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Construction and Validation of a Risk Prediction Model for Aspiration in Stroke Patients with Dysphagia

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Abstract

Objective

To analyze factors influencing aspiration in stroke patients with dysphagia, construct and validate a risk prediction model, and provide a reference for early identification and prevention of aspiration.

Methods: A retrospective study design was used. Clinical data were collected from 951 stroke patients with dysphagia admitted to a tertiary Grade A hospital in Jinan from January 2024 to December 2024. Patients were randomly divided into a training set (n = 667) and a validation set (n = 284) at a ratio of 7:3. Multivariable logistic regression analysis was used to identify factors associated with aspiration, construct a risk prediction model, and evaluate its predictive performance.

Results: Among the 667 patients in the training set, 206 experienced aspiration. Logistic regression analysis showed that stroke location, artificial airway, mechanical ventilation, history of aspiration, feeding method, food source, language disorder, sedative drugs, and albumin were factors associated with aspiration in stroke patients with dysphagia ($P < 0.05$). Based on these findings, a prediction model suitable for nurses to identify aspiration risk early in stroke patients with dysphagia was constructed. In the validation set, the optimal cut-off value was 0.368, with an accuracy of 89.9%, sensitivity of 90.1%, specificity of 89.7%, positive predictive value of 82.5%, and negative predictive value of 94.8%. The Hosmer-Lemeshow test showed $\chi^2=5.430$ ($P = 0.608$).

Conclusion: The risk prediction model for aspiration in stroke patients with dysphagia showed good discrimination and calibration and may provide a reference for clinical nurses in predicting related risks.

Introduction

Stroke is a major public health issue in China and is characterized by high incidence, high disability, high recurrence, and high mortality, which place a substantial medical burden on families and society [1]. Dysphagia is a common complication after stroke, with an incidence of 37%-78%. It directly impedes oral intake, causes nutritional disorders and dehydration, and seriously hinders rehabilitation [2]. Aspiration is one of the most dangerous secondary events associated with dysphagia. It can induce aspiration pneumonia, respiratory failure, and even asphyxia; it also significantly prolongs hospitalization, increases medical costs, and worsens long-term prognosis [3]. Studies have shown that aspiration, especially silent aspiration, is closely associated with pneumonia, in-hospital mortality, and poor functional recovery in stroke patients, and is an important risk factor affecting clinical outcomes [4]. Silent aspiration is especially problematic because it lacks overt signs such as choking or coughing, making clinical recognition difficult and often delaying early intervention, thereby further increasing the risk of adverse events [5]. Therefore, rapid and accurate screening of high-risk individuals among stroke patients with dysphagia, followed by graded nursing interventions, is of great practical importance for improving patients' quality of life.

At present, commonly used clinical aspiration screening tools include the water swallow test, the Standardized Swallowing Assessment, and the Gugging Swallowing Screen, which have value in preliminary screening [6]. However, existing tools mainly focus on swallowing function and have limited ability to comprehensively predict risk using underlying disease status, treatment-related factors, and nutritional status. They also lack integrated analysis across multiple levels of risk factors, resulting in limitations for individualized risk prediction [7]. A risk prediction model based on multifactorial clinical information is therefore needed. In recent years, risk prediction models based on multivariable regression have become important tools for disease risk stratification because they can integrate multiple independent factors and quantify individual disease probability [8]. In China, however, research on aspiration risk prediction in stroke patients with dysphagia remains relatively insufficient. Few prediction models have been constructed and validated using multifactorial clinical indicators, and simple, efficient, and generalizable assessment tools are still lacking in clinical practice [9].

Clinical practice still lacks a simple and efficient aspiration risk prediction tool for stroke patients with dysphagia that is suitable for nursing settings. Therefore, this observational study based on clinical case data screened independent risk factors for aspiration and constructed and validated a visual risk prediction model, with the aim of providing evidence for clinical nurses to identify high-risk patients early and implement precise, individualized aspiration-prevention nursing care.

1 Methods

1.1 Participants

A total of 951 stroke patients with dysphagia admitted to the departments of neurology, neurosurgery, and rehabilitation at a tertiary Grade A general hospital in Jinan from January 2024 to December 2024 were retrospectively collected as study participants. According to whether aspiration occurred during hospitalization, patients were divided into an aspiration group and a non-aspiration group. The sample was then randomly divided into a training set and a validation set at a ratio of 7:3. Clinical data were compared between the two sets, and an aspiration risk prediction model was further constructed. Inclusion criteria were as follows: (1) stroke confirmed by cranial CT or MRI and meeting the diagnostic criteria for stroke in the Diagnostic Criteria for Major Cerebrovascular Diseases in China (2019) [10]; (2) dysphagia confirmed by swallowing function assessment; (3) age > = 18 years; and (4) complete collection of aspiration status and related clinical data during hospitalization. Exclusion criteria were as follows: (1) dysphagia caused by other conditions, such as head and neck tumors or severe oral diseases; (2) transient ischemic attack, craniocerebral trauma, or tumors; (3) severe cardiac, pulmonary, hepatic, or renal dysfunction, malignant tumors, or other conditions affecting the judgment of clinical outcomes; and (4) extensive missing key variables that precluded model analysis. Aspiration was determined comprehensively by the attending physician based on electronic medical records during hospitalization, choking or coughing, oxygen saturation, moist rales, imaging findings, swallowing assessment, videofluoroscopic swallowing study (VFSS), fiberoptic endoscopic evaluation of swallowing (FEES), and clinical manifestations.

Based on the literature and clinical experience, 19 candidate predictors were initially identified; therefore, at least 190 participants were required. Considering possible missing or invalid data during the study, the sample size was increased by 20%, resulting in a minimum required sample size of 238. This study actually included 951 stroke patients with dysphagia, meeting the requirements for model construction. This study was approved by the Medical Ethics Committee of the First Affiliated Hospital of Shandong First Medical University (Shandong Provincial Qianfoshan Hospital) (ethics approval No.2026-S712).

1.2 Measures

1.2.1 Assessment tool

The Chinese version of the Barthel Index (BI) was used to assess patients' activities of daily living. The total score ranges from 0 to 100; higher scores indicate stronger self-care ability in daily life, whereas lower scores indicate a greater degree of dependence. Dependence was classified into four levels based on the total score: 91–100, independent; 61–90, mild dependence; 41–60, moderate dependence; and 0–40, severe dependence.

1.2.2 Data collection

Based on the study purpose, relevant literature was reviewed and data were collected in combination with clinical experience and expert opinion. Data included two parts. First, general information on stroke patients with dysphagia, including sex and age. Second, clinical data, including disturbance of consciousness, stroke type, stroke location, artificial airway, mechanical ventilation, history of aspiration, feeding method, gastrointestinal decompression, food source, Barthel Index, language disorder, limb movement disorder, acid-suppressive drugs, sedative drugs, albumin, white blood cell count, and hemoglobin. To ensure data accuracy, two trained team members jointly reviewed the hospital electronic medical record system, objectively completed the data forms, and cross-checked the entries. Disagreements were adjudicated by the team leader. Cases with > = 20% missing data were regarded as invalid.

1.3 Statistical analysis

SPSS 25.0 and R 4.5.3 were used for statistical analysis. Categorical data were expressed as counts and percentages (rates), and between-group comparisons were performed using the chi-square test. Ranked data were analyzed using the rank-sum test. Univariate analysis and collinearity testing were performed for candidate variables. A variance inflation factor (VIF) < 5 was considered to indicate no obvious multicollinearity. Variables with $P < 0.05$ in univariate analysis and clinical significance were included in multivariable logistic regression analysis. Receiver operating characteristic (ROC) curves were used to evaluate model discrimination; an area under the curve (AUC) closer to 1 indicates better discrimination, and AUCs were reported with 95% confidence intervals (CIs). Calibration was evaluated using calibration curves and the Hosmer-Lemeshow test. Decision curve analysis (DCA) was used to evaluate clinical net benefit. Internal validation was performed using a 7:3 random split. The significance level was alpha = 0.05, and all tests were two-sided.

2 Results

2.1 General characteristics of participants

A total of 951 stroke patients with dysphagia were included and randomly divided at a ratio of 7:3 into a training set (n = 667) and a validation set (n = 284). There were no statistically significant differences in general characteristics between the two sets (P > 0.05), indicating comparability. General characteristics are shown in Table 1.

Table 1
Baseline characteristics of patients in the training and validation sets (n = 951)

Item	Category	Training set (n = 667)	Validation set (n = 284)	Statistic	P
Sex (1)				0.4702)	0.493
	Female	305(45.7%)	123 (43.3%)		
	Male	362 (54.3%)	161 (56.7%)		
Age (1)				0.5212)	0.471
	≤ 60	228 (34.2%)	104 (36.6%)		
	> 60	439 (65.8%)	180 (63.4%)		
Disturbance of consciousness (1)				1.6002)	0.206
	No	299 (44.8%)	140 (49.3%)		
	Yes	368 (55.2%)	144 (50.7%)		
Stroke type (1)				0.0852)	0.958
	Ischemic	204 (30.6%)	88 (31.0%)		
	Hemorrhagic	437 (65.5%)	186 (65.5%)		
	Mixed	26 (3.9%)	10 (3.5%)		
Stroke location (1)				0.0572)	0.811
	Cerebellum or brainstem	193 (28.9%)	80 (28.2%)		
	Other locations	474 (71.1%)	204 (71.8%)		
Artificial airway (1)				2.2032)	0.138
	No	491 (73.6%)	222 (78.2%)		
	Yes	176 (26.4%)	62 (21.8%)		
Mechanical ventilation (1)				0.0012)	0.975
	No	462 (69.3%)	197 (69.4%)		
	Yes	205 (30.7%)	87 (30.6%)		
History of aspiration (1)				1.2542)	0.263
	No	521 (78.1%)	231 (81.3%)		

Item	Category	Training set (n = 667)	Validation set (n = 284)	Statistic	P
	Yes	146 (21.9%)	53 (18.7%)		
Feeding method (1)				0.9262)	0.629
	Oral feeding	265 (39.7%)	119 (41.9%)		
	Gastric tube feeding	376 (56.4%)	157 (55.3%)		
	Intestinal tube feeding	26 (3.9%)	8 (2.8%)		
Gastrointestinal decompression (1)				0.6702)	0.413
	No	579 (86.8%)	252 (88.7%)		
	Yes	88 (13.2%)	32 (11.3%)		
Food source (1)				0.3142)	0.855
	Hospital-prepared	329 (49.3%)	135 (47.5%)		
	Home-prepared	318 (47.7%)	141 (49.6%)		
	Mixed	20 (3.0%)	8 (2.8%)		
Barthel Index (1)				-1.5873)	0.112
	Independent	19 (2.8%)	9 (3.1%)		
	Mild dependence	94 (14.1%)	46 (16.2%)		
	Moderate dependence	69 (10.3%)	38 (13.4%)		
	Severe dependence	485 (72.7%)	191 (67.3%)		
Language disorder (1)				0.4362)	0.509
	No	79 (11.8%)	38 (13.4%)		
	Yes	588 (88.2%)	246 (86.6%)		
Limb movement disorder (1)				0.0272)	0.870
	No	82 (12.3%)	36 (12.7%)		
	Yes	585 (87.7%)	248 (87.3%)		

Item	Category	Training set (n = 667)	Validation set (n = 284)	Statistic	P
Acid-suppressive drugs (1)				0.6742)	0.412
	No	256 (38.4%)	101 (35.6%)		
	Yes	411 (61.6%)	183 (64.4%)		
Sedative drugs (1)				0.0042)	0.951
	No	464 (69.6%)	197 (69.4%)		
	Yes	203 (30.4%)	87 (30.6%)		
Hypoalbuminemia (1)				0.6582)	0.417
	No	203 (30.4%)	94 (33.1%)		
	Yes	464 (69.6%)	190 (66.9%)		
Leukocytosis (1)				0.0292)	0.864
	No	307 (46.0%)	129 (45.4%)		
	Yes	360 (54.0%)	155 (54.6%)		
Low hemoglobin (1)				0.2462)	0.620
	No	296 (44.4%)	131 (46.1%)		
	Yes	371 (55.6%)	153 (53.9%)		
Aspiration (1)				0.0342)	0.854
	No	461(69.1%)	198(69.7%)		
	Yes	206(30.9%)	86(30.3%)		

Notes: (1) Data are presented as n (%); (2) χ^2 value; (3) Z value.

2.2 Univariate analysis of aspiration in stroke patients with dysphagia

According to whether aspiration occurred, stroke patients with dysphagia in the training set were divided into an aspiration group (n = 206) and a non-aspiration group (n = 461). Univariate analysis showed statistically significant differences between the two groups in disturbance of consciousness, stroke location, artificial airway, mechanical ventilation, history of aspiration, feeding method, gastrointestinal decompression, food source, Barthel Index, and other variables ($P < 0.05$), as shown in Table 2. The VIF values for the above 14 factors ranged from 1.140 to 2.811, indicating no obvious collinearity.

Table 2
Univariate analysis of general characteristics and aspiration in patients in the training set (n = 667)

Item	Category	Non-aspiration group	Aspiration group	Statistic	P
Sex (1)				2.1932)	0.139
	Female	202	103		
	Male	259	103		
Age (1)				1.2852)	0.257
	≤ 60	164	64		
	> 60	297	142		
Disturbance of consciousness (1)				5.8442)	0.016
	No	221	78		
	Yes	240	128		
Stroke type (1)				3.1212)	0.210
	Ischemic	132	72		
	Hemorrhagic	309	128		
	Mixed	20	6		
Stroke location (1)				159.7702)	< 0.001
	Cerebellum or brainstem	65	128		
	Other locations	396	78		
Artificial airway (1)				8.8482)	0.003
	No	355	136		
	Yes	106	70		
Mechanical ventilation (1)				194.0232)	< 0.001
	No	396	66		
	Yes	65	140		
History of aspiration (1)				339.4912)	< 0.001

Item	Category	Non-aspiration group	Aspiration group	Statistic	P
	No	451	70		
	Yes	10	136		
Feeding method (1)				12.7122)	0.002
	Oral feeding	201	64		
	Gastric tube feeding	239	137		
	Intestinal tube feeding	21	5		
Gastrointestinal decompression (1)				13.4722)	< 0.001
	No	415	164		
	Yes	46	42		
Food source (1)				37.3112)	< 0.001
	Hospital-prepared	192	137		
	Home-prepared	256	62		
	Mixed	13	7		
Barthel Index (1)				-2.3703)	0.018
	Independent	17	2		
	Mild dependence	76	18		
	Moderate dependence	43	26		
	Severe dependence	325	160		
Language disorder (1)				36.8292)	< 0.001
	No	78	1		
	Yes	383	205		
Limb movement disorder (1)				4.5152)	0.034

Item	Category	Non-aspiration group	Aspiration group	Statistic	P
	No	65	17		
	Yes	396	189		
Acid-suppressive drugs (1)				1.8702)	0.171
	No	169	87		
	Yes	292	119		
Sedative drugs (1)				32.5092)	< 0.001
	No	352	112		
	Yes	109	94		
Hypoalbuminemia (1)				60.4732)	< 0.001
	No	183	20		
	Yes	278	186		
Leukocytosis (1)				8.4392)	0.004
	No	195	112		
	Yes	266	94		
Low hemoglobin (1)				0.1662)	0.683
	No	207	89		
	Yes	254	117		

Notes: (1) Data are presented as n (%); (2) χ^2 value; (3) Z value.

2.3 Multivariable analysis of factors influencing aspiration in stroke patients with dysphagia

Whether aspiration occurred in stroke patients with dysphagia was used as the dependent variable (no = 0, yes = 1), and the 14 variables with $P < 0.05$ in univariate analysis were used as independent variables for binary logistic regression analysis. The coding of independent variables is shown in Table 3. The results showed that stroke location, artificial airway, mechanical ventilation, history of aspiration, feeding method, diet source, language disorder, sedative drugs, and albumin level were factors influencing aspiration in stroke patients with dysphagia ($P < 0.05$), as shown in Table 4.

Table 3
Coding of independent variables

Independent variable	Coding
Disturbance of consciousness	No disturbance of consciousness = 0; disturbance of consciousness = 1
Stroke location	Cerebellum or brainstem = 0; other locations = 1
Artificial airway	No artificial airway = 0; artificial airway = 1
Mechanical ventilation	No mechanical ventilation = 0; mechanical ventilation = 1
History of aspiration	No history of aspiration = 0; history of aspiration = 1
Feeding method	Oral feeding = 0; gastric tube feeding = 1; intestinal tube feeding = 2 (oral feeding as the reference)
Gastrointestinal decompression	No gastrointestinal decompression = 0; gastrointestinal decompression = 1
Diet source	Hospital-prepared diet = 0; home-prepared diet = 1; mixed diet = 2 (hospital-prepared diet as the reference)
Barthel Index	Independent = 0; mild dependence = 1; moderate dependence = 2; severe dependence = 3
Language disorder	No language disorder = 0; language disorder = 1
Limb disorder	No limb disorder = 0; limb disorder = 1
Sedative drugs	No sedative drugs = 0; sedative drugs = 1
Albumin level	No hypoalbuminemia = 0; hypoalbuminemia = 1
White blood cell level	Normal white blood cell count = 0; elevated white blood cell count = 1

Table 4
Logistic regression analysis of aspiration among stroke patients with dysphagia in the training set

Item	Regression coefficient	Standard error	Wald χ^2	P	OR	95%CI
Constant	-6.458	4.364	2.190	0.139	0.002	-
Stroke location	-2.066	0.381	29.355	< 0.001	0.127	0.060–0.267
Artificial airway	-1.082	0.509	4.517	0.034	0.339	0.125–0.919
Mechanical ventilation	2.187	0.442	24.454	< 0.001	8.909	3.744–21.199
History of aspiration	5.668	0.621	83.202	< 0.001	289.364	85.614-978.009
Feeding method	-	-	-	-	-	-
Oral feeding	-	-	-	-	-	-
Gastric tube feeding	-1.859	0.647	8.257	0.004	0.156	0.044–0.554
Intestinal tube feeding	-5.638	1.581	12.711	< 0.001	0.004	0.000-0.079
Diet source	-	-	-	-	-	-
Hospital-prepared	-	-	-	-	-	-
Home-prepared	-1.109	0.547	4.106	0.043	0.330	0.113–0.964
Mixed	-2.268	1.316	2.971	0.085	0.104	0.008–1.365
Language disorder	3.440	1.497	5.282	0.022	31.185	1.659-586.143
Sedative drugs	1.652	0.413	16.031	< 0.001	5.216	2.324–11.707
Albumin level	3.305	0.632	27.364	< 0.001	27.523	7.899–94.022

2.4 Construction and validation of the aspiration risk prediction model

Based on the logistic regression results, the factors influencing aspiration in stroke patients with dysphagia were used as independent variables to construct the risk prediction model. The prediction formula was: Logit P=-6.458-2.066 x stroke location (cerebellum or brainstem)-1.082 x artificial airway +

2.187 x mechanical ventilation + 5.668 x history of aspiration-1.859 x feeding method (gastric tube feeding)-5.638 x feeding method (intestinal tube feeding)-1.109 x diet source (home-prepared) + 3.440 x language disorder + 1.652 x sedative drugs + 3.305 x hypoalbuminemia. A visual nomogram was drawn according to this prediction model (Fig. 1). The AUC of the prediction model was 0.97 (95% CI: 0.96–0.98) in the training set and 0.94 (95% CI: 0.91–0.97) in the validation set (Fig. 2).

In the training set, the optimal cut-off value calculated based on the Youden index was 0.375, with an accuracy of 92.4%, sensitivity of 92.6%, specificity of 92.3%, positive predictive value of 88.1%, and negative predictive value of 95.3%. The Hosmer-Lemeshow test showed χ^2=9.569 and P = 0.297, indicating good model fit (Fig. 3). The DCA showed a wide range of risk thresholds, suggesting good clinical utility. In the validation set, the optimal cut-off value calculated based on the Youden index was 0.368, with an accuracy of 89.9%, sensitivity of 90.1%, specificity of 89.7%, positive predictive value of 82.5%, and negative predictive value of 94.8%. The Hosmer-Lemeshow test showed χ^2=5.430 and P = 0.608, indicating good model fit. The DCA also showed a wide range of risk thresholds (Fig. 4).

3 Discussion

3.1 Stroke patients with dysphagia have a high risk of aspiration

Aspiration is one of the most serious adverse consequences of post-stroke dysphagia, with a reported incidence of 15%-54% [11]. Therefore, early identification of aspiration risk in stroke patients with dysphagia is an important measure for reducing aspiration pneumonia and improving prognosis. In this study, the incidence of aspiration in the training set was 30.9%, which is broadly consistent with previous reports, suggesting that stroke patients with dysphagia remain a key population for aspiration prevention and control. Possible reasons include delayed swallowing reflex, weakened cough reflex, and reduced airway protection caused by central nervous system injury. Meanwhile, many patients in this cohort had varying degrees of restricted limb activity, reduced self-care ability in daily life, and weak coughing and sputum expectoration, making timely clearance of foreign material difficult. Some patients also had disturbance of consciousness or nasal feeding, and long-term bed rest and inadequate oral care further increased aspiration risk. Because silent aspiration lacks typical manifestations such as obvious choking, coughing, and cyanosis, it is easily overlooked in clinical assessment, which may lead to missed aspiration events and increase the risk of subsequent complications such as aspiration pneumonia [12]. In summary, stroke patients with dysphagia are at high risk of aspiration. Nurses should strengthen management of these patients, identify aspiration-related factors early, and implement targeted interventions promptly to reduce aspiration risk.

3.2 Multiple factors influence aspiration in stroke patients with dysphagia

3.2.1 Mechanical ventilation and artificial airway status are associated with aspiration risk

The results of this study showed that stroke patients with dysphagia who received mechanical ventilation were more likely to experience aspiration (OR = 8.909), which is consistent with previous research reporting an increased aspiration risk among mechanically ventilated patients [13]. Previous studies have also found that factors related to tracheal intubation and mechanical ventilation are associated with impaired swallowing function after extubation and increased swallowing-related complications [14]. Notably, this study found that mechanical ventilation and artificial airway status had different directions of association with aspiration risk, which may be related to differences in their roles in clinical management. In this study, artificial airway was negatively associated with aspiration risk. This result may have been affected by disease severity, airway management strategies, and selection bias; that is, patients with an established artificial airway usually receive stricter airway management and nursing monitoring. Previous research suggests that standardized airway management and nursing monitoring may help reduce the risk of microaspiration in patients with tracheal intubation [15]. However, because this was a retrospective study, the result may have been influenced by confounding factors such as disease severity, nursing interventions, and patient selection. It should not be interpreted simply as evidence that an artificial airway has a direct protective effect, and multicenter prospective studies are needed for further verification.

3.2.2 Patients with a previous history of aspiration are more likely to aspirate

This study showed that stroke patients with dysphagia and a previous history of aspiration were more likely to experience aspiration (OR = 289.364), making this the independent risk factor with the strongest association in the model. A possible explanation is that patients with a history of aspiration may have persistent swallowing impairment, manifested as reduced swallowing coordination, weakened cough reflex, and reduced airway protection. When oral feeding is resumed or secretion reflux occurs, insufficient airway protection may increase the risk of recurrent aspiration. Previous research has found that silent aspiration significantly increases the risk of pulmonary complications in stroke patients, suggesting that persistent swallowing dysfunction may affect prognosis [16]. This study further identified previous aspiration history as an important risk factor for aspiration among stroke patients with dysphagia. However, the OR for this factor was large and its 95% CI was wide (85.614-978.009), which may be related to the small number of patients with a previous aspiration history in this study and the resulting amplification of the estimated effect in the model. The parameter estimate may therefore be unstable. The effect size of this variable should be further verified in studies with larger samples, and the clinical application value of the prediction model should be further evaluated through external validation [17]. Future prospective studies are recommended, and penalized likelihood methods may be used to improve the stability of parameter estimation. Clinical nurses should classify patients with a history of aspiration as an extremely high-risk group and carry out strict feeding management,

swallowing function assessment, and targeted nursing interventions as early as possible to minimize recurrent aspiration risk.

3.2.3 Dietary management mode affects aspiration risk in stroke patients with dysphagia

This study found that patients receiving a hospital-prepared diet had a lower aspiration risk (OR = 0.330). One possible reason is that although home-prepared diets may have advantages in meeting individual patient needs, the observed association may have been affected by disease severity, nursing management, and the caregiver's knowledge of swallowing management and ability to adjust food texture during preparation. Hospital diets are usually managed relatively systematically by healthcare professionals according to the patient's disease status and swallowing ability. Food selection, feeding methods, and management processes may therefore be more consistent with the patient's functional status, reducing unreasonable adjustments that may occur when patients and caregivers modify diets independently. Different dietary modes may be affected by food texture modification, caregivers' swallowing-management ability, and patient adherence; therefore, further analysis in combination with swallowing function grading is still needed. Wang et al. [18] also reported that the individualized preparation of diets is closely related to aspiration risk and that targeted dietary modification can effectively reduce aspiration in patients with dysphagia. In clinical practice, attention should be paid to whether different dietary modes match patients' swallowing function. Risk judgment should not be based solely on food source; individualized dietary management should be implemented together with swallowing function assessment.

3.2.4 Patients with language disorder are more likely to aspirate

This study showed that stroke patients with dysphagia and language disorder were more likely to experience aspiration (OR = 31.185). A possible explanation is that language disorder often indicates more extensive neurological impairment. Such patients are often accompanied by impaired swallowing coordination and have difficulty accurately expressing swallowing discomfort and choking symptoms. At the same time, cognitive and response abilities may be limited in patients with impaired language function, increasing the difficulty of identifying aspiration risk. Zhang et al. [19] found that the incidence of aspiration in stroke patients with language disorder was 3.2 times that in patients without language disorder, and that language disorder was an independent risk factor for aspiration. The European Stroke Organisation and European Society for Swallowing Disorders guideline indicates that post-stroke dysphagia often coexists with other neurological impairments and increases the risk of complications such as aspiration pneumonia [20]. Therefore, individualized risk assessment and nursing management should be strengthened for patients with both language disorder and dysphagia. The present findings may provide a reference for clinical identification of aspiration risk in patients with language disorder. Clinicians should enhance swallowing function assessment in these patients, closely monitor feeding status through nonverbal communication, and promptly detect signs of silent aspiration.

3.2.5 Patients with hypoalbuminemia are more likely to aspirate

This study showed that stroke patients with dysphagia and hypoalbuminemia were more likely to experience aspiration (OR = 27.523). A possible explanation is that decreased albumin levels usually indicate poor nutritional status and may be accompanied by reduced muscle strength and immune function. Swallowing coordination and cough-sputum clearance may decline, and inadequate airway clearance may increase susceptibility to aspiration. Jiang et al. [21] noted that nutritional support plays an important role in functional recovery after stroke, and the ESPEN guideline also emphasizes the importance of nutritional management in neurological diseases [22]. The present study suggests that nutritional status may be closely related to aspiration risk and provides a reference for clinical nutritional risk assessment and support. Clinicians should regularly monitor albumin levels, implement early nutritional support interventions, improve nutritional status, and provide a foundation for swallowing function recovery.

3.3 The aspiration risk prediction model showed good predictive performance

Internal validation was performed for the constructed risk prediction model. The results showed that the AUCs in both the training and validation sets were > 0.9, indicating good discrimination. According to principles for prediction model evaluation, calibration, clinical benefit, and risk of bias should also be assessed in addition to discrimination [23, 24]. In this study, the calibration curves were close to the ideal curves. The Hosmer-Lemeshow test P value was 0.297 in the training set and 0.608 in the validation set. DCA showed that the model had good clinical net benefit across a certain range of risk thresholds, indicating good discrimination, calibration, and clinical utility. Compared with traditional single swallowing screening tools, this model further integrates disease status, treatment factors, and nutritional indicators, thereby improving the comprehensiveness of risk prediction. It may help nurses complete rapid risk stratification early after admission, improve the specificity of aspiration-prevention nursing care, provide a basis for reducing adverse events such as aspiration pneumonia and asphyxia, optimize nursing decision-making, and improve nursing quality and safety for stroke patients with dysphagia.

4 Conclusion

The aspiration risk prediction model for stroke patients with dysphagia constructed in this study showed good discrimination, high calibration, and certain predictive value. It can be used as an auxiliary tool for clinical nurses to assess aspiration risk and can provide a reference for risk-stratified management. In the future, risk assessment tools or information-based early warning systems may be further developed to improve the application value of this model in clinical nursing decision-making, thereby helping to identify patients at high risk of aspiration early and achieve risk-stratified management and individualized nursing intervention. This study used random grouping for internal validation; however,

because the sample came from a single center, there may still be a risk of model overfitting. Future studies may use bootstrap resampling and external validation to further evaluate model stability and provide a more generalizable assessment tool for clinical practice.

Declarations

Ethics approval and consent to participate

This study was approved by the Medical Ethics Committee of the First Affiliated Hospital of Shandong First Medical University (Shandong Provincial Qianfoshan Hospital) (ethics approval No. 2026-S712). All procedures involving human participants were conducted in accordance with the ethical standards of the Declaration of Helsinki and its later amendments. The requirement for informed consent to participate was waived by the Medical Ethics Committee of the First Affiliated Hospital of Shandong First Medical University (Shandong Provincial Qianfoshan Hospital) because of the retrospective nature of the study.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Author Contribution

Ruixin Wang: Writing – original draft, Resources, Methodology, Investigation. Junying Qian: Writing – review & editing, Supervision, Project administration. Yun Li : Resources. Mengqiu Liu: Methodology. Yannan Jia: Investigation. Shuai Yan: Writing – review & editing.

Data Availability

The datasets generated and/or analyzed during the current study are not publicly available due to privacy and ethical restrictions but are available from the corresponding author on reasonable request.

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Figures

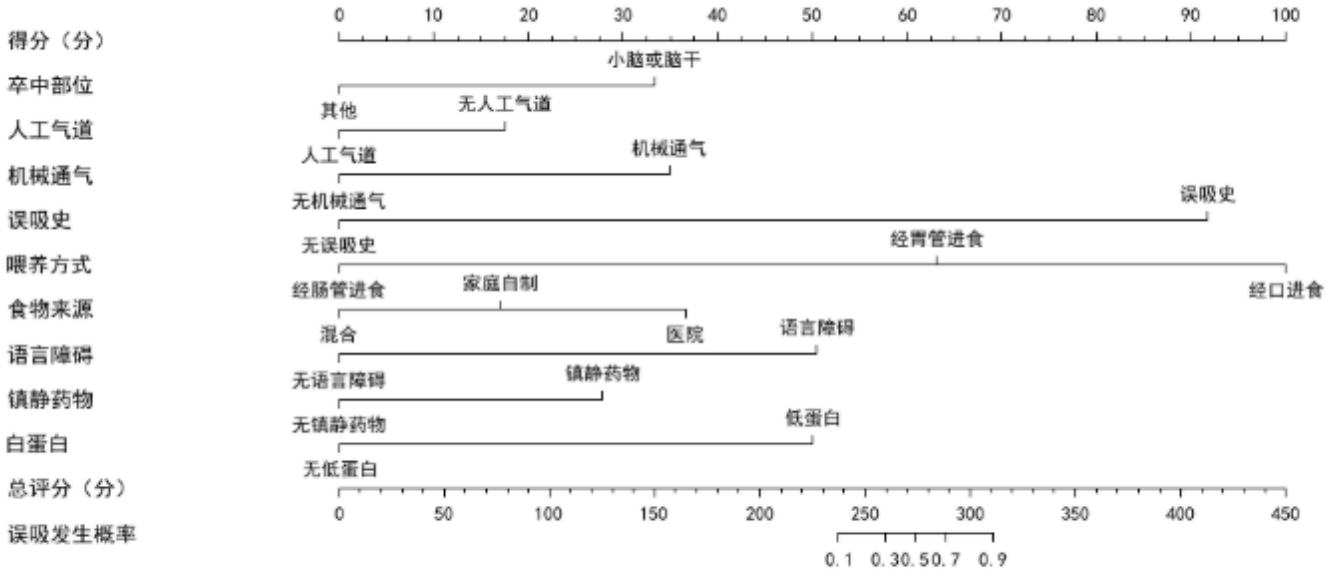


Figure 1

Nomogram of the aspiration risk prediction model for stroke patients with dysphagia. The Chinese labels denote points, stroke location, artificial airway, mechanical ventilation, aspiration history, feeding method, food source, language disorder, sedative drugs, albumin, total points, and aspiration probability.

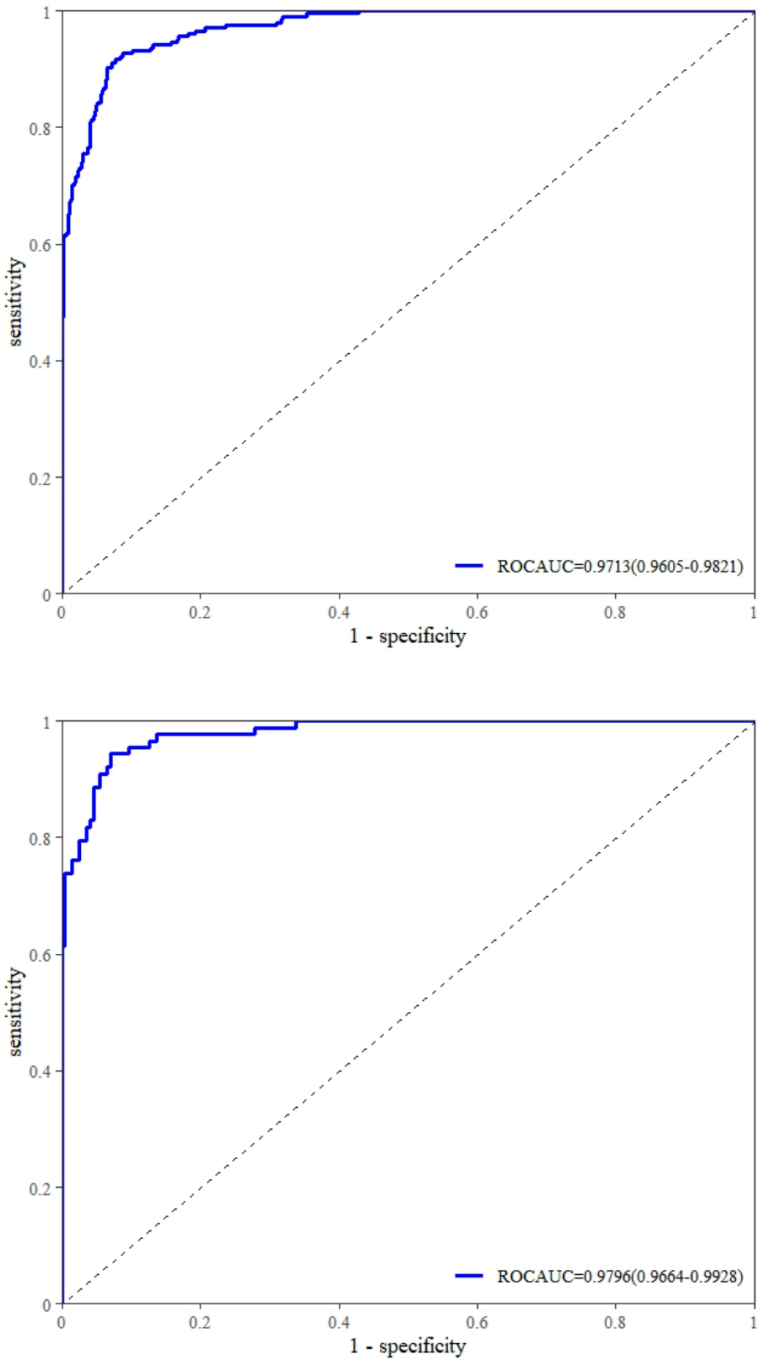


Figure 2

Receiver operating characteristic curves of the risk prediction model for aspiration in stroke patients with dysphagia. Note: a, training set; b, validation set.

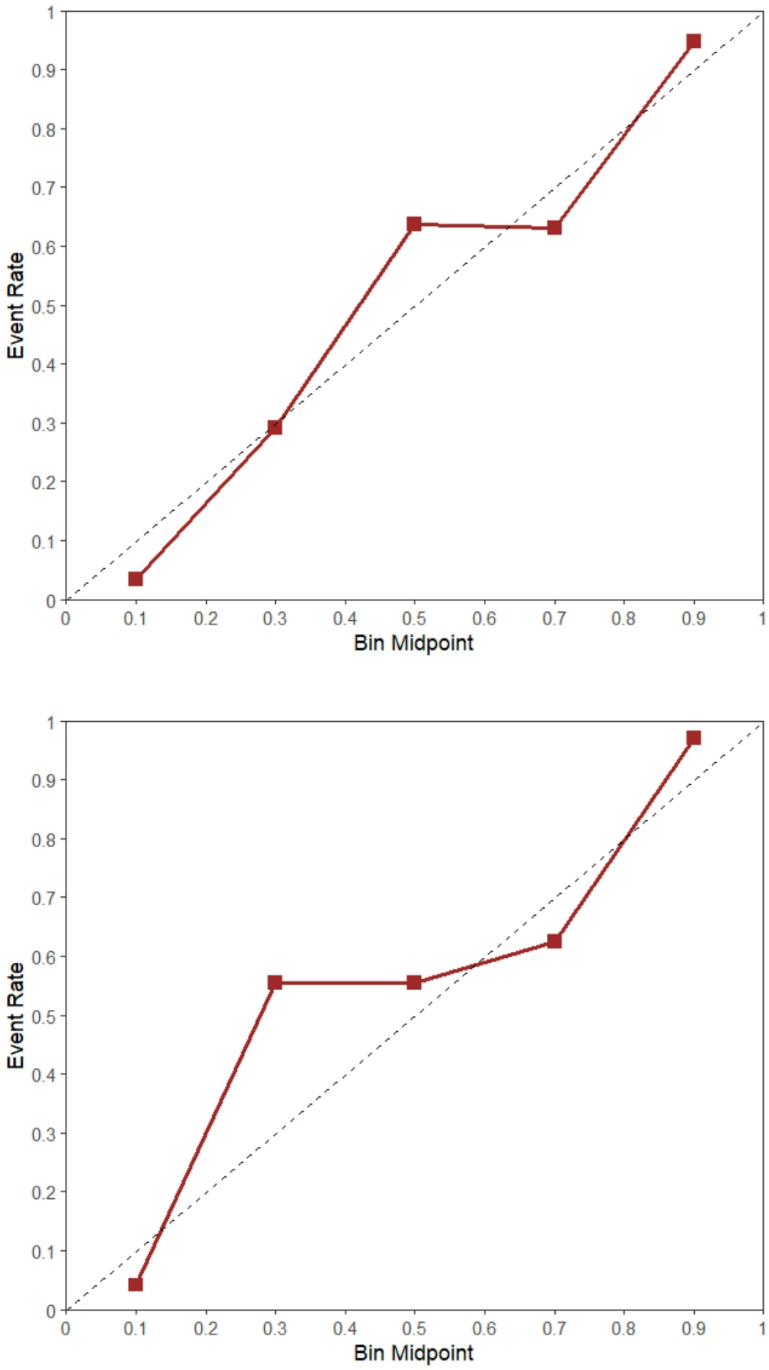


Figure 3

Calibration curves of the aspiration risk prediction model for stroke patients with dysphagia. Note: a, training set; b, validation set.

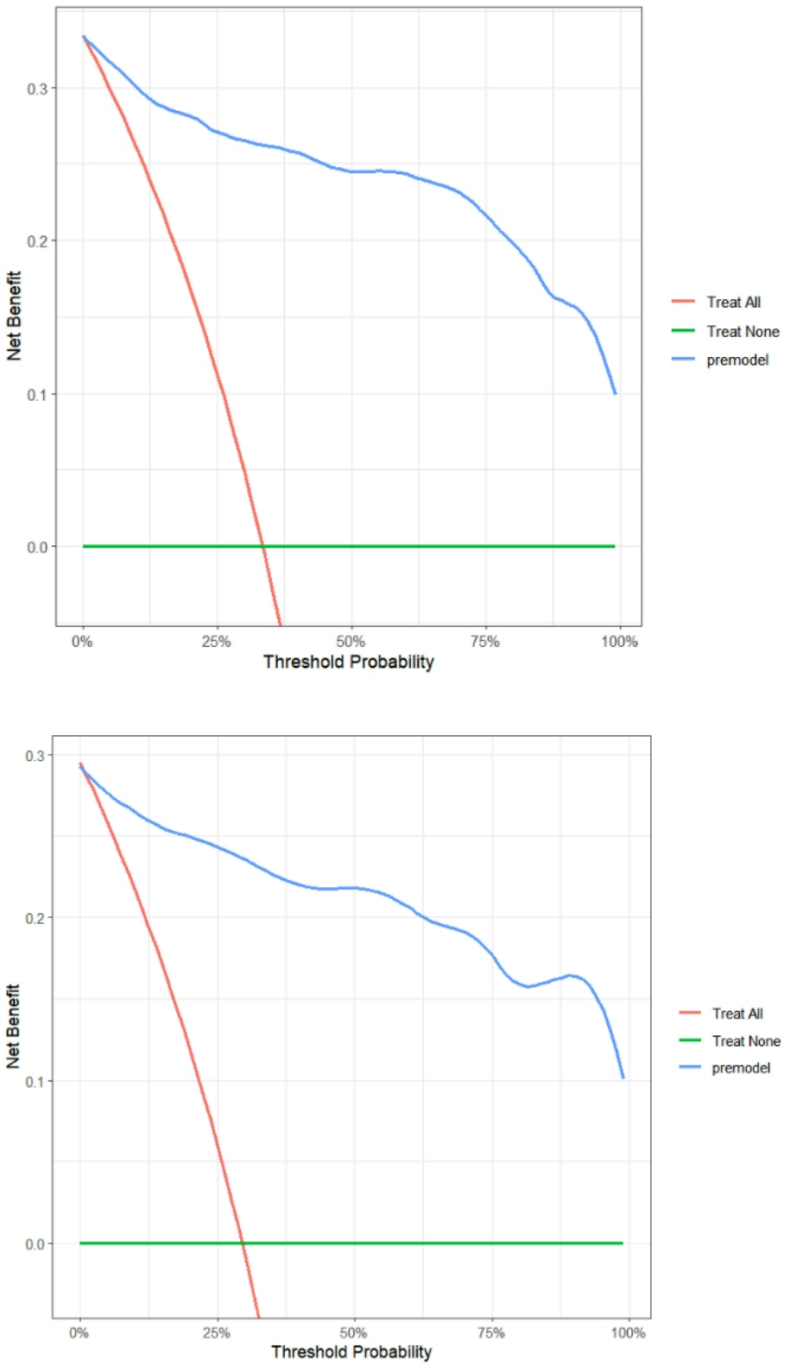


Figure 4

Decision curve analysis of the aspiration risk prediction model in stroke patients with dysphagia. Note: a, training set; b, validation set.