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Analysis of influencing factors and construction of nomogram model for short term prognosis in patients with tuberculous meningitis

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Abstract

Objective: To identify risk factors and develop a nomogram for predicting short-term prognosis in tuberculous meningitis (TBM). *Methods:* This retrospective study analyzed 99 TBM patients (70 with good and 29 poor prognosis patients based on modified Rankin Scale) from Guiyang Public Health Treatment Center (February 2023–June 2024). Clinical variables were compared, and logistic regression used to identify prognostic factors. A nomogram was constructed and validated using ROC, calibration, and decision curve analyses. *Results:* Age, hydrocephalus, acute cerebral infarction, and cerebrospinal fluid (CSF) chloride/ADA levels independently predicted poor prognosis ($P < 0.05$). ROC analysis revealed AUCs of 0.69 (age), 0.65 (hydrocephalus), 0.58 (cerebral infarction), 0.76 (CSF chloride), and 0.73 (CSF ADA). The combined nomogram model demonstrated superior predictive performance (AUC: 0.86) versus individual factors. Calibration and decision curves confirmed high accuracy and clinical utility.
Conclusion: The nomogram incorporating age, hydrocephalus, acute cerebral infarction, CSF chloride, and ADA levels effectively predicts short-term TBM prognosis with robust clinical applicability.

Keywords: Tuberculous meningitis; Short-term prognosis; Nomogram prediction model; Risk factors; Cerebrospinal fluid biomarkers.

INTRODUCTION

Tuberculosis is a chronic infectious disease caused by *Mycobacterium tuberculosis* (MTB), is a multi-organ destructive disease. According to the World Health Organization, there were 8.2 million new cases of TB worldwide in 2023, with an incidence rate of 134/100,000. In China, the incidence of TB is 52/100,000, making it one of the countries with a high burden of TB.[1] Tuberculous meningitis (TBM), the most serious extrapulmonary complication of tuberculosis, is a non-suppurative inflammation of the meninges and its surrounding tissues.[2,3] Besides the cerebral pia mater, MTB often invades arachnoid and cerebral parenchyma. The mortality rate of TBM is as high as 20%-50%, and more than 50% of surviving patients have permanent central nervous system sequelae even with sufficient anti tuberculosis drug treatment.[4,5] Therefore, accurate prognostic assessment in TBM facilitates timely clinical decision-making, which may play a critical role in improving quality of life and reducing mortality.

TBM is a serious central nervous system infection that progresses rapidly and can pose a threat to the patient's life in the short term.[6] Short-term prognostication may provide timely feedback on the patient's condition and the effect of treatment, which may help management decisions.[7] A novel method of prediction model based on the use of the nomogram has become popular in recent years. The nomogram model is simple, convenient, practical and low cost, and can accurately predict the risk of death, recurrence, disability and complications of diseases.[8] However, there were few reports on the nomogram prediction model for prognosis of TBM. In this study, we analyzed the independent prognostic factors in TBM and constructed a nomogram to predict its outcome, which could provide a simple and objective prognostic prediction tool, to

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assist in targeted intervention on high-risk factors for poor prognosis, and achieve personalized precision medicine for TBM patients.

METHODS

A total of 148 patients diagnosed with TBM admitted to Guiyang Public Health Treatment Center from February 1, 2023 to June 2, 2024 were collected. The inclusion criteria include: (1) age ≥18 years old (2) meeting the published diagnostic criteria of TBM.[9] The exclusion criteria include: (1) tuberculous meningitis combined with other central nervous system pathologies such as cryptococcal meningitis, bacterial meningitis, neurosyphilis, toxoplasmosis encephalopathy, lymphoma and progressive multifocal leukoencephalopathy, etc. (2) Positive human immunodeficiency virus antibodies (anti-HIV). (3) Incomplete case information. According to the inclusion criteria and exclusion criteria, 99 TBM patients were finally included. This study was approved by the Ethics Committee of Guiyang Public Health Treatment Center.

Diagnostic criteria of TBM

According to the diagnostic criteria[9], central nervous system tuberculosis is divided into confirmed cases, highly suspected cases and suspected cases. (1) Confirmed cases: clinical signs and symptoms associated with TBM, accompanied by one or more of the following: ① Acid-fast bacilli were found in CSF. ② Positive culture of acid-fast bacilli in CSF. ③ Positive nucleic acid test of acid-fast bacilli in CSF; i.e., CSF tested positive for acid-fast Bacillus nucleic acid. (2) Highly suspected cases: Diagnostic score ≥12 (with cranial imaging examination) or ≥10 (without cranial imaging examination). (3) Suspected cases: Diagnostic score 6-11 (with cranial imaging examination) or 6-9 (without cranial imaging examination). The diagnostic scoring criteria for TBM were listed in Table 1. The above diagnosis should exclude other central nervous system diseases as far as possible.

Clinical data collection

The clinical data on patients' gender, age, clinical manifestations, blood test results, CSF test results and cranial imaging examination through CT as well as MRI were collected for retrospective analysis.

Prognostic judgment and grouping

The patients' prognosis was scored according to the modified Rankin scale (mRS) at discharge. According to the score, the patients were divided into good prognosis group (mRS Score: 0-2 points) and poor prognosis group (mRS Score: 3-6 points).

Statistical analysis

SPSS 27.0 software was used for statistical analysis of the data. Measurement information conforming to normal distribution was expressed as mean ± standard deviation and T-test was used to analyze data. Measurement information that did not conform to normal distribution was represented by M (Q_1, Q_3) and Mann-Whitney U test was employed to analyze data. The categorical data was expressed as the number of cases (%) and treated with the chi-square test. The prognostic factors for short term outcomes in TBM patients were analyzed by univariate and multivariate logistic regression. The ROC curve was plotted by Graphpad Prism 8.0 software to evaluate the predictive value of related risk factors on the short term prognosis of TBM patients. The patients included in the study were randomly divided into a training set (n=69) and a validation set (n=30) based on a ratio of 7:3. A nomogram model for predicting the short term prognosis of TBM patients was constructed using R software. And the model was evaluated by ROC curve, calibration curve and decision curve. $P<0.05$ was considered a statistically significant difference.

RESULTS

The basic information of patients

A total of 99 patients with an average age of 47 ± 17years were included in this study. There were 65 (66%) male and 34 (34%) female patients, of which 72 cases (73%) were initially treated and 27 cases (27%) were re-treatment. And a total of 39 cases (40%) were complicated by other chronic diseases. The common clinical symptoms included fever (96 cases, 97%), night sweats (11 cases, 11%), emaciation (54 cases, 55%), meningeal irritation (77 cases, 78%), consciousness impairment (81 cases, 82%), peripheral nerve dysfunction (58 cases, 59%) and cranial nerve palsy (26 cases, 26%). Blood tests showed lymphopaenia ($0.98 \pm 0.44 \times 10^9$/L) and hyponatraemia (133.41 ± 16.03mmol/L), an increase in erythrocyte sedimentation rate (133.41 ± 16.03mm/h) and hypersensitive

Table 1: The diagnostic scoring criteria for TBM

Classification (Maximum Score)	Scoring Criteria	Total points (Points)
Clinical Criteria (6 points)	Duration of symptoms ≥ 5 days	4
	Systemic symptoms of tuberculosis infection (at least 1 of the following): weight loss (or growth retardation in children), night sweats, cough lasting ≥ 2 weeks	2
	Recent (within 1 year) contact with a tuberculosis patient or positive TST/IGRA (for children under 10 years)	2
	Focal neurological deficits (excluding cranial nerve palsy)	1
	Altered consciousness	1
	Cranial nerve palsy	1
CSF Criteria (4 points)	Clear appearance	1
	Leukocyte count: 10-500 cells/μL	1
	Lymphocyte predominance (>50%)	1
	Protein concentration > 1 g/L	1
	CSF-to-plasma glucose ratio < 50% or CSF glucose < 2.2 mmol/L	1
Cranial imaging Criteria (6 points)	Hydrocephalus	1
	Basilar meningeal enhancement	1
	Tuberculoma	1
	Acute cerebral infarction	1
	Enhanced anterior cranial base high signal	1
Evidence of Tuberculosis in Other Sites (4 points)	Chest radiograph suggestive of active tuberculosis: signs of tuberculosis = 2; miliary tuberculosis = 4	4/2
	CT/MRI/ultrasound evidence of tuberculosis foci outside CNS	2
	Positive acid-fast staining or MTB culture in sputum, lymph nodes, urine, gastric lavage fluid, or blood cultures	4
	Positive MTB nucleic acid test in other clinical specimens (excluding CSF)	4

Note: TST: Tuberculin test; IGRA: Interferon - γ Release Assay; CT: Computed Tomography; MRI: Magnetic Resonance Imaging; CNS: Central Nervous System

C-reactive protein (16.58 ± 5.42mg/L). CSF examination showed that the opening pressure (211.36 ± 36.65 mm H_2O), leukocyte count [121.00 (69.00, 172.50) × 10^6/L], lymphocyte ratio [62.10 (45.60, 78.80) %], the content of protein [1.64 (1.15, 1.96) g/L], and the levels of Adenosine deaminase (ADA) [16.10 (13.90, 18.95) U/L] in CSF were significantly increased. The content of glouse(1.81 ± 0.66 mmol/L) and chloride [112.09 (100.31, 119.59) mmol/L] in CSF were significantly decreased. Besides, 91% (90/99) of TBM patients have cranial imaging abnormalities, such as hydrocephalus, basilar meningeal enhancement, tuberculoma, acute cerebral infarction and enhanced anterior cranial base high signal. The details were seen in Table 2.

Comparison of clinical features between the two groups

According to mRS Scores of patients at discharge, the study subjects were divided into good prognosis group (n=70) and poor prognosis group (n=29). There were statistically significant differences in age, peripheral nerve dysfunction, peripheral blood lymphocyte count, platelet count, serum sodium, hypersensitive C-reactive protein (hs-CRP), the content of protein, the levels of chloride and ADA in CSF, hydrocephalus and acute cerebral infarction between 2 groups (P<0.05, Table 2).

Table 2: Comparison of clinical features of 99 TBM patients and patients with different prognosis

Clinical data	Total (n=99)	good prognosis (n=29)	poor prognosis (n=70)	$x^2/t/Z$	*P*
Age (years, x±s)	47 ± 17	64 ± 13	40 ± 14	7.78	<0.001
Sex				1.89	0.169
Male	65 (66)	22 (76)	43 (61)		
Female	34 (34)	7 (24)	27 (39)		
BMI(kg/m^2)	21.20 ± 2.36	21.14 ± 2.01	21.23 ± 2.50	-0.17	0.864
Treatment condition				2.35	0.125
Initial treatment	72 (73)	18 (62)	54 (77)		
Re-treatment	27 (27)	11 (38)	16 (23)		
Basic disease	39 (39)	14 (48)	25 (36)	1.36	0.244
Clinical symptoms					
Fever	96 (97)	29 (100)	67 (96)	1.282	0.258
Night sweats	11 (11)	2 (7)	9 (13)	0.26	0.612
Emaciation	54 (55)	14 (48)	40 (57)	0.65	0.420
Meningeal irritation	77 (78)	23 (79)	54 (77)	0.06	0.813
Consciousness disorder	81 (82)	27 (93)	54 (77)	3.51	0.061
Peripheral nerve dysfunction	58 (59	23 (79)	35 (50)	7.26	0.007
Cranial nerve paralysis	26 (26)	8 (28)	18 (26)	0.04	0.847
Blood test					
Leukocyte ($\times10^9$/L)	5.95 (5.24, 6.50)	6.15 (5.80, 6.47)	5.85 (5.18, 6.51)	-1.07	0.283
Neutrophil ($\times10^9$/L)	4.36 (3.70, 4.79)	4.53 (3.60, 5.00)	4.24 (3.73, 4.69)	-1.33	0.183
Hemoglobin (g/L)	116.04 ± 25.83	109.61 ± 26.40	118.70 ± 25.30	-1.61	0.111
Lymphocyte ($\times10^9$/L)	0.98± 0.44	0.67 ± 0.19	1.11 ± 0.45	-6.84	<0.001
Platelet ($\times10^9$/L)	215.45 ± 48.12	198.59 ± 41.68	222.44 ± 49.14	-2.29	0.024
Serum sodium (mmol/L)	133.41 ± 16.03	127.55 ± 17.92	135.84 ± 14.64	-2.40	0.018
Erythrocyte sedimentation rate(mm/h)	24.33 ± 4.61	25.60 ± 4.70	23.81 ± 4.50	1.78	0.077
hs-CRP(mg/L)	16.58 ± 5.42	19.15 ± 6.19	15.52 ± 4.71	3.17	0.002
CSF examination					
Opening pressure (mm H_2O)	211.36 ± 36.65	208.34 ± 41.44	212.61 ± 34.72	-0.53	0.600
Leukocyte count($\times10^6$/L)	121.00 (69.00, 172.50)	139.00 (96.00, 185.00)	116.50 (64.00, 166.75)	-1.59	0.111
Lymphocyte ratio(%)	62.10 (45.60, 78.80)	62.10 (47.80, 76.10)	62.25 (45.40, 81.05)	-0.65	0.516
Chloride (mmol/L)	112.09 (100.31, 119.59)	92.68 (87.44, 103.83)	114.66 (109.41,120.32)	-5.00	<0.001

Protein(g/L)	1.64 (1.15, 1.96)	2.63 (2.04, 3.21)	1.35 (1.00, 1.70)	-6.91	<0.001
Content of glouse(mmol/L)	1.81 ± 0.66	1.71 ± 0.43	1.86 ± 0.73	-1.30	0.196
ADA(U/L)	16.10 (13.90, 18.95)	39.70 (37.41, 41.00)	15.40 (13.60, 16.78)	-4.70	<0.001
Cranial imaging examination					
Hydrocephalus	38 (38)	16(55)	22 (31)	4.89	0.027
Basilar meningeal enhancement	58 (59)	21 (72)	37 (53)	3.23	0.072
Tuberculoma	8 (8)	3 (10)	5 (7)	0.02	0.899
Acute cerebral infarction	35 (35)	15 (52)	20 (29)	4.81	0.028
Enhanced anterior cranial base high signal	47 (47)	17 (59)	30 (43)	2.04	0.153

Analysis of risk factors for short-term prognosis in TBM patients

Clinical characteristics of patients as independent variables and different prognostic outcomes as dependent variables (good prognosis =0, poor prognosis =1) were included in univariate Logistic regression analysis. The assignment of relevant independent variables were shown in Table 3. Univariate analysis showed that age, peripheral nerve dysfunction, serum sodium, the content of protein, the levels of ADA and chloride in CSF, hydrocephalus, and acute cerebral infarction were statistically significant (P<0.05). Multivariate logistic regression analysis was conducted on the statistically significant independent variables mentioned above. The results showed that old age, hydrocephalus, acute cerebral infarction, the levels of chloride and ADA in CSF were independent risk factors for short term prognosis of TBM patients (P<0.05). See details in Table 4.

Predictive value of risk factors for short term prognosis in TBM patients

ROC curve was used to evaluate the predictive value of related risk factors for short term prognosis in TBM patients. The results showed that the area under the curve (AUC) of age, hydrocephalus, acute cerebral infarction, chloride and ADA levels in CSF for predicting short term prognosis of TBM patients were 0.6882(95%CI: 0.6232-0.7532), 0.6466(95%CI: 0.5312-0.7619), 0.5798(95%CI: 0.4618-0.6978), 0.7580(95%CI:

Table 3: Assignment table of influencing factors related to TBM patients

Variable	Description of the assignment
Age; BMI; Leukocyte; Neutrophil; Lymphocyte; Hemoglobin; Platelet; Serum sodium; Erythrocyte sedimentation rate; hs-CRP; the opening pressure, leukocyte count and lymphocyte ratio, the content of protein and glouse; the levels of ADA and chloride in CSF	measured value
Sex	male=0; female=1
Treatment condition	initial treatment=0; re-treatment=1
Basic disease; fever; night sweats; emaciation; meningeal irritation; consciousness disorder; peripheral nerve dysfunction; cranial nerve paralysis; hydrocephalus; basilar meningeal enhancement; tuberculoma; acute cerebral infarction; enhanced anterior cranial base high signal	No=0; Yes=1

Table 4: Analysis of risk factors for short term prognosis in TBM patients

Variable	Univariate regression analysis			Multivariate regression analysis		
	P	OR	95%CI	*P*	OR	95%CI
Age	0.023	1.754	1.079-2.852	0.024	0.815	0.683-0.973
Sex	0.112	3.428	0.749-15.689	-	-	-
BMI	0.732	1.022	0.904-1.155	-	-	-
Treatment condition	0.175	2.111	0.717-6.215	-	-	-
Basic disease	0.135	2.277	0.773-6.706	-	-	-
Fever	0.688	1.077	0.750-1.548	-	-	-
Night sweats	0.177	2.104	0.715-6.196	-	-	-
Emaciation	0.126	2.326	0.790-6.848	-	-	-
Meningeal irritation	0.578	1.102	0.783-1.551	-	-	-
Consciousness disorder	0.261	0.897	0.743-1.084	-	-	-
Peripheral nerve dysfunction	0.046	2.904	1.022-8.254	0.323	1.723	0.585-5.073
Cranial nerve paralysis	0.273	0.906	0.759-1.081	-	-	-
Leukocyte	0.368	1.642	0.558-4.835	-	-	-
Neutrophil	0.303	1.763	0.599-5.191	-	-	-
Hemoglobin	0.239	1.914	0.650-5.635	-	-	-
Lymphocyte	0.578	1.102	0.783-1.551	-	-	-
Platelet	0.196	2.033	0.692-6.001	-	-	-
Serum sodium	0.039	2.627	1.052-6.562	0.178	2.102	0.714-6.190
Erythrocyte sedimentation rate	0.243	1.902	0.646-5.601	-	-	-
hs-CRP	0.287	1.799	0.611-5.296	-	-	-
Opening pressure in CSF	0.232	1.933	0.656-5.691	-	-	-
leukocyte in CSF	0.196	2.040	0.693-6.007	-	-	-
Lymphocyte ratio in CSF	0.206	2.008	0.682-5.912	-	-	-
Chloride in CSF	0.012	2.123	1.180-3.822	0.009	0.287	0.113-0.732
protein in CSF	0.045	3.114	1.025-9.462	0.091	2.008	0.894-4.511
Content of glouse in CSF	0.077	2.008	0.928-4.346	-	-	-
ADA in CSF	0.013	0.739	0.582-0.937	0.011	0.175	0.046-0.668
Hydrocephalus	0.027	0.650	0.444-0.951	0.023	2.102	1.107-3.991
Basilar meningeal enhancement	0.085	2.004	0.908-4.423	-	-	-
Tuberculoma	0.073	2.065	0.935-4.558	-	-	-
Acute cerebral infarction	0.046	0.778	0.608-0.996	0.024	1.908	1.087-3.349
Enhanced anterior cranial base high signal	0.108	2.282	0.833-6.249	-	-	-

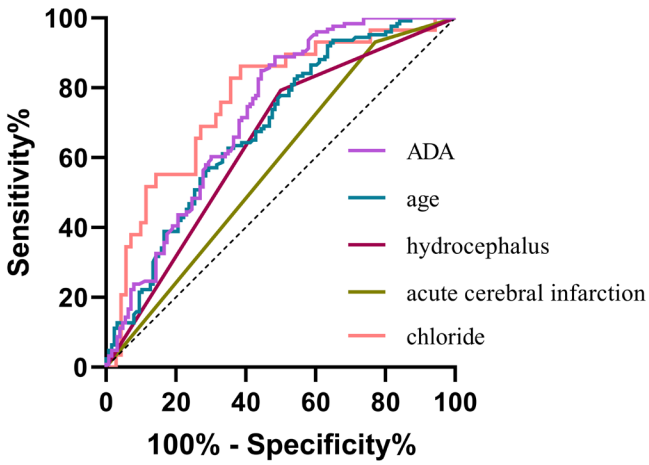

Figure 1. ROC curve of different risk factors predicting short term prognosis in TBM patients

0.6659-0.8701) and 0.7253(95%CI: 0.6627-0.7880) (Fig 1, Table 5). All risk factors had certain predictive value for short term prognosis in TBM patients.

Construction of a nomogram model for predicting the short-term prognosis of TBM patients

Based on the results listed above, the Logistic regression equation is derived as: Logit(P)=1.726 +1.625*hydrocephalus-0.617*chloride+1.631*ADA+1.148*age+1.196*acute cerebral infarction. The nomogram model constructed based on the results of the regression equation was shown in Fig 2. The line segments corresponding to each variable in the nomogram have corresponding scores. By calculating the total score of each variable for each patient, the probability of predicting short term prognosis of TBM patients could be obtained.

Validation of nomogram prediction model

ROC curve, calibration curve and decision curve were used to evaluate the accuracy and prediction efficiency of the nomogram model. The ROC curve showed that the model had an AUC of 0.86 (95%CI: 0.81-0.90) in the training set (Figure 3A) and 0.83 (95%CI: 0.76-0.90) in the validation set (Figure 3B). The results of the calibration curve showed that the probability of the nomogram predicting the short term prognosis of TBM patients was accurate, and the model fit well (Figure 3C-D). The results of the decision curve suggested that when the threshold probability is within the range of 0-1, the net benefit value of using the nomogram model to predict the short term prognosis in TBM patients is high, which has certain clinical practicability (Figure 3E-F).

DISCUSSION

The onset of TBM may be acute or insidious, with non-specific clinical manifestations and low pathogen detection rates. It is difficult to distinguish TBM from other central nervous system infections. At present, the diagnosis of TBM mainly relies on the clinical judgment, laboratory and imaging examinations, which may

Table 5: Analysis of the predictive value of different risk factors for short term prognosis in TBM patients

	AUC	95% CI	P-value	Sensitivity (%)	Specificity (%)
Age	0.6882	0.6232-0.7532	<0.001	64.22	35.56
Hydrocephalus	0.6466	0.5312-0.7619	0.022	68.54	32.06
Acute cerebral infarction	0.5798	0.4618-0.6978	0.012	69.92	22.86
Chloride	0.7580	0.6659-0.8701	<0.001	75.40	80.48
ADA	0.7253	0.6627-0.7880	<0.001	73.02	76.03

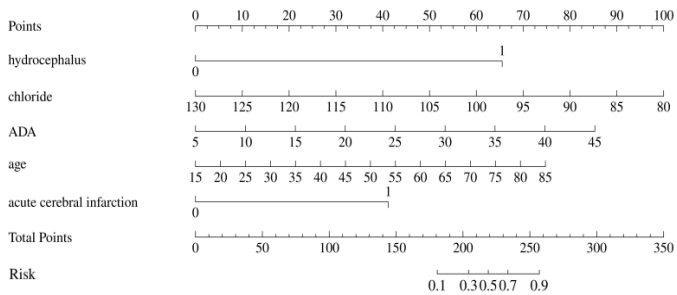

Figure 2. A nomogram model for predicting short term prognosis of TBM patients

lead to misdiagnosis. TBM is difficult to treat and is characterized by high risk of disability and mortality.[10] Therefore, effective prediction of the risk of poor prognosis in TBM may help in identifying high-risk patients at an early stage for timely therapeutic measures, hopefully, to reduce disability and mortality rates.

In this study, logistic regression analysis revealed that older age, elevated ADA levels in CSF, decreased chloride content in CSF, acute cerebral infarction and hydrocephalus were independent risk factors affecting the short term prognosis of TBM patients. The average age of the TBM patients in our study was about 47 years old. We found that the risk of short term poor prognosis increases with age, which may be due

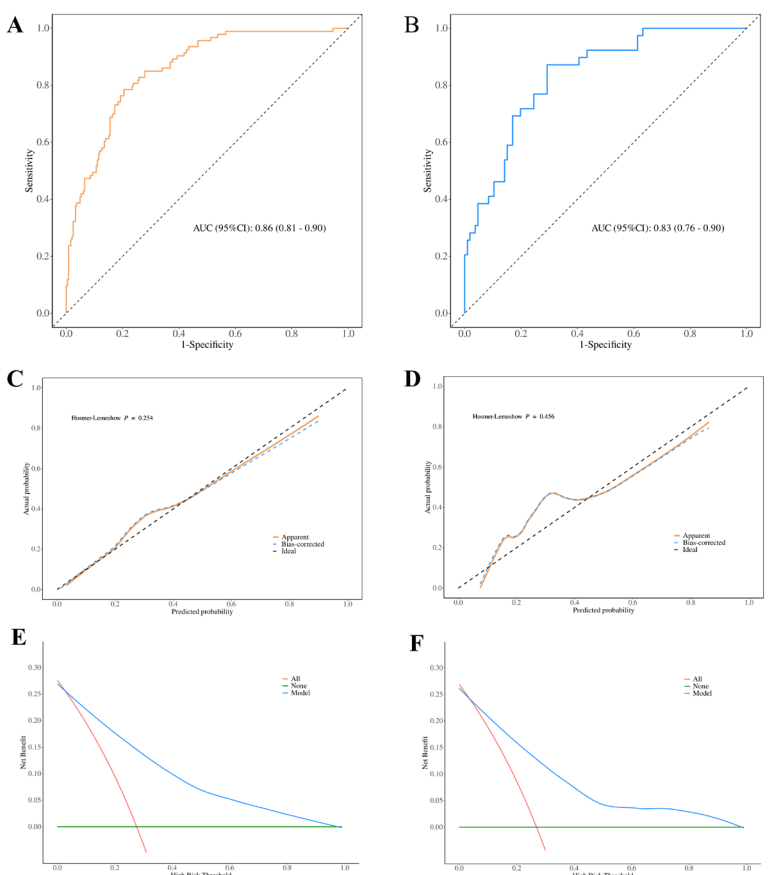

Figure 3. Accuracy verification and prediction efficiency evaluation of the nomogram model
Note: A: ROC curve of training set; B: ROC curve of validation set; C: Calibration curve of training set; D: Calibration curve of validation set; E: Decision curve of training set; F: Decision curve of validation set

to the decline of immune function in middle-aged and elderly patients, thus weakening the body's resistance to pathogens.[11] In addition, middle-aged and elderly patients often have other chronic diseases, such as diabetes, chronic kidney disease, malignant tumors, neurological degeneration and non-specific clinical manifestations, which make it difficult to diagnose and delay the disease, affecting the prognosis of patients.

ADA was a key enzyme in purine nucleotide metabolism, which was widely distributed in brain tissue, thymus and spleen, and participates in the proliferation and differentiation of T lymphocytes in the body.[12] Elevated ADA activity in CSF was common in patients with TBM, which might be attributed to the cellular immune response triggered by MTB infection. After invading the central nervous system, MTB activated immune cells such as T lymphocytes and macrophages, which aggregated locally and released large amounts of ADA.[13] Increased ADA activity reflected the proliferation and activation of lymphocytes, indicating a stronger immune response to MTB, but it might also indicate a more severe inflammatory response, which was associated with a poor prognosis. A prospective cohort study proved that increased CSF ADA levels were independent risk factors for poor prognosis in childhood TBM, which was consistent with our study.[14]

Moreover, this study found that the content of chloride in CSF of patients with good prognosis was higher than that of patients with poor prognosis, suggesting that patients with TBM with a poorer prognosis had lower chloride levels in CSF. We speculated that the decrease CSF chloride levels were related to the disruption of blood-brain barrier and the changes of protein content in CSF. Tuberculous inflammation could increase the permeability of the blood-brain barrier, allowing large molecules such as proteins in the plasma to enter the CSF. At the same time, due to the binding of chloride ions to proteins, the relative contents of chloride in the CSF decreased and the formation of inflammatory exudates increased.[15] Inflammatory exudate adhering to the meninges could cause obstruction of subarachnoid circulation, which is not conducive to the action of anti-tuberculosis drugs on the lesion, affecting the curative effect and prognosis of patients.[16]

Cranial imaging examination indicated that acute cerebral infarction and hydrocephalus were often closely related to the severity of TBM disease.[17,18] In our study, acute cerebral infarction and hydrocephalus were independent risk factors affecting the prognosis of TBM. The incidence of acute cerebral infarction in TBM patients has been reported to be about 30%, which can lead to poor prognosis, and its pathophysiological mechanisms included occlusive vasculitis, intimal hyperplasia and hypercoagulability.[19,20] TBM cerebral infarction is most commonly seen in the basal ganglia region.[21] Studies have shown that acute cerebral infarction is associated with vasospasm and vasculitis, which lead to vascular stenosis and subsequent stroke, thereby increasing the risk of poor prognosis in TBM patients.[18,22] TBM hydrocephalus is mainly manifested as communicating hydrocephalus and obstructive hydrocephalus. Obstructive hydrocephalus is mainly caused by inflammatory exudate blocking the outlet of the fourth ventricle and the midbrain aqueduct, while communicating hydrocephalus is caused by excessive CSF production or arachnoid malabsorption.[23] A meta-analysis displayed that inflammatory factors such as interleukin-6 (IL-6), IL-1β, IL-18, vascular endothelial growth factor (VEGF) and interferon gamma (IFN-γ) were elevated in the CSF of patients with hydrocephalus, which may be involved in the occurrence and development of hydrocephalus and are important potential biological markers for evaluating the diagnosis and prognosis of hydrocephalus.[24] Due to chronic inflammation potentially causing meningeal adhesions and fibrosis that impede the flow of CSF, long-term hydrocephalus and intracranial hypertension can compress the cranial base and cranial nerves. Simultaneously, inflammatory exudates may directly infiltrate or compress blood vessels, leading to sequelae such as facial paralysis, blindness, aphasia, and paralysis, ultimately affecting patient prognosis.[25] Early screening and surgical intervention were necessary.

Due to the lack of specific clinical manifestations and low microbial detection rate, there was no single reliable biomarker that could accurately predict the clinical outcomes of TBM.[26] The nomogram model can effectively predict the incidence rate and prognosis of various diseases.[27,28] It is a commonly used statistical model for individualized predictive analysis, which has the advantages of intuition and visualization, and can provide a better risk assessment for clinical use. This study constructed a nomogram model by combining the levels of ADA, chloride in CSF and related clinical features. The results showed that the AUC of this model for predicting short term prognosis of TBM patients was 0.86 (95% CI: 0.81-0.90),

and its predictive value was significantly higher than that of each indicator used separately. The calibration curve showed that the prediction curve of the model was basically consistent with the measured curve, indicating that the new model had high discriminative ability and accuracy for short term prognosis of TBM. At the same time, the decision curve also showed that the model had high clinical application prospects. In addition, the predictive factors included in the model are clinical data that are easily accessible to clinicians, which makes it easy to use and provides a visual computational tool for communication between doctors and patients. By this model, TBM patients could be individually and systematically assessed and predicted in real time at the time of admission. TBM patients with high risk of poor prognosis could be identified early, monitored and intervened as early as possible, so as to slow down the progression of TBM, reduce the severity of TBM and improve the prognosis of the patients as much as possible.[29]

In summary, compared to traditional risk factors, the nomogram model based on ADA and chloride levels combined with other clinical features had higher accuracy and reliability in predicting the short term prognosis of patients with TBM. This model provided important reference information for clinicians to develop personalized treatment plans and prognostic assessment strategies. However, the study has several limitations. First, its single-center retrospective design may limit the generalizability of the nomogram model. Second, the model's long-term prognostic performance remains untested. Third, it relies on specific biomarkers (ADA and chloride levels) and clinical features, potentially excluding other relevant factors. Future research should validate the model prospectively with larger, diverse cohorts. Exploring additional biomarkers and advanced imaging data for model enhancement is also recommended. Furthermore, assessing the model's utility in long-term prognosis and its integration into clinical decision-making workflows would be valuable.

DISCLOSURE

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