.42±141.03	<0.0001*
WBC×10 ⁹	8.10±3.28	11.28±4.68	0.0003*
NE(%)	45.69±12.26	51.38±16.42	0.0735
CRP(mg/L)	5.34±7.91	15.10±33.47	0.0512

PH potential of hydrogen;HCO₃⁻ bicarbonate ;BE bases excess; CKMB creatine kinase myocardial band; CRP C-reactive protein; NE neutrophil elastase; WBC white blood cell. * Significant difference (p < 0.05) was noted between the groups.

Figures

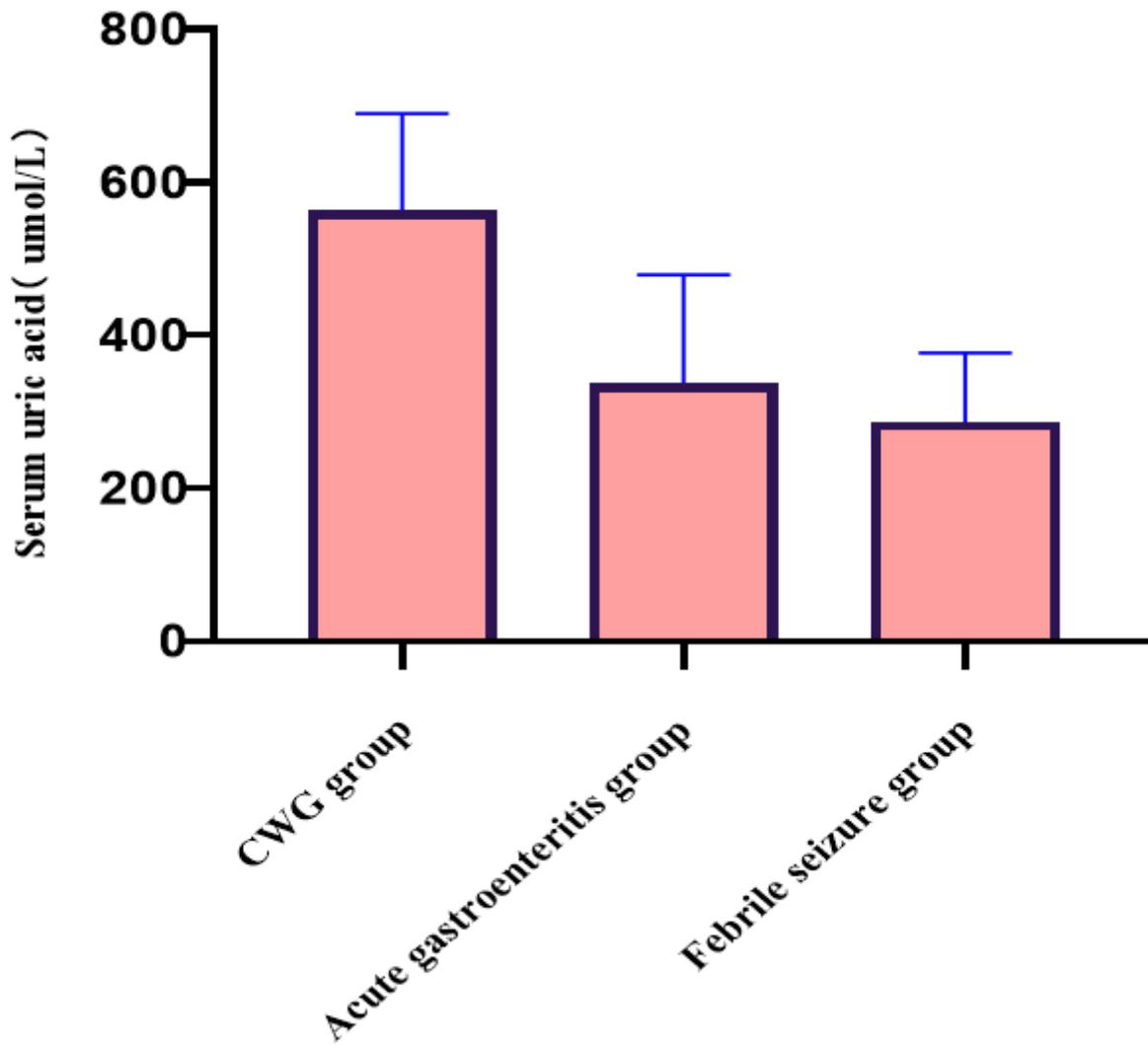


Figure 1

Bar charts of serum uric acid level of the three groups (CwG, acute gastroenteritis, and febrile seizure).
CwG: benign convulsions associated with mild gastroenteritis

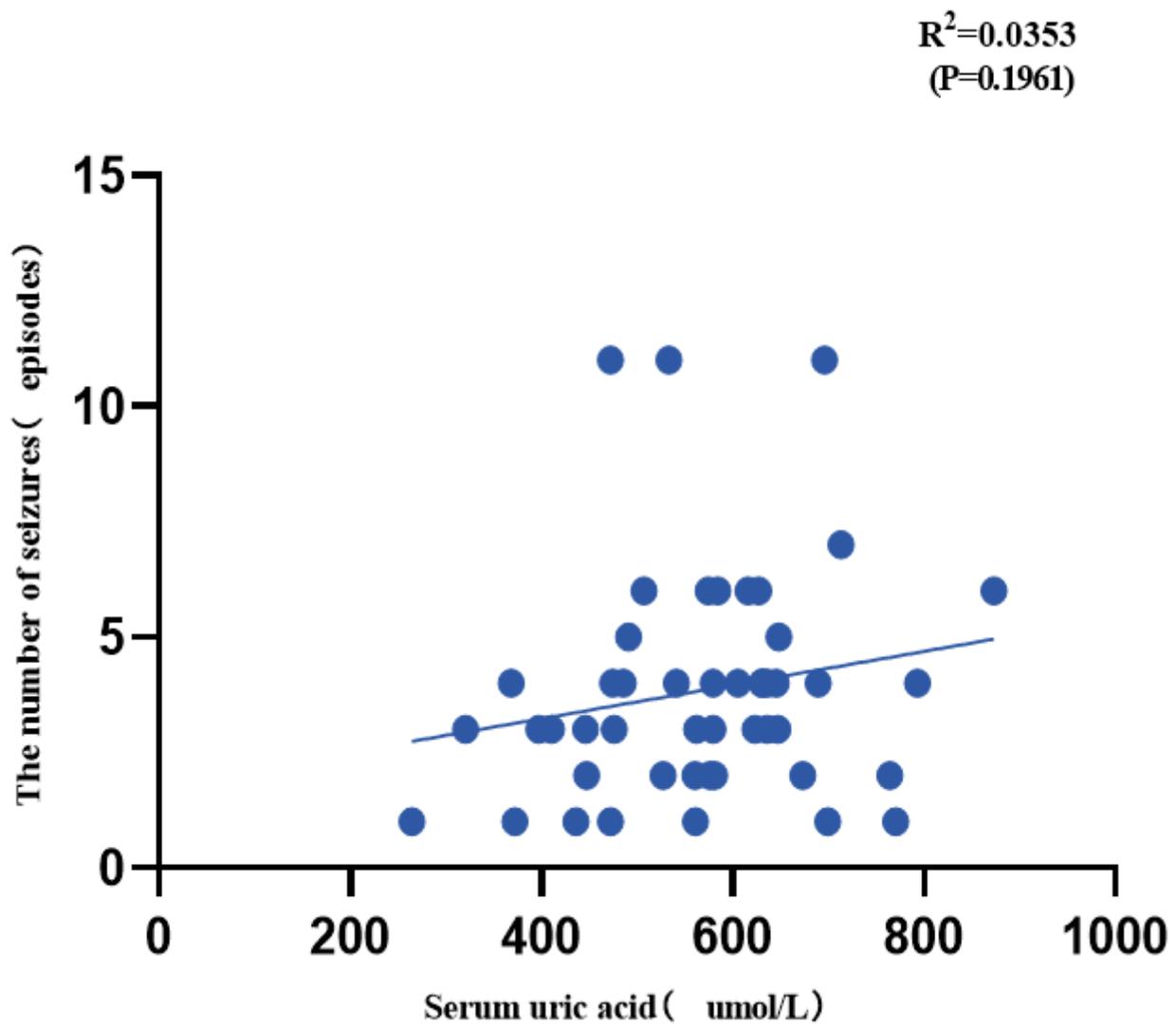


Figure 2

Scatter plot of the relationship between serum uric acid level and seizures episodes in CwG group. r: Pearson r; R^2 : R squared

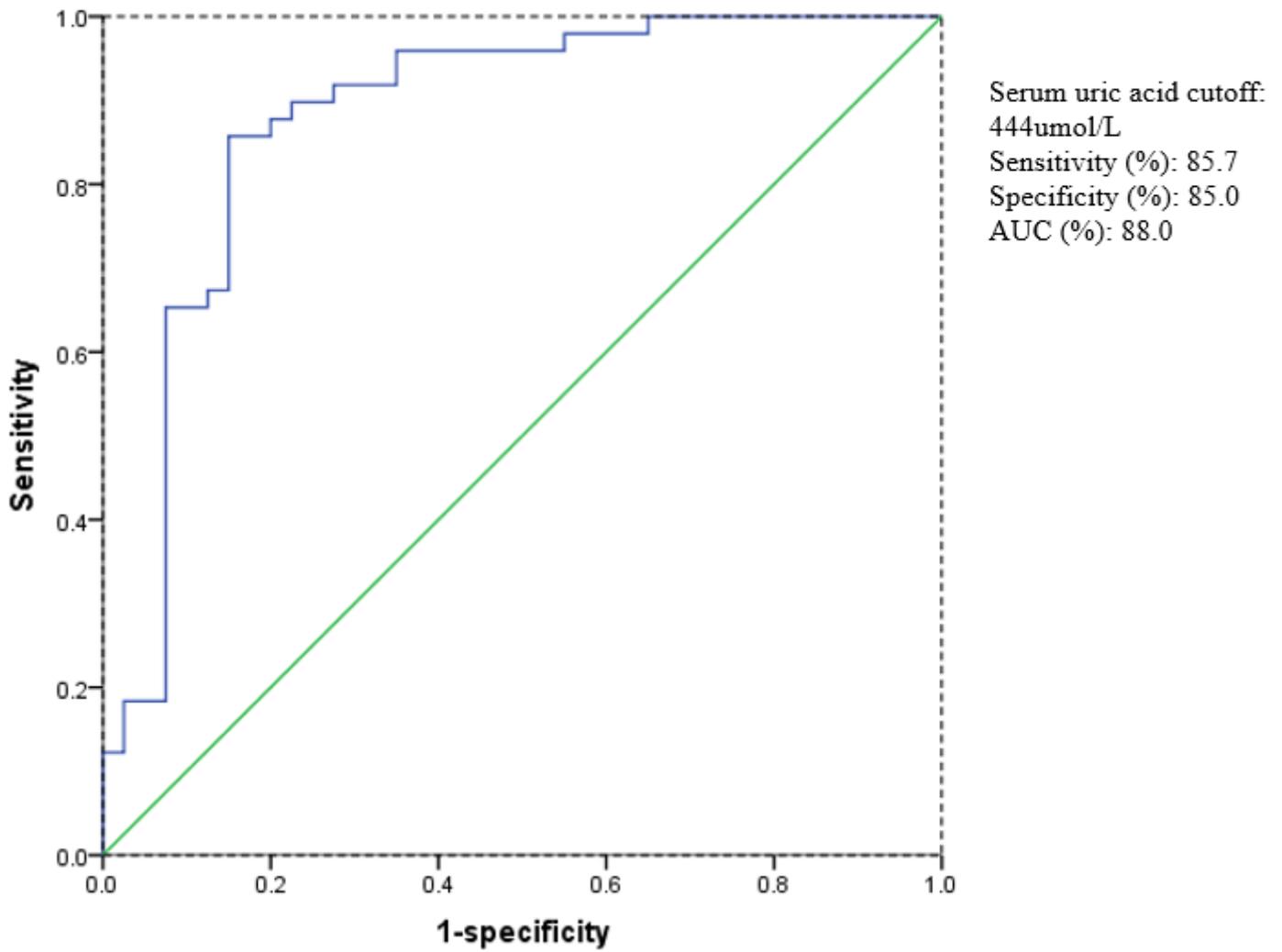


Figure 3

Receiver operating characteristics curve of serum uric acid level's capacity to predict CwG over acute gastroenteritis patients. AUC: area under the curve, CwG: benign convulsions associated with mild gastroenteritis.