Research Square

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Development and validation of a predictive model for symptomatic urinary stones in pregnant women

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Research Article

Keywords: urinary tract stones, pregnancy, predictive model

Posted Date: April 9th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-8851902/v1

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Additional Declarations: No competing interests reported.

Abstract

Background

This study aims to construct a predictive model by analyzing clinical data of patients, providing a reference for selecting treatment strategies for symptomatic urinary tract stones in pregnant women.

Methods

We performed a retrospective review of 252 pregnant women with symptomatic urinary tract stones from January 2018 to January 2025. Multivariate logistic regression analysis was used to identify factors influencing the efficacy of conservative treatment, and a nomogram was constructed. The model was evaluated using ROC curves, the area under the curve (AUC), and the Hosmer-Lemeshow test.

Results

A total of 252 patients were included in the study, of whom 198 showed no response to conservative treatment. Identified independent risk factors included white blood cell count, number of stones, stone size, and degree of hydronephrosis. The AUC for the training set was 0.84 (95% CI: 0.77–0.91), and for the validation set, it was 0.81 (95% CI: 0.70–0.93). The optimal cutoff value for the ROC curve in the training set was 0.738, corresponding to a sensitivity of 0.78 and a specificity of 0.76. Using the same cutoff value in the validation set, the sensitivity was 0.78 and the specificity was 0.83. The Hosmer-Lemeshow test indicated good model fit.

Conclusions

This study identified white blood cell count, number of stones, stone size, and degree of hydronephrosis as factors influencing the efficacy of conservative treatment. The predictive model constructed based on these factors provides guidance for treatment decision-making in pregnant patients with symptomatic renal stones.

Introduction

Urinary stone disease has become a global public health challenge, with its incidence and prevalence showing a continuous upward trend [1, 2]. Epidemiological data indicate regional variations in the prevalence of kidney stones: 1–5% in Asia, 5–9% in Europe, and 7–13% in North America [3]. In the United States, approximately 7.1% of women are affected by stones, and this proportion continues to rise. Notably, the recurrence rate of stones in pregnant women is higher than in the general population [4, 5].

Clinically diagnosed urinary tract stones during pregnancy predominantly occur in the mid-to-late stages of gestation. Patients often present with symptoms such as backache, hematuria, vomiting, and fever [6–8]. Urinary tract stones in pregnancy pose a serious risk, as they can lead to urinary tract obstruction, upper urinary tract infection, and even sepsis, directly endangering the lives of both the mother and the fetus [9]. Therefore, timely management of kidney stones during pregnancy is particularly crucial. Currently, for pregnant patients with stones showing no obvious signs of infection, conservative management remains the clinically preferred approach [10, 11]. Studies have indicated that urinary stones smaller than 1 cm in diameter during pregnancy have a spontaneous passage rate of 70%-80%, a mechanism potentially attributable to elevated progesterone levels [12–14]. Although most patients can achieve relief through conservative management, a significant proportion of those with persistent symptoms may ultimately require further interventions such as percutaneous nephrostomy, ureteral stent placement, or ureteroscopy [14–16]. Appropriate treatment measures help reduce the risk of adverse outcomes for pregnant women, including miscarriage, preterm birth, and fetal death.

Therefore, accurately evaluating the impact of different treatment approaches on symptomatic urinary stones in pregnant women is of critical importance. However, research guiding treatment decisions based on laboratory and imaging findings remains relatively limited. Thus, this study aims to retrospectively analyze clinical data from relevant patients to develop a predictive model, thereby offering guidance for selecting treatment options for pregnant women with symptomatic urinary stones.

Methods

Study design

This study included a total of 252 pregnant women with symptomatic urinary stones who visited the outpatient and emergency departments of Hangzhou First People's Hospital between January 2018 and January 2025. All patients were randomly divided into a training set and a validation set in a 7:3 ratio, with 176 patients in the training set and 76 in the validation set. The inclusion criteria were as follows: (1) age ≥ 18 years; (2) confirmed pregnancy; (3) presence of symptoms such as backache, fever, and vomiting; (4) diagnostic findings indicating urinary stones. The exclusion criteria included: (1) incomplete medical records; (2) severe comorbidities (placental abruption, eclampsia); (3) significant urinary system diseases (congenital malformations, severe urethral strictures).

Data acquisition and definition

Based on expert recommendations and clinical experience, we preliminarily included the following variables: age, gestational week, number of pregnancies, history of kidney stones, hypertension, diabetes, duration of symptoms, white blood cell count, high-sensitivity C-reactive protein (CRP), neutrophil count, urine nitrite, urine white blood cell count, stone location, stone size, stone number, and degree of hydronephrosis. Among these, categorical variables included gestational week, number of pregnancies, history of kidney stones, hypertension, diabetes, urine nitrite, stone location, stone number,

degree of hydronephrosis, and treatment approach. Gestational week was categorized into first trimester (≤ 12 weeks), second trimester (13–28 weeks), and third trimester (≥ 28 weeks). The number of pregnancies was classified as 1, 2, or ≥ 3. Based on urine nitrite positivity, patients were divided into those with and without urinary tract infection. Stone location was classified as left, right, or bilateral. Stone number was categorized as single or multiple. The degree of hydronephrosis was graded as none, mild, moderate, or severe. Patients who underwent interventions such as double-J stent placement, nephrostomy, or experienced outcomes such as miscarriage or preterm delivery during pregnancy were considered as having failed conservative treatment. Conversely, those without such events were deemed to have responded effectively to conservative treatment.

Statistical and analysis

Data processing and analysis were performed using R (version 4.4.2), along with Zstats v1.0 (www.zstats.net). Measurement data conforming to a normal distribution are expressed as mean ± standard deviation, and intergroup comparisons were conducted using the independent samples t-test. Measurement data not conforming to a normal distribution are expressed as the interquartile range, with intergroup comparisons performed using the Mann-Whitney U test. Categorical variables are expressed as percentages, and intergroup comparisons were carried out using the chi-square test or Fisher's exact test. Variables that showed statistical significance in the univariate analysis were further included in a multivariate logistic regression analysis to identify independent risk factors. The predictive ability of the model was evaluated by plotting the receiver operating characteristic (ROC) curve and calculating the area under the curve (AUC). We used the Hosmer-Lemeshow test to assess the model's goodness-of-fit. A P-value < 0.05 was considered statistically significant for all tests.

Results

Basic features

In this study, a total of 252 patients were included, among whom 198 patients were ineffective after conservative treatment and subsequently underwent ureteral stent placement, with 2 patients receiving double-J stent insertion after nephrostomy. The subjects were randomly divided into a training set and a validation set at a ratio of 7:3, consisting of 176 patients in the training set and 76 patients in the validation set. The general and clinical characteristics of the patients in the two groups are detailed in Table 1, with no statistically significant differences observed in comparisons between the two groups (P > 0.05).

Table 1
Comparison of results between training set and validation set

Variables	Total (n = 252)	Validation (n = 76)	Train (n = 176)	statistic	*P*
Age, M (Q_1, Q_3)	29.00 (27.00, 32.00)	30.00 (27.00, 32.00)	29.00 (27.00, 32.00)	Z=-0.14	0.893
Duration of symptoms, M (Q_1, Q_3)	2.00 (1.00, 3.00)	2.00 (1.00, 3.00)	2.00 (1.00, 3.00)	Z=-0.05	0.960
WBC, M (Q_1, Q_3)	11.05 (8.40, 13.80)	11.05 (8.38, 13.45)	11.05 (8.40, 14.03)	Z=-0.42	0.678
CRP, M (Q_1, Q_3)	6.30 (2.68, 15.72)	7.15 (2.38, 20.12)	6.00 (2.90, 14.43)	Z=-0.49	0.626
Neutrophil count, M (Q_1, Q_3)	8.80 (6.60, 12.30)	8.75 (6.88, 11.35)	8.90 (6.55, 12.53)	Z=-0.30	0.763
Urine WBC, M (Q_1, Q_3)	23.50 (7.00, 90.25)	23.00 (7.00, 107.75)	23.50 (7.00, 89.25)	Z=-0.34	0.735
Size, M (Q_1, Q_3)	0.80 (0.50, 1.10)	0.80 (0.60, 1.10)	0.80 (0.50, 1.10)	Z=-0.41	0.680
Gestational week, n(%)				χ^2=1.57	0.455
1	21 (8.33)	6 (7.89)	15 (8.52)		
2	149 (59.13)	41 (53.95)	108 (61.36)		
3	82 (32.54)	29 (38.16)	53 (30.11)		
Number of pregnancies, n(%)				χ^2=0.11	0.946
1	136 (53.97)	40 (52.63)	96 (54.55)		
2	104 (41.27)	32 (42.11)	72 (40.91)		
3	12 (4.76)	4 (5.26)	8 (4.55)		
History of kidney stones, n(%)				χ^2=0.00	0.964
0	206 (81.75)	62 (81.58)	144 (81.82)		
1	46 (18.25)	14 (18.42)	32 (18.18)		
Hypertension, n(%)				χ^2=1.95	0.163
0	225 (89.29)	71 (93.42)	154 (87.50)		
1	27 (10.71)	5 (6.58)	22 (12.50)		
M: Median, Q_1: 1st Quartile, Q_3: 3rd Quartile					

Variables	Total (n = 252)	Validation (n = 76)	Train (n = 176)	statistic	*P*
Diabetes, n(%)				χ^2=1.71	0.191
0	236 (93.65)	74 (97.37)	162 (92.05)		
1	16 (6.35)	2 (2.63)	14 (7.95)		
Urine nitrite, n(%)				χ^2=0.00	0.976
0	229 (90.87)	69 (90.79)	160 (90.91)		
1	23 (9.13)	7 (9.21)	16 (9.09)		
Location, n(%)				χ^2=0.49	0.783
1	91 (36.11)	25 (32.89)	66 (37.50)		
2	104 (41.27)	33 (43.42)	71 (40.34)		
3	57 (22.62)	18 (23.68)	39 (22.16)		
Number, n(%)				χ^2=0.47	0.491
0	131 (51.98)	37 (48.68)	94 (53.41)		
1	121 (48.02)	39 (51.32)	82 (46.59)		
Hydronephrosis, n(%)				χ^2=1.03	0.794
0	23 (9.13)	7 (9.21)	16 (9.09)		
1	186 (73.81)	57 (75.00)	129 (73.30)		
2	33 (13.10)	8 (10.53)	25 (14.20)		
3	10 (3.97)	4 (5.26)	6 (3.41)		
Treatment, n(%)				χ^2=2.06	0.152
0	54 (21.43)	12 (15.79)	42 (23.86)		
1	198 (78.57)	64 (84.21)	134 (76.14)		
Z: Mann-Whitney test, χ^2: Chi-square test					
M: Median, Q_1: 1st Quartile, Q_3: 3rd Quartile					

Model construction

Univariate logistic regression analysis was performed on the relevant data from the conservative treatment failure group and the conservative treatment success group within the training set. The results showed that gestational age, white blood cell count, number of stones, stone size, and degree of hydronephrosis were all statistically significant ($P < 0.05$), as shown in Table 2. These variables were

subsequently included in a multivariate logistic regression analysis. The results revealed that white blood cell count, number of stones, stone size, and degree of hydronephrosis were independent influencing factors for conservative treatment failure ($P < 0.05$), as presented in Table 3. Consequently, based on these four independent risk factors, a nomogram was constructed to visually assess the probability of pregnant women with symptomatic urolithiasis requiring intervention, as illustrated in Fig. 1.

Table 2
Univariate logistic regression analysis

Variables	β	S.E	Z	*P*	OR (95%CI)
Gestational week					
1					1.00 (Reference)
2	1.29	0.57	2.25	0.024	3.62 (1.18 ~ 11.12)
3	0.89	0.60	1.47	0.140	2.44 (0.75 ~ 7.96)
Number of pregnancies					
1					1.00 (Reference)
2	0.63	0.38	1.65	0.100	1.87 (0.89 ~ 3.93)
3	1.06	1.09	0.97	0.332	2.88 (0.34 ~ 24.52)
History of kidney stones					
0					1.00 (Reference)
1	0.37	0.49	0.75	0.455	1.44 (0.55 ~ 3.79)
Hypertension					
0					1.00 (Reference)
1	1.26	0.76	1.64	0.100	3.51 (0.79 ~ 15.68)
Diabetes					
0					1.00 (Reference)
1	0.68	0.79	0.86	0.389	1.97 (0.42 ~ 9.17)
Location					
1					1.00 (Reference)
2	0.10	0.40	0.25	0.806	1.10 (0.51 ~ 2.39)
3	0.30	0.49	0.61	0.543	1.34 (0.52 ~ 3.49)
Number					
0					1.00 (Reference)
1	1.01	0.38	2.63	0.009	2.73 (1.29 ~ 5.79)
Urine nitrite					
0					1.00 (Reference)
OR: Odds Ratio, CI: Confidence Interval					

Variables	β	S.E	Z	*P*	OR (95%CI)
1	1.64	1.05	1.57	0.117	5.17 (0.66 ~ 40.35)
Hydronephrosis					
0					1.00 (Reference)
1	1.33	0.54	2.44	0.015	3.78 (1.30 ~ 10.99)
2	0.94	0.67	1.41	0.158	2.57 (0.69 ~ 9.55)
3	16.57	979.61	0.02	0.987	15651360.79 (0.00 ~ Inf)
Age	0.08	0.05	1.75	0.080	1.09 (0.99 ~ 1.19)
Duration of symptoms	0.01	0.04	0.15	0.878	1.01 (0.93 ~ 1.09)
WBC	0.20	0.06	3.44	< .001	1.22 (1.09 ~ 1.36)
CRP	0.02	0.01	1.64	0.101	1.02 (1.00 ~ 1.03)
Neutrophil count	-0.01	0.02	-0.72	0.473	0.99 (0.95 ~ 1.02)
Urine WBC	0.00	0.00	1.08	0.282	1.00 (1.00 ~ 1.00)
Size	2.54	0.66	3.84	< .001	12.64 (3.46 ~ 46.18)
OR: Odds Ratio, CI: Confidence Interval					

Table 3
Multivariate logistic regression analysis

Variables	β	S.E	Z	*P*	OR (95%CI)
Gestational week					
1					1.00 (Reference)
2	1.46	0.76	1.93	0.054	4.30 (0.98 ~ 18.98)
3	1.06	0.80	1.33	0.184	2.90 (0.60 ~ 13.91)
Number					
0					1.00 (Reference)
1	1.11	0.45	2.47	0.014	3.04 (1.26 ~ 7.37)
Hydronephrosis					
0					1.00 (Reference)
1	1.54	0.67	2.28	0.022	4.66 (1.24 ~ 17.46)
2	0.82	0.82	0.99	0.320	2.26 (0.45 ~ 11.34)
3	17.63	1294.52	0.01	0.989	45302428.51(0.00 ~ Inf)
WBC	0.21	0.07	3.24	0.001	1.24 (1.09 ~ 1.41)
Size	2.61	0.74	3.53	< .001	13.58 (3.19 ~ 57.83)
OR: Odds Ratio, CI: Confidence Interval					

Model validation

As shown in Fig. 2 (Fig. 2A for the training set, Fig. 2B for the validation set), the ROC curves of both the training and validation sets demonstrated high discriminative ability. The AUC for the training set was 0.84 (95% CI: 0.77–0.91), while that for the validation set was 0.81 (95% CI: 0.70–0.93). The optimal cutoff value from the training set ROC curve was 0.738, corresponding to a sensitivity of 0.78 and a specificity of 0.76. When applying the same cutoff value to the validation set, the sensitivity was 0.78 and the specificity was 0.83. The model fit was assessed using the Hosmer–Lemeshow test, yielding a P-value of 1 for the training set and 0.068 for the validation set (both P > 0.05), indicating good model calibration in both datasets.

Discussion

Urinary tract stones have a widespread impact both developed and developing countries. They not only impose a significant socioeconomic burden but also cause poses serious harm to the health of patients [17, 18]. In order to provide early intervention for symptomatic urinary tract stones in pregnant women, this

study aims to analyze relevant risk factors and develop a predictive model, thereby reducing the severity of the disease.

This study identified white blood cell count, number of stones, stone size, and degree of hydronephrosis as influencing factors for the failure of conservative treatment. Hydronephrosis during pregnancy is commonly observed in the third trimester, with its etiology being multifactorial. It is mainly due to the compression of the ureter by the enlarged uterus at the pelvic brim. At the same time, the increased progesterone levels cause the smooth muscles to relax and the peristalsis to weaken. Due to engorgement of the overlying uterine veins and physiological dextrorotation of the uterus, the right ureter is more likely to be affected [19, 20].

Symptomatic hydronephrosis may present with flank pain, urinary tract irritation symptoms. Studies indicate that surgical intervention is often considered when severe flank pain or significant upper urinary tract dilation occurs. Without active treatment, symptomatic hydronephrosis may increase the risk of preterm delivery or adverse maternal and fetal outcomes [21, 22].

Stone size plays a crucial role in determining the treatment approach. In the general population, stones smaller than 1 centimeter have a higher likelihood of spontaneous passage, whereas stones larger than 1 centimeter are typically considered too large to pass through. It has been reported that kidney stones diagnosed during pregnancy, if they are of an appropriate size (< 1 centimeter), are usually treated with symptomatic supportive measures. Intervention is generally required if the stone exceeds 1 cm, bilateral obstruction is present, or conservative treatment fails [23].

Additionally, research indicated that a high white blood cell count may suggest suitability for surgical treatment, although this indicator still requires validation through further prospective studies [19].

Multiple urinary tract stones refer to the presence of two or more stones in both side of the urinary tract. The formation of such stone is due to the slow flow of urine in certain areas, creating conditions conducive to the deposition of crystals in the urine. Multiple calculi form because there are multiple deposition centers, and the crystals in the urine will continuously precipitate on these centers, eventually leading to the formation of multiple urinary calculi. Compared to single stones, multiple stones carry a higher risk of causing acute obstruction. Urinary tract obstruction caused by stones is often accompanied by urinary tract infections. If patients have underlying urinary system diseases or systemic conditions, this could even be life-threatening [24]. Acute obstruction increases pressure within the renal pelvis, facilitating the entry of bacteria or toxins into the bloodstream and triggering systemic inflammatory response syndrome. In severe cases, it can lead to systemic poisoning symptoms or shock [25]. Therefore, for patients with acute obstruction, urinary tract infection, or sepsis, surgery is often necessary to decompress the collecting system and prevent serious complications [26, 27].

Based on the clinical characteristic differences between patients who responded to conservative treatment and those who did not, this study developed a predictive model with favorable performance. In

clinical practice, this model can be utilized to formulate more personalized treatment plans for patients, thereby improving their prognosis and demonstrating significant clinical application value.

However, this study also has several limitations. First, the retrospective design may introduce potential bias. Second, the relatively limited sample size may increase the risk of model overfitting. Additionally, due to the lack of detailed data on hormonal changes during pregnancy, this variable could not be included in the analysis. Finally, the current validation was conducted only on internal data. In the future, it is necessary to incorporate multi-center and cross-regional external data for further validation to more comprehensively assess the clinical predictive performance of the model.

Conclusion

This study demonstrates that white blood cell count, number of stones, stone size, and degree of hydronephrosis are important factors influencing the effectiveness of conservative treatment. The predictive model constructed based on these factors can provide guidance for treatment decision-making in pregnant patients with symptomatic renal stones.

Abbreviations

CRP
high-sensitivity C-reactive protein
WBC
White blood cell count
ROC
receiver operating characteristic
AUC
area under the curve

Declarations

Availability of data and materials

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

Funding

No funding was received for conducting this study.

Acknowledgements

We extend sincere appreciation to all participants for their essential contributions

Authors' Contributions

XHM, CC, CJL, WYC and CTL: designing of the study. XHM: data collection. XHM: data analysis. XHM: manuscript writing. CJL and CC: reviewing the article. All authors contributed to the article and approved the submitted version.

Ethics approval and consent to participate

Our study adhered to the Declaration of Helsinki.

This study was approved by the Ethics Committee of Hangzhou First People's Hospital (Reference number: 2026ZN095-1). As a retrospective study, the requirement for written informed consent was waived by the committee.

Clinical trial number

Reference number: 2026ZN095-1.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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Figures

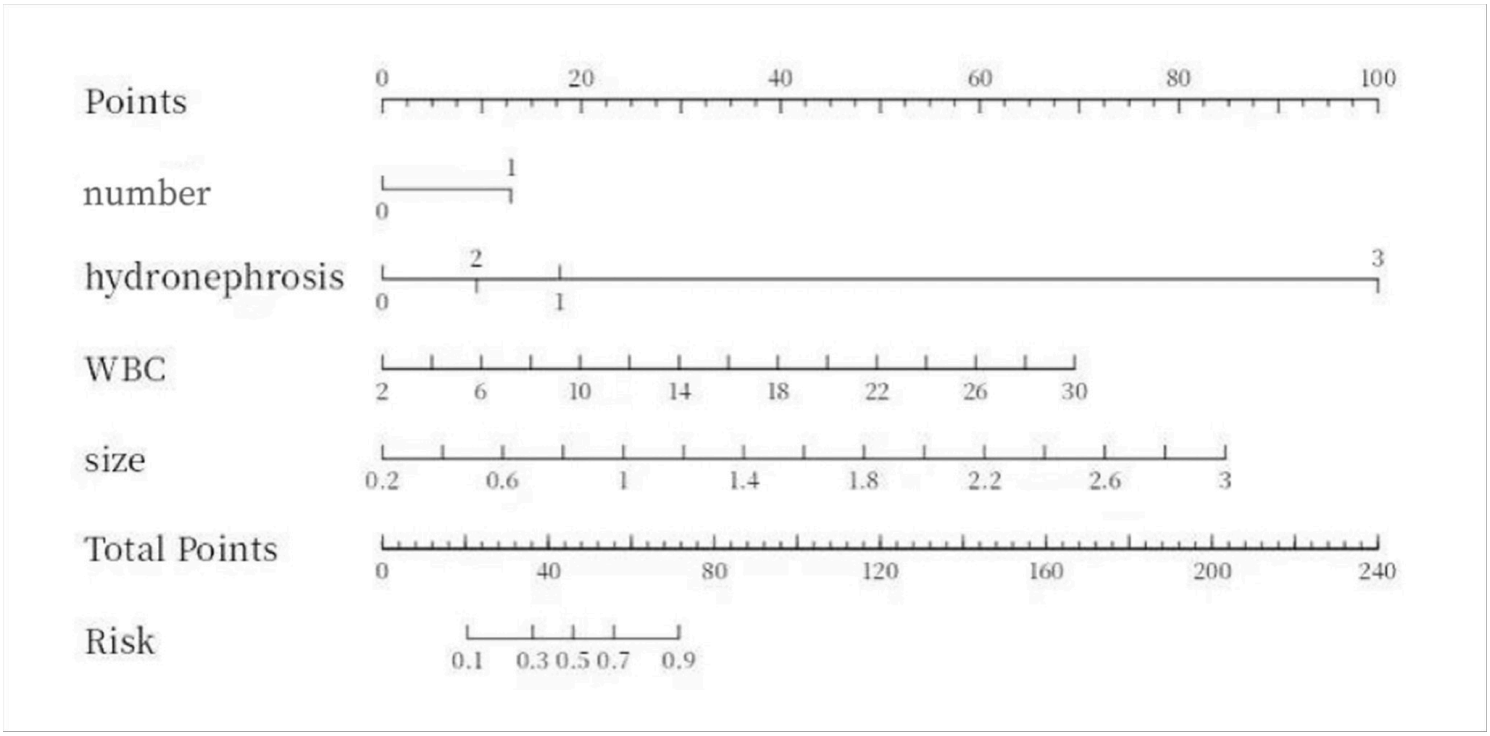


Figure 1

Nomogram for treatment decisions in pregnant women with symptomatic urinary tract stones

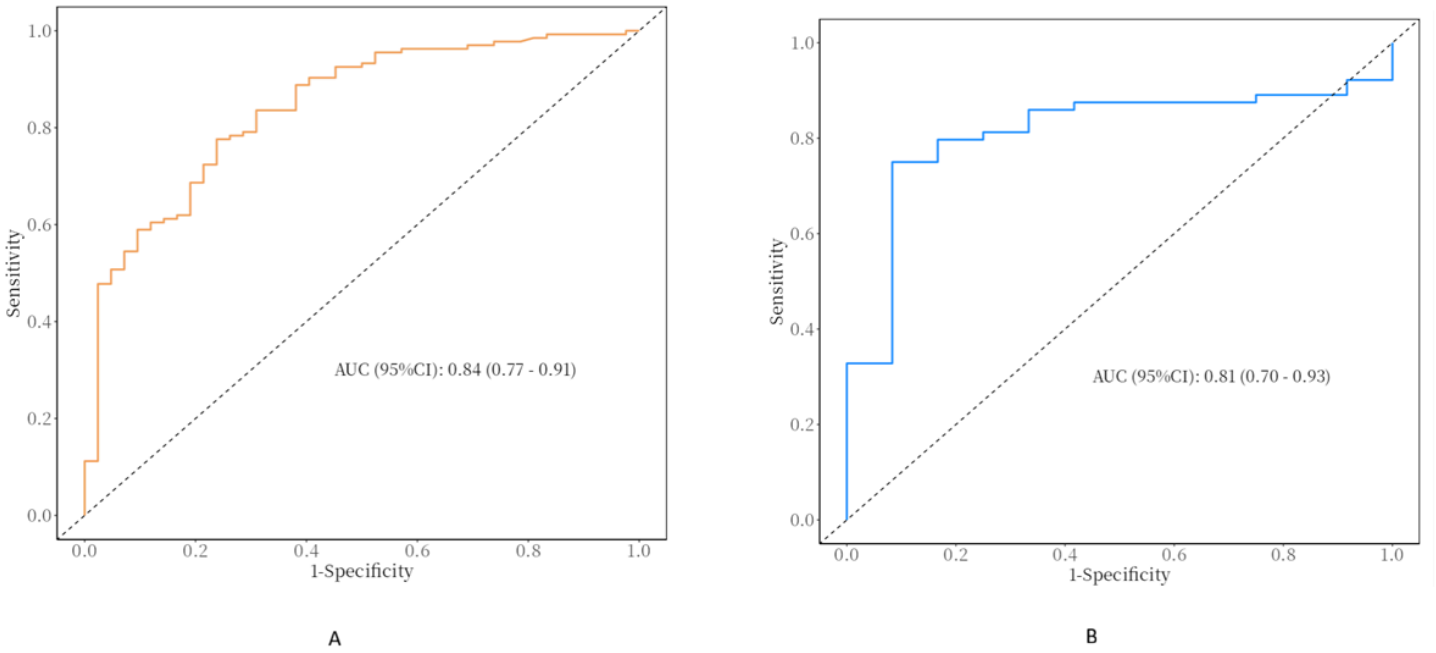


Figure 2

A ROC curve of the training set

B ROC curve of the validation set