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Original Article

Risk factors for low intake dehydration in malignant tumor patients and predictive model construction

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Abstract: Objective: To investigate the factors influencing low intake dehydration in patients with malignant tumors and to construct a nomogram model for predicting its risk. Methods: A total of 383 patients with malignant tumors were enrolled in this study. Based on the presence of low intake dehydration at admission, patients were classified into a dehydration group (119 patients) and a non-dehydration group (264 patients). Multiple logistic regression analysis was used to identify factors associated with low intake dehydration. A nomogram model was subsequently constructed, and its predictive performance was validated. Results: Significant differences were observed between the dehydration and non-dehydration groups in age (χ^2 = 6.988, P = 0.008), serum albumin (t = 3.158, P = 0.002), tumor duration (t = 4.257, P < 0.001), swallowing disorders (χ^2 = 8.753, P = 0.003), Cancer Patient Appetite Questionnaire (CASQ) score (t = 3.373, P = 0.001), and Barthel Index (BI) score (t = 2.768, P = 0.006). Logistic regression analysis revealed that age ≥ 60 years, serum albumin level, tumor duration, dysphagia, CASQ score, and BI score were significant factors associated with low intake dehydration in cancer patients. The constructed nomogram model showed no overfitting (P > 0.05 in the goodness-of-fit test), with an area under the ROC curve of 0.861. Decision curve analysis confirmed the model's practical value. Ten-fold cross-validation demonstrated the robustness of the model. Conclusions: The risk of low intake dehydration in cancer patients is influenced by age, albumin level, tumor duration, dysphagia, CASQ score, and BI score. The nomogram model effectively assesses the risk of low intake dehydration in these patients.

Keywords: Malignant tumors, low intake dehydration, influencing factors, nomogram

Introduction

Water is a vital component of the human body's internal environment, playing key roles in maintaining organ function, eliminating waste, regulating body temperature, and ensuring cellular water balance [1]. Low intake dehydration increases the body's water demand, surpassing its physiological regulatory capacity, leading to a reduction in body fluid. This causes an increase in both intracellular and extracellular osmotic pressure due to the loss of intracellular fluid. Malignant tumors are highly consumptive lesions, and cancer patients often experience metabolic disorders, making them a high-risk group for low intake dehydration [2]. Previous studies have shown that the incidence of low intake dehydration at admission in cancer patients is 18%, with age and tumor duration identified as influencing factors [3]. Prolonged low fluid intake dehydration in cancer patients increases the risk of adverse events such as urinary tract infections, constipation, and pressure sores [4]. It can also exacerbate tumor progression and raise the risk of mortality. In some countries, the prevention of low intake dehydration and fluid balance management have already been integrated into routine clinical care [5]. Given that water is an essential nutrient for the body [6], insufficient intake or excessive loss can lead to a range of acute or chronic health issues. This study calculates blood osmotic pressure based on biochemical indicators from malignant tumor patients at admission, combines various questionnaires, analyzes the factors influencing low intake dehydration in cancer patients, and constructs a nomogram model to provide a reference for assessing, preventing, and intervening in the risk of low intake dehydration in this population.

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Material and methods

Research subjects

A total of 383 patients with malignant tumors treated in the Oncology Department of the Ninth People's Hospital of Suzhou from January 2024 to May 2025 were selected using a convenience sampling method. Patients were divided into two groups based on the presence of low-volume dehydration at admission: the dehydration group (119 patients) and the non-dehydration group (264 patients).

Inclusion criteria: (1) Diagnosis of a solid malignant tumor confirmed by pathological examination; (2) Age ≥ 18 years; (3) Eastern Cooperative Oncology Group (ECOG) performance status score ≤ 2 at admission; (4) Availability of swallowing function, appetite status, and activities of daily living questionnaire assessment at admission.

Exclusion criteria: (1) Severe dementia or psychiatric disorders; (2) Renal or heart failure requiring fluid restriction; (3) Fluid therapy administered on the day of admission; (4) Incomplete case data.

Sample size calculation was based on the Kendall sample estimation method, requiring 10 times the number of variables in the study. With 18 variables in this study, the minimum sample size was calculated to be 180 cases. Considering a 20% data loss, the required sample size was 216 cases. A total of 383 patients were included, meeting the sample size requirement. This study was approved by the Medical Ethics Committee of Suzhou Ninth People's Hospital (Batch number: KYLW2025-009-01).

Research methods

Data collection: General information: Patient data, including age, body mass index, gender, smoking history, alcohol use, living status, number of comorbidities (e.g., hypertension, diabetes, vascular diseases, hyperuricemia, arthritis), number of medications, daily drinking habits, and blood indices at admission (albumin, D-dimer, total bilirubin), tumor course, type, and treatment method, were collected from electronic medical records.

Swallowing function: The Wada Drinking Test was used to assess swallowing function. Patients were seated or semi-reclined at a 30° angle and asked to drink 3-5 mL of warm water. If choking or coughing occurred, a swallowing disorder was diagnosed. If no discomfort was reported, patients were asked to drink 30 mL of water. Smooth swallowing in one go or more than two swallows without choking was classified as normal (level 1 or 2). Choking during the first swallow or requiring more than two swallows with choking (levels 3-5) indicated a swallowing disorder [7].

Appetite status: Appetite was evaluated using the Cancer Patient Appetite Questionnaire (CASQ) [8], which consists of 12 items scored on a 4-point scale. The total score ranges from 0 to 48, with a lower score indicating poorer appetite. The Cronbach's alpha coefficient of the scale is 0.925, and test-retest reliability is 0.914.

Daily living activity ability: The Barthel Index (BI) [9] was used to assess daily living activity ability. It includes 10 items such as bathing, dressing, eating, grooming, and mobility. The total score ranges from 0 to 100, with a lower score indicating poorer functionality. The Cronbach's alpha coefficient of the scale is 0.972, and test-retest reliability is 0.908.

Low intake dehydration: Blood sodium, potassium, glucose, and urea values were obtained from the fasting blood tests of cancer patients at admission. Blood osmotic pressure was calculated using the formula recommended by the European Society of Clinical Nutrition and Metabolism [5]:

Blood osmotic pressure = 1.86 × (blood sodium + blood potassium) + 1.15 × blood glucose + urea + 14 (Units: mmol/L).

A blood osmotic pressure > 295 mmol/L was used to define low intake dehydration [10].

Statistical methods

Data were analyzed using SPSS 27.0 software. Count data were presented as [n (%)], and group comparisons were performed using the χ^2 test. Measurement data were expressed as mean ± SD, with comparisons between two groups using the t-test. Statistical significance was defined as $P < 0.05$. To address multicollinearity, variables with $P < 0.1$ between groups were examined for collinearity. A variance inflation factor (VIF) < 5 was considered acceptable, and non-collinear variables were included in multivariate logistic regression analysis to identify factors associated with low intake dehydration in cancer patients. R software (version 4.2.2) was used to construct a nomogram to visualize the prediction model. Model performance was evaluated through goodness-of-fit tests, receiver operating characteristic (ROC) curve analysis, and decision curve analysis. The stability of the model was further assessed using ten-fold cross-validation.

Results

Univariate analysis

Significant differences were observed between the dehydration and non-dehydration groups in terms of age (χ^2 = 6.988, P = 0.008), serum albumin (t = 3.158, P = 0.002), tumor duration (t = 4.257, P < 0.001), swallowing disorders (χ^2 = 8.753, P = 0.003), CASQ score (t = 3.373, P = 0.001) and BI score (t = 2.768, P = 0.006). However, there were no statistically significant differences between the two groups in terms of body mass index, gender, smoking history, alcohol consumption, living status, number of comorbidities, number of medications, daily water-drinking habits, D-dimer, total bilirubin levels, tumor type, or tumor treatment methods (all P > 0.05). See **Table 1**.

Collinearity analysis

To minimize the impact of multicollinearity, collinearity analysis was conducted on the variables with P < 0.1 in the univariate analysis (age, body mass index, daily water-drinking habits, serum albumin, tumor duration, swallowing disorders, CASQ score, and BI score). The results indicated that age, serum albumin, tumor duration, dysphagia, CASQ score, and BI score did not exhibit significant collinearity (VIF < 5). However, body mass index and daily water-drinking habits showed significant collinearity (VIF > 5) (**Table 2**). To ensure model stability, LASSO regression was used for variable selection to mitigate multicollinearity.

Multivariate logistic regression analysis

The outcome variable was whether patients with malignant tumors had low intake dehydration upon admission (no = 0, yes = 1). Eight variables with P < 0.1 in the univariate analysis (age, body mass index, daily drinking water habits, serum albumin, tumor duration, dysphagia, CASQ score, and BI score) were included in the model. After dimensionality reduction using LASSO regression and cross-validation, body mass index and daily drinking habits were found to have regression coefficients close to zero (**Figures 1** and **2**). Ultimately, six variables (age, serum albumin, tumor duration, dysphagia, CASQ score, and BI score) were retained. These variables were then assigned values, and measurement data were categorized based on the median value of the research sample (**Table 3**). According to the logistic regression analysis, the following factors were identified as significant for low intake dehydration in cancer patients: age ≥ 60 years (OR = 2.606, P = 0.018), albumin < 35 g/L (OR = 1.813, P = 0.006), tumor duration > 8 months (OR = 3.607, P < 0.001), swallowing disorders (OR = 2.863, P = 0.013), CASQ score < 27 points (OR = 1.793, P = 0.002), and BI score < 63 points (OR = 1.659, P = 0.011) (**Table 4**).

Nomogram model construction

The factors identified by multivariate logistic regression (age, serum albumin, tumor duration, swallowing function, CASQ score, and BI score) were used as predictive indicators in constructing the nomogram model. Using R software, the nomogram was created, allowing for the calculation of the corresponding score for each variable. The total score is the sum of the individual scores, and the total score corresponds to the risk of low intake dehydration in cancer patients. For example, if a tumor patient is over 60 years old, with albumin < 35 g/L, tumor duration > 8 months, no dysphagia, CASQ score < 27, and BI score < 63, their total score would be 37.5 + 58 + 100 + 0 + 53 + 45 = 293.5 points, corresponding to a 78% risk of low intake dehydration (**Figure 3**).

Efficiency of nomogram model

The goodness-of-fit test revealed no statistically significant deviation between the predicted and actual values of the model (χ^2 = 1.782, P = 0.712), indicating no overfitting. The area under the ROC curve (AUC) was 0.861 (95% CI: 0.818-0.902), with a sensitivity of 0.853 and specificity of 0.793. These results suggest that the model demonstrates good predictive performance (**Figure 4**). Decision curve analysis showed that the net benefit of the prediction

Table 1. Univariate analysis of low intake dehydration in patients with malignant tumors

Information	Dehydrated group (n = 119)	Non dehydrated group (n = 264)	statistical value	P value
Age (years)			χ^2 = 6.988	0.008
≥ 60	102 (85.71)	194 (73.48)		
< 60	17 (14.29)	70 (26.52)		
Body mass index (kg/m^2)			χ^2 = 5.844	0.054
< 18.5	24 (20.17)	29 (10.99)		
18.5~24	61 (51.26)	148 (56.06)		
> 24	34 (28.57)	87 (32.95)		
Gender			χ^2 = 1.263	0.261
Male	74 (62.18)	148 (56.06)		
Female	45 (37.82)	116 (43.94)		
Smoking history			χ^2 = 1.758	0.185
Have	37 (31.09)	65 (24.62)		
No have	82 (68.91)	199 (75.38)		
History of Drinking			χ^2 = 0.943	0.332
Have	29 (24.37)	77 (29.17)		
No have	90 (75.63)	187 (70.83)		
To live alone			χ^2 = 0.322	0.570
Yes	14 (11.76)	26 (9.85)		
No	105 (88.24)	238 (90.15)		
Number of coexisting diseases			χ^2 = 2.447	0.118
0~2 types	69 (57.98)	175 (66.29)		
> 2 types	50 (42.02)	89 (33.71)		
Number of drug combinations used			χ^2 = 1.965	0.161
< 5 types	84 (70.59)	204 (77.27)		
≥ 5 types	35 (29.41)	60 (22.73)		
Daily water - drinking habits			χ^2 = 5.430	0.066
Thirst drinking water	50 (42.02)	81 (30.68)		
Conscious water replenishment	49 (41.18)	140 (53.03)		
Control drinking water	20 (16.80)	43 (16.29)		
Albumin (g/L)	34.93±3.85	36.37±4.25	t = 3.158	0.002
D-dimer (mg/L)	0.51±0.15	0.49±0.12	t = 1.393	0.164
Total bilirubin value (μmol/L)	21.14±5.67	20.09±6.21	t = 1.572	0.117
Tumor course (months)	9.35±3.08	8.02±2.71	t = 4.257	< 0.001
Tumor type			χ^2 = 1.576	0.813
Digestive system tumors	45 (37.82)	96 (36.36)		
Respiratory system tumors	39 (32.77)	81 (30.68)		
Genitourinary tumors	17 (14.29)	48 (18.18)		
Breast system tumors	12 (10.08)	30 (11.37)		
Tumors of other systems	6 (5.04)	9 (3.41)		
Tumor treatment methods			χ^2 = 5.479	0.602
Surgery	34 (28.57)	78 (29.55)		
Chemotherapy	18 (15.13)	47 (17.80)		
Radiotherapy	15 (12.61)	30 (11.36)		
Targeted therapy	9 (7.56)	28 (10.61)		
Surgery + chemotherapy	12 (10.08)	25 (9.47)		
Surgery + radiotherapy	8 (6.72)	11 (4.17)		

Surgery + targeted therapy	13 (10.93)	16 (6.06)		
Radiotherapy + chemotherapy	10 (8.40)	29 (10.98)		
Dysphagia			$\chi^2 = 8.753$	0.003
Have	31 (26.05)	36 (13.64)		
No have	88 (73.95)	228 (86.36)		
CASQ score (points)	26.04±3.81	27.55±4.16	$t = 3.373$	0.001
BI score (points)	61.63±7.39	63.98±7.82	$t = 2.768$	0.006

Note: CASQ: cancer patient appetite symptom questionnaire; BI: Barthel index.

Table 2. Collinearity analysis

Variable	Non standardized coefficient		Standard coefficient beta	*t* value	*P* value	Collinearity statistics	
	b	*SE*				Tolerance	*VIF*
Age	0.046	0.041	0.159	1.934	0.017	0.089	2.176
Body mass index	0.062	0.013	1.307	4.251	0.016	0.296	8.531
Daily water - drinking habits	0.098	0.034	0.176	2.882	0.011	0.234	7.302
Albumin	-0.006	0.002	-0.138	-4.071	0.006	0.097	2.263
Tumor course	0.072	0.013	1.468	6.617	< 0.001	0.114	3.017
Dysphagia	0.363	0.131	0.029	2.404	0.009	0.038	1.139
CASQ score	-0.009	0.002	-0.128	-4.503	0.003	0.103	1.963
BI score	-0.098	0.046	-0.145	-2.683	0.012	0.032	2.311

Note: CASQ: cancer patient appetite symptom questionnaire; BI: Barthel index.

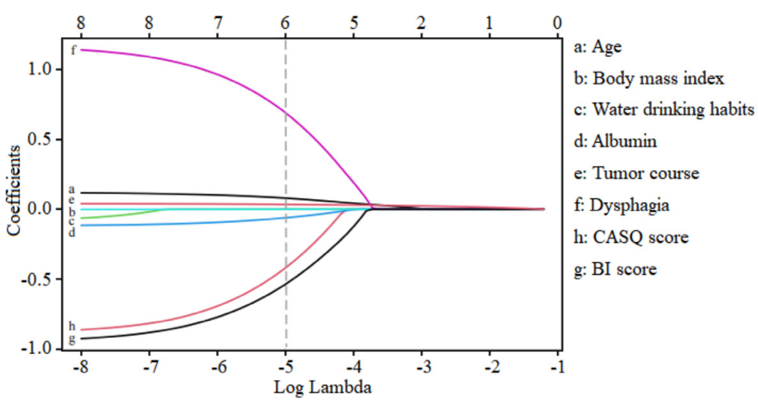

Figure 1. Coefficient path diagram of Lasso Regression.

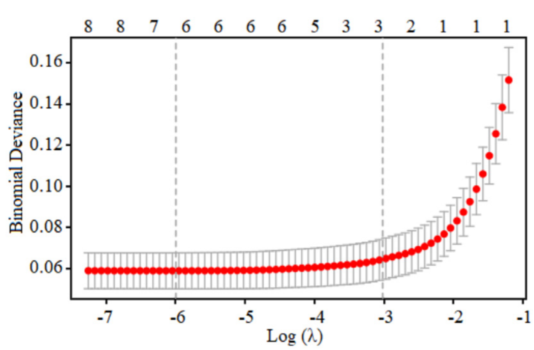

Figure 2. Cross validation curve of Lasso Regression.

model was higher than the extreme curves (assuming all patients had low intake dehydration or none had it), confirming its practical value in clinical settings (**Figure 5**).

Stability of nomogram model

The stability and reliability of the model were evaluated using ten-fold cross-validation. The original dataset was randomly divided into 10 subsets, with one subset used as the test set and the other 9 used for training. The performance of the model was assessed by synthesizing the results of all 10 evaluations. The distribution of accuracy rates in the 10 validations was symmetric, with no significant skew (**Figure 6**). The median accuracy was 0.868, with an interquartile range of 0.841-0.866. The best accuracy obtained from cross-validation was 0.864, with an AUC of 0.862, sensitivity of 0.849, specificity of 0.785, and an expected calibration error of 0.014 in the calibration curve, confirming the model's robustness and high reliability.

Table 3. Explanation of variable assignment

Variable	Assignment instructions
Age	0 = < 60 year; 1 = ≥ 60 year
Albumin	0 = ≥ 35 g/L; 1 = < 35 g/L
Tumor course	0 = ≤ 8 months; 1 = > 8 months
Dysphagia	0 = No have; 1 = Have
CASQ score	0 = ≥ 27 points; 1 = < 27 points
BI score	0 = ≥ 63 points; 1 = < 63 points

Note: CASQ: cancer patient appetite symptom questionnaire; BI: Barthel index.

Discussions

The process of aging is closely related to changes in physiological fluid balance [11]. Serra et al. [12] found that dehydration is a common clinical condition in the elderly population, with the risk increasing with age. This study identified age ≥ 60 years as a factor affecting low intake dehydration in patients with malignant tumors, which aligns with the findings of Buaprasert et al. [13]. Elderly cancer patients may experience a decrease in intracellular fluid and total body water due to the gradual aging of the body and a reduction in fat-free body mass, making them more prone to low-intake dehydration. Additionally, cancer patients typically have an elevated metabolic rate, which significantly increases daily metabolic water consumption. Tumor treatments, such as radiotherapy and chemotherapy, can damage the oral mucosa, affecting swallowing function. Chemotherapy can also lead to esophageal ulcers, diarrhea, and vomiting, disrupting the balance of water and electrolytes and increasing the risk of dehydration. Thus, elderly cancer patients are particularly vulnerable to dehydration due to the combined effects of "physiological aging", the disease itself, and treatment toxicity.

Malnutrition is a prominent issue among cancer patients. Serum albumin, which participates in the entire process of protein synthesis and is highly concentrated in plasma, effectively reflects the nutritional status of the body. Botigu et al. [14] found that malnutrition increases the risk of low intake dehydration, which is consistent with our study's findings. Tumors are high-energy-consuming diseases, and nutrients are extensively used by tumor cells, leading to a decrease in albumin levels and contributing to malnutrition. In a malnourished state, tumor cells adapt their metabolism, primarily using glucose and, when glucose consumption is excessive, shifting to alternative metabolic pathways [15], which makes patients more prone to dehydration. Furthermore, low albumin levels can cause imbalances in static water pressure and colloid osmotic pressure within blood vessels, resulting in edema in gastrointestinal tissues [16]. This leads to symptoms like loss of appetite, nausea, and vomiting, which further impact food and water intake, raising the risk of dehydration. The high consumption nature of malignant tumors results in a synergistic effect with malnutrition: the longer the tumor course, the more cancer cells proliferate, consuming large amounts of energy and nutrients, indirectly increasing the risk of dehydration. This study also found that a prolonged tumor course is a significant factor for low intake dehydration. This may be due to the periodic treatments, such as radiotherapy and chemotherapy, which induce side effects like taste disorders, nausea, vomiting, and diarrhea [17]. These symptoms affect appetite and digestive function, indirectly impacting fluid intake and increasing the risk of low intake dehydration.

Patients with dysphagia experience difficulty drinking water due to choking and coughing, which reduces their water intake. Makhnevich et al. [18] found that swallowing difficulties are associated with hospital-acquired dehydration in hospitalized patients. Viñas et al. [19] similarly found that swallowing disorders increase the risk of dehydration, which supports our study's results. Cancer patients with swallowing disorders tend to drink smaller amounts of water or even avoid it due to concerns about coughing and pain, leading to inadequate water intake and increased dehydration risk. Additionally, some dysphagic patients prefer viscous liquid diets to avoid choking, which reduces their overall fluid intake and can contribute to low intake dehydration.

Cancer anorexia is a significant concern for cancer patients throughout their diagnosis and treatment [20]. Characterized by a loss of appetite due to tumor effects, treatment side effects, and psychological changes [21], cancer anorexia leads to reduced food and fluid intake [22], thereby increasing the risk of dehydration. In our study, a low CASQ score was found to be a contributing factor to low intake dehydration.

Table 4. Multivariate logistic regression analysis

Variable	*β*	*SE*	Wald χ^2	*P* value	*OR* (95% *CI*)
Age ≥ 60 years old	0.958	0.405	5.595	0.018	2.606 (1.178-5.766)
Albumin < 35 g/L	0.595	0.217	7.518	0.006	1.813 (1.185-2.773)
Tumor course > 8 months	1.283	0.329	15.208	< 0.001	3.607 (1.893-6.876)
Dysphagia	1.052	0.424	6.156	0.013	2.863 (1.247-6.573)
CASQ score < 27 points	0.584	0.189	9.548	0.002	1.793 (1.239-2.596)
BI score < 63 points	0.506	0.199	6.465	0.011	1.659 (1.123-2.449)

Note: CASQ: cancer patient appetite symptom questionnaire; BI: Barthel index.

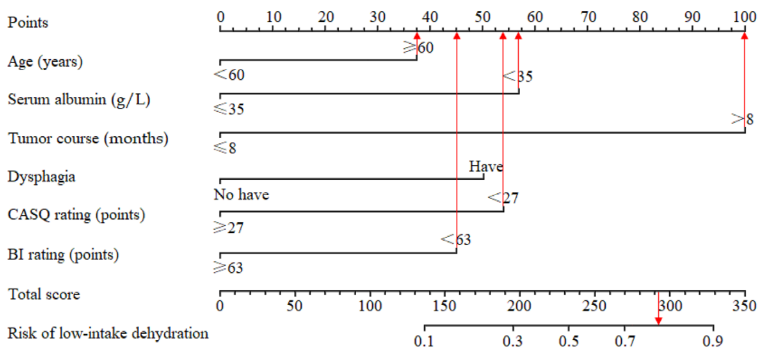

Figure 3. Nomogram prediction model of low intake dehydration risk in patients with malignant tumors. Note: CASQ: cancer patient appetite symptom questionnaire; BI: Barthel index.

Currently, the diagnosis of low intake dehydration in patients primarily relies on objective blood indicators, such as sodium, potassium, glucose, and urea, to calculate osmotic pressure [28]. However, due to cost and issues with blood sample processing, it is not feasible to measure blood osmotic pressure for cancer patients every time they are admitted for treatment. This can result in clinical misdiagnosis or missed diagnoses, preventing some patients from receiving appropriate care. By analyzing clinical data, effective information can be mined to help healthcare providers make better predictions and select appropriate preventive measures. Since low intake dehydration in cancer patients is influenced by multiple interconnected factors, this study constructed a nomogram prediction model based on the identified risk factors. This model serves as a risk assessment tool, quantifying the risk of low intake dehydration in individual cancer patients and providing actionable recommendations for healthcare professionals.

Daily living ability is essential for maintaining basic self-care functions [23], and the BI score is commonly used to assess this ability, with lower scores indicating poorer functional ability. This study found that a low BI score is a significant factor for low intake dehydration in cancer patients. Poor self-care ability and the need for family assistance may lead patients to reduce their fluid intake, fearing the inconvenience of frequent urination, which in turn increases the risk of dehydration [24]. Moreover, patients with low BI scores often experience weakness, cognitive decline, and a diminished thirst response, increasing their dehydration risk [25]. As cancer patients typically have elevated metabolic rates and increased daily water consumption, these factors further elevate the risk of dehydration. Patients with low BI scores are also more likely to suffer from psychological issues such as depression and anxiety, which can reduce appetite. In turn, the metabolic demands of tumor cells exacerbate anorexia, and treatments like chemotherapy or radiotherapy may alter taste, making water unpalatable and reducing fluid intake, thus contributing to low-intake dehydration [26, 27].

Our analysis shows that the nomogram prediction model does not exhibit overfitting. The ROC curve analysis reveals an area under the curve (AUC) of 0.861, indicating strong predictive performance in identifying the risk of low intake dehydration in cancer patients. Decision curve analysis demonstrated that the model's net benefit rate was higher than the extreme curves (assuming all patients had low intake dehydration or none did), confirming its practical value in clinical practice. Stability was further validated using ten-fold cross-validation, where the accuracy distribution of the 10 validations

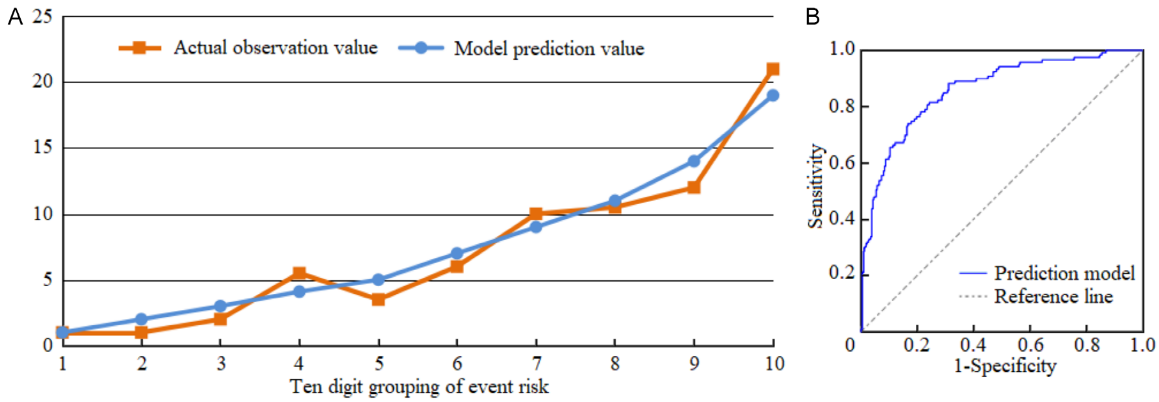

Figure 4. Evaluation of the efficacy of the nomogram prediction model. A: Test of the model's goodness of fit; B: Analysis of the *ROC* curve of the model.

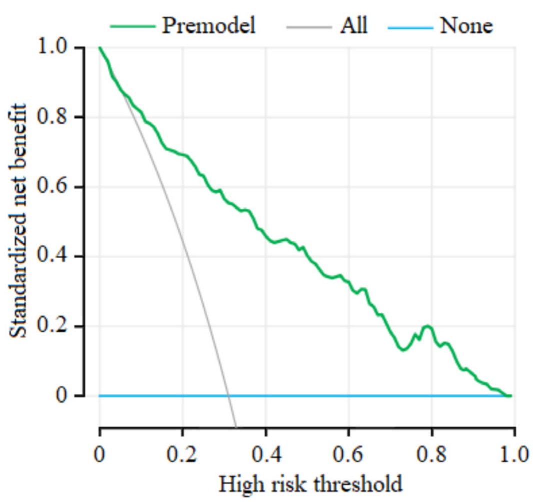

Figure 5. Decision curve analysis of nomogram model.

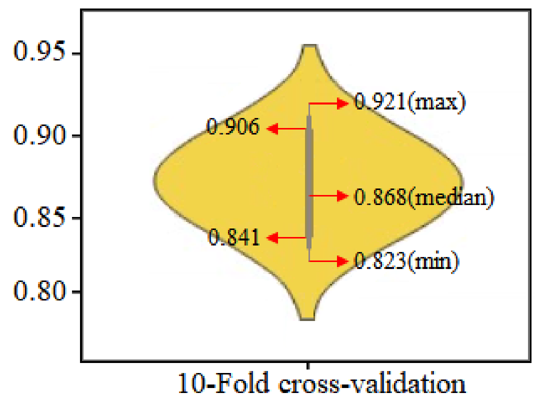

Figure 6. Accuracy result graph of ten-fold cross validation.

showed no significant skew. The median accuracy reached 0.868, indicating the model's robustness. During cross-validation, the highest accuracy rate achieved was 0.864, confirming the model's reliability.

There are still some limitations to this study. Firstly, convenience sampling was used, which may introduce selection bias due to the lack of a sampling framework. Secondly, the study was conducted at a single hospital, limiting its generalizability. Future multi-center, large-sample studies with long-term follow-up are needed to analyze the longitudinal trends of low intake dehydration in cancer patients.

In conclusion, the risk of low intake dehydration in cancer patients is associated with factors such as age ≥ 60 years, low serum albumin, long tumor duration, dysphagia, low CASQ score, and low BI score. The nomogram model constructed in this study provides a reliable predictive tool for assessing low intake dehydration risk, offering valuable guidance for fluid balance management in cancer patients.

Disclosure of conflict of interest

None.

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