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Association between the geriatric nutritional risk index and adverse post-extubation outcomes for critically ill older adults: a retrospective study

Sheng-chang Ye[1†], Yu-ting Mao[2†], Bo-li Huang[3*] and Li-li Hou[1*]

Abstract

Background and purpose Malnutrition commonly predicts adverse outcomes among older adults in the intensive care unit (ICU). The Geriatric Nutritional Risk Index (GNRI) is a simple and practical tool for assessing nutritional status in older adults. This study aims to explore the association between GNRI and adverse post-extubation outcomes in critically ill older adults.

Methods A total of 1,153 older adults aged 65–82 years in the ICU were included in this retrospective cohort study. GNRI categories were stratified into four subgroups based on nutritional risk: major risk (GNRI < 82), moderate risk (GNRI 82–91), low risk (GNRI 92–98), and no risk (GNRI > 98). Adverse post-extubation outcomes included mortality or pneumonia within 30 days post-extubation, reintubation within 72 h, post-extubation dysphagia, and length of stay (LOS) in the ICU and hospital. Multivariable logistic regression analysis and restricted cubic spline (RCS) were used to explore the association between GNRI categories and dichotomous adverse outcomes. Additionally, multivariable linear regression was used to evaluate the association between GNRI and LOS in the ICU and hospital.

Results Older adults with dichotomous adverse outcomes had lower GNRI values compared with those without (*P*-value<0.001), and increasing LOS in ICU and hospital was associated with decreasing GNRI value ($P_{\text{for trend}}$<0.001). Patients at major nutritional risk had the highest risk of mortality [OR = 2.76, 95%CI: 1.40 ~ 5.46] or pneumonia [OR = 3.07, 95%CI: 1.42 ~ 6.68] within 30 days post-extubation, reintubation within 72 h [OR = 2.41, 95%CI: 1.06 ~ 5.49] and post-extubation dysphagia [OR = 2.94, 95%CI: 1.19 ~ 7.31](P for trend<0.001). The RCS study also validated the linear relationship between GNRI and mortality/pneumonia within 30 days post-extubation and post-extubation dysphagia. Conversely, there were non-linear associations between GNRI and ICU and hospital LOS, as well as reintubation within 72 h. Furthermore, GNRI showed a significant negative correlation with LOS in both the ICU and

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hospital. Kaplan-Meier curve analysis demonstrated that survival within 30 days post-extubation was significantly reduced in major nutritional risk group compared to the no risk group (*P*-value = 0.018).

Conclusions Our findings demonstrated that major nutritional risk defined by GNRI was associated with a higher risk of adverse post-extubation outcomes in critically ill older adults.

Keywords Geriatric nutrition risk index, Older adults, Adverse post-extubation outcomes, Intensive care, Mortality

Introduction

It is estimated that the number of older adults aged over 65 years will reach 1.6 billion by 2050 [1]. Malnutrition is prevalent among the older population, with rates ranging from 10 to 50% [1], particularly among critically ill geriatric patients. This condition often leads to poor prognosis, including short-term mortality, severe infections, and impaired physical function [2, 3]. Malnutrition can also prolong hospital stays and increase medical costs. Therefore, early identification of malnourished patients is crucial for preventing adverse outcomes and providing appropriate clinical nutritional support.

However, dozens of nutrition assessment tools have been recommended for evaluating clinical nutritional status, yet no tool for assessing malnutrition risk has been recognized as a gold standard for geriatric patients [4]. The Mini Nutritional Assessment-Short Form (MNA-SF) requires a brief interview and evaluation of anthropometric measurements without the need for blood-based indicators [5, 6], and it is recommended by the European Society for Clinical Nutrition and Metabolism (ESPEN) for use in institutions or community settings [7]. Additionally, the Nutritional Risk Screening-2002 (NRS-2002) is proposed by the American Society for Parenteral and Enteral Nutrition (ASPEN) for assessing nutritional risk in hospitalized patients [8]. Nevertheless, the nutritional risk tools mentioned above rely on questionnaires or short conversations, which are only suitable for patients without cognitive decline or nonverbal communication issues. Moreover, the use of NRS-2002 requires consideration of the Acute Physiology and Chronic Health Evaluation II (APACHE II) score, which may be impractical for clinicians due to its time-consuming nature [9]. Therefore, a simple and efficient indicator for nutritional assessment is needed to assist clinicians in screening malnutrition risk among critically ill older adults in the ICU.

Geriatric Nutritional Risk Index (GNRI), proposed by Bouillanne et al., is calculated based on the serum albumin (Alb) level and present body weight/ideal body weight ratio, and is designed specially as a nutritional assessment indicator for hospitalized older adults [10]. Previous studies have demonstrated that low GNRI scores have been significantly associated with adverse outcomes in patients with undergoing hemodialysis [11] advanced cancer [12], trauma [13] acute ischemic stroke [14]. Various indicators have been confirmed to reflect an ideal prediction value for post-extubation outcomes, However, scarce study had ever explored the association of GNRI and adverse post-extubation outcomes in critically ill older adults. Therefore, this retrospective cohort study was conducted to estimate whether GNRI could predict the adverse post-extubation outcomes of geriatric patients in ICU.

Materials and methods

Study design and participants

This retrospective cohort study consecutively included older adults between July 1st,2017 and January 31st,2022 in intensive care unit of Ninth People's Hospital Affiliated to Shanghai Jiao Tong University School of Medicine. All patients aged ≥ 65 years were eligible for enrollment if they required intubation and mechanical ventilation and were extubated during their ICU stay after receiving adequate treatment and meeting extubation criteria. The decision to extubate patients was based on a comprehensive assessment of their clinical status. Patients were considered for extubation if they met the following criteria: (1) hemodynamic stability, defined as a mean arterial pressure (MAP) > 65 mmHg without vasopressor support; (2) adequate oxygenation, indicated by a PaO_2/FiO_2 ratio > 150 mmHg; (3) sufficient respiratory drive, with a respiratory rate < 30 breaths per minute; and (4) absence of significant respiratory distress or excessive secretions. The final decision was made by the attending physician in consultation with the critical care team, ensuring that all criteria were met and the patient was deemed ready for extubation. Patients were excluded based on the following criteria: (1) death without an extubation attempt: these patients did not reach the point of extubation due to critical illness leading to death; (2) terminal extubation or tracheostomy without an extubation attempt: these patients either had a planned terminal extubation or underwent a tracheostomy without a preceding extubation attempt; (3) pre-existing dysphagia before ICU admission: these patients had documented dysphagia prior to their ICU admission, which could confound the study outcomes; (4) incomplete medical information: these patients had missing data in their medical records that were critical for the study, such as specific laboratory results or clinical assessments. A total of 1,359 older patients were initially enrolled in the study, however, 206

of them were excluded due to death without extubation attempt ($n = 65$), terminal extubation or tracheostomy without extubation attempt ($n = 115$), pre-existing dysphagia before ICU admission ($n = 10$) and incomplete medical information ($n = 16$). Finally, 1,153 older adults were included in the study and sorted into four groups based on their GNRI categories (Fig. 1). This study was approved by the Ethics and Research Committee of Ninth People's Hospital Affiliated to Shanghai Jiao Tong University School of Medicine (Clinical Trial Number: not applicable). This study was conducted in accordance with the STROBE guidelines for the reporting of observational studies (Supplementary Material 1).

Sample size Estimation

To ensure our analysis was adequately powered, we conducted a power calculation using PASS 2021 software. Assuming a 95% confidence level and a 5% margin of error, we determined that a sample size of 366 patients would be sufficient to detect an expected prevalence of nutritional risk of 68% [15]. Accounting for a potential 10% inefficiency rate, we increased the sample size to 403. Ultimately, our study enrolled 1,153 participants, well exceeding the calculated requirement. This robust sample size provides ample power to identify significant associations in our data.

Data collection

Personal medical information of older adults (age range: 65 ~ 82 years) was extracted from electronic medical records within 24 h after ICU admission. The following characteristics of patients were collected: demographic characteristics (age, gender, weight, height); comorbidities based on International Classification of Diseases, 10th edition (ICD-10) diagnosis codes [diabetes, hypertension, chronic obstructive pulmonary disease (COPD), chronic kidney disease (CKD), sepsis and cardiovascular diseases (CVD), CVD included coronary heart disease, congestive heart failure, severe arrhythmias, and valvular heart disease]; laboratory indicators (WBC count, serum albumin, serum creatinine, serum hemoglobin); clinical severity scales (Sequential Organ Failure Assessment (SOFA) scores and Acute Physiologic and Chronic Health Evaluation (APACHE) II scores at ICU admission); therapeutic measures (renal replacement therapy (RRT) and vasopressor). To handle missing data, we employed multiple imputation by chained equations using the "mice" package in R, creating five imputed datasets to ensure the robustness of our analyses.

The GNRI was calculated based on the previously proposed equation [10]: GNRI = 1.489 × serum albumin (g/L) + 41.7 × present weight/ideal weight (kg). The ideal weight was derived from the Lorentz formula as follows: ideal weight for women = 0.60 × height (cm)– 40, ideal weight for men = 0.75 × height (cm)– 62.5, and a present weight/ ideal weight ratio is set to 1 if the ratio is more than 1. According to the GNRI cut-off values suggested by Cereda et al., all participants were stratified into four subgroups indicating different levels of nutritional risk:

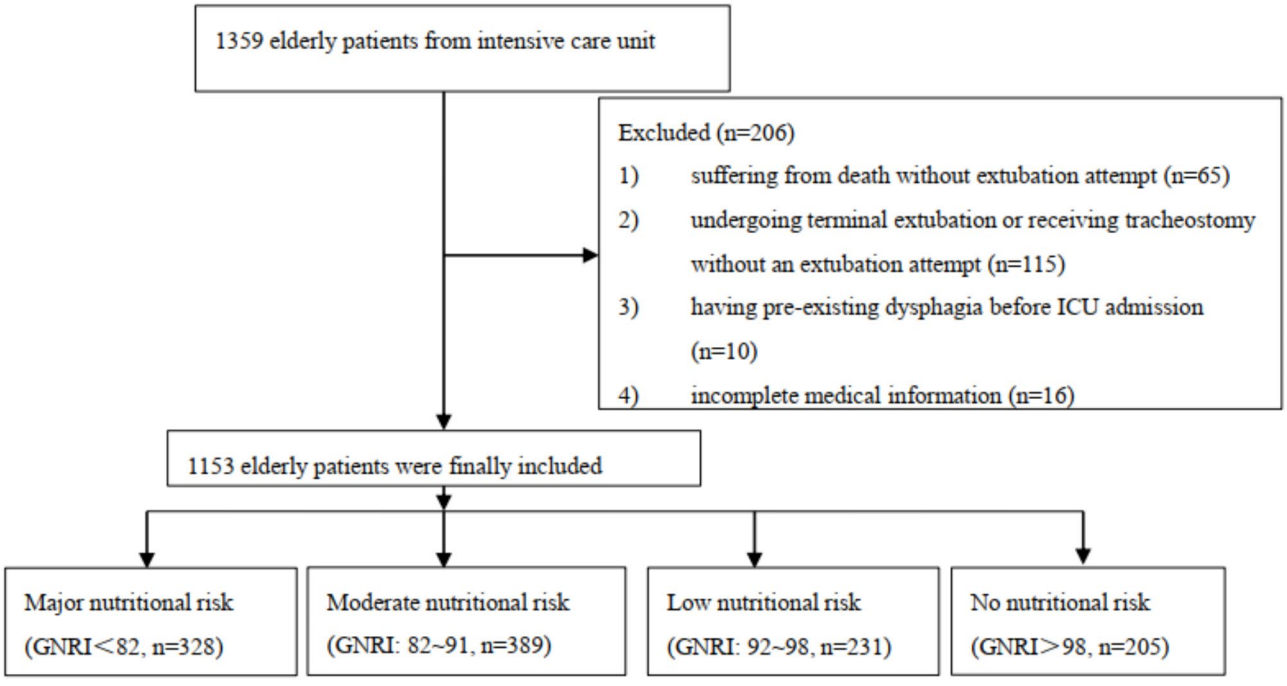

Fig. 1 Flowchart of older adults selection in ICU. GNRI: geriatric nutritional risk index

GNRI < 82, major risk; GNRI:82 ~ 91, moderate risk; GNRI 92 ~ 98, low risk; GNRI > 98, no risk.

Adverse post-extubation outcomes

The adverse post-extubation outcomes were the incidence of mortality within 30 days post-extubation, pneumonia within 30 days post-extubation, reintubation within 72 h, post-extubation dysphagia, and length of stay in ICU and hospital. Post-extubation dysphagia examined by professional speech and language pathologists was defined by functional oral intake scale (FOIS) score<5, which indicated a severely abnormal oral intake [16, 17]. Scores of FOIS range from one (nothing by mouth) to seven (total oral diet without restrictions), with higher scores representing better swallowing function [16].

Statistical analyses

All statistical analyses were conducted by SPSS 25.0 and STATA 17.0 software packages. Continuous variables were presented as the mean ± standard deviation(SD)or median (interquartile ranges) based on the evaluation of normal distribution by Shapiro-Wilk test, while categorical variables were presented as numbers and percentages. Continuous variables were compared by one-way ANOVA or Kruskal-Wallis H test among groups. Comparisons of GNRI values among those who experienced each dichotomous adverse post-extubation outcome versus those without adverse post-extubation outcome were performed by the two-sample Student's t test. Categorical variables were compared by chi-square test. Multivariable logistic regression models were used to calculate adjusted odds ratios (ORs) and 95% confidence intervals (CIs) for the association between GNRI categories and dichotomous adverse post-extubation outcome after adjusting for potential confounding factors including age, sex, hypertension, WBC, Hb, creatinine, SOFA, APACHE II, sepsis, vasopressor, RRT and CKD, and multivariable linear regression was also used to evaluate the association between GNRI (both as continuous and categorical variables) and LOS in ICU and hospital. The confounding variables included in the multivariable logistic regression analysis were chosen based on their established associations with post-extubation outcomes in the literature and their clinical relevance in the context of critical care. The presence of multicollinearity was evaluated using the variance inflation factor (VIF). A VIF value of less than 4 for all variables indicated that multicollinearity was not a significant concern. Restricted cubic spline regression was performed to estimate the dose-response relationship between GNRI value and dichotomous outcomes in a fully adjusted model. The knots were positioned at the 5th, 35th, 65th, and 95th percentiles of GNRI. These positions were chosen based on theoretical considerations to capture the non-linear relationship across the full range of GNRI values and empirical data to ensure a balanced representation of the data. Furthermore, we investigated the threshold saturation effect of GNRI on the risk of adverse post-extubation outcomes. Subgroup analyses were conducted to determine if potential covariates, including age, gender, history of hypertension, diabetes, COPD, CKD, and CVD, modified the association between GNRI and adverse post-extubation outcomes. A *p*-value less than 0.05 was considered to indicate significant interactions. We also conducted sensitivity analyses by comparing data from the pre-pandemic and pandemic periods to confirm the consistency of the findings. Moreover, Kaplan–Meier and log-rank analyses were utilized to create survival curves and demonstrate the cumulative risk of death within 30 days post-extubation across various GNRI levels after adjusting for significant variables identified in univariate analysis ($p < 0.05$). Hazard ratio (HR) was calculated using a Cox regression analysis, and *p* value was estimated using the log-rank test. Furthermore, to verify the consistency of the findings, a sensitivity analysis was conducted, excluding participants who had poor oral hygiene habits. A two-sided *P*-value of less than 0.05 was considered statistically significant for all analyses.

Results

Baseline characteristics of study population

Baseline characteristics according to GNRI categories were presented in Table 1, Based on GNRI stratification, 328 (28.4%) patients were in major risk group, 389 (33.7%) patients were in moderate risk group, 231(20.0%) patients were in mild risk group, and 205 (17.8%) patients were in no risk group. With the decreasing value of GNRI, critically ill patients tended to be older, and had a higher level of WBC count, Hemoglobin, serum creatinine, SOFA and APACHE II ($P_{\text{for trend}}$<0.001). Besides, Patients in major nutritional risk group had the highest proportion of hypertension, chronic kidney disease (CKD), sepsis, vasopressor and renal replacement therapy (RRT). Moreover, patients in major risk group had a higher prevalence of mortality (18.9% vs. 11.2%) or pneumonia(15.5% vs. 6.3%) within 30 days post-extubation, reintubation within 72 h (14.0% vs. 7.3%)and dysphagia (12.2% vs. 4.4%) ($P_{\text{for trend}}$<0.05), and also had longer LOS in ICU [10.00(7.00 ~ 12.00) vs. 6.00(5.00 ~ 8.00)]and hospital [25.00(20.00 ~ 30.00) vs. 17.00(14.00 ~ 20.00)] compared with those in no nutritional risk group(all *p*-value<0.001). Besides, patients with dichotomous outcomes had a lower GNRI value compared with those without, additionally, patients with increasing length of stay in ICU or hospital tended to have a decreasing GNRI value (all *P* for trend <0.001)(Fig. 2).

Table 1 Baseline characteristics of the study population grouped by GNRI ($n = 1,153$)

Characteristics	Total	GNRI				$P_{\text{for trend}}$
		<82 ($n = 328$)	82 ~ 91 ($n = 389$)	92 ~ 98 ($n = 231$)	>98 ($n = 205$)	
Age (years)	73.79 ± 5.02	74.86 ± 4.95	73.66 ± 5.05	73.42 ± 4.90	72.77 ± 4.95	<0.001
Male, *n*(%)	563(48.8)	141(43.0)	193(49.6)	123(53.2)	106(51.7)	0.070
Comorbidities, *n*(%)						
Diabetes, *n*(%)	144(12.5)	50(15.2)	48(12.3)	27(11.7)	19(9.3)	0.224
Hypertension, *n*(%)	225(19.5)	84(25.6)	76(19.5)	32(13.9)	33(16.1)	0.003
COPD, *n*(%)	114(9.9)	36(11.0)	37(9.5)	25(10.8)	16(7.8)	0.632
CKD, *n*(%)	230(19.9)	80(24.4)	70(18.0)	49(21.2)	31(15.1)	0.042
Cardiovascular Diseases, *n*(%)	172(14.9)	57(17.4)	50(12.9)	31(13.4)	34(16.6)	0.292
Sepsis, *n*(%)	361(31.3)	117(35.7)	128(32.9)	58(25.1)	58(28.3)	0.039
Laboratory parameters						
WBC count (10^9/L)	10.10 ± 2.43	11.43 ± 2.94	9.87 ± 2.15	9.48 ± 1.82	9.11 ± 1.58	<0.001
Hemoglobin (g/L)	99.87 ± 13.19	91.53 ± 9.68	98.54 ± 10.82	103.77 ± 10.62	111.33 ± 14.79	<0.001
Creatinine (mg/dl)	1.40 ± 0.51	1.49 ± 0.62	1.45 ± 0.53	1.29 ± 0.44	1.27 ± 0.29	<0.001
Scoring						
SOFA	5.00[3.00 ~ 7.00]	6.00(4.00 ~ 8.00)	5.00(3.00 ~ 7.00)	5.00(3.00 ~ 7.00)	4.00(2.00 ~ 5.00)	<0.001
APACHE II	17.00[13.00 ~ 20.00]	20.00(16.00 ~ 24.00)	16.00(12.00 ~ 19.00)	15.00(10.00 ~ 19.00)	15.00(12.00 ~ 19.00)	<0.001
Treatment*n*, (%)						
RRT, *n*(%)	97(8.4)	43(13.1)	28(7.2)	16(6.9)	10(4.9)	0.003
Vasopressor, *n*(%)	483(41.9)	162(49.4)	144(37.0)	97(42.0)	80(39.0)	0.007
Primary outcomes						
Mortality within 30 days post-extubation, *n*(%)	166(14.4)	62(18.9)	48(12.3)	33(14.3)	23(11.2)	0.038
Pneumonia within 30 days post-extubation, *n*(%)	139(12.1)	51(15.5)	50(12.9)	25(10.8)	13(6.3)	0.014
Reintubation within 72 h, *n*(%)	103(8.9)	46(14.0)	28(7.2)	14(6.1)	15(7.3)	0.002
Dysphagia, *n*(%)	99(8.6)	40(12.2)	38(9.8)	12(5.2)	9(4.4)	0.003
Secondary outcomes						
LOS in ICU (days)	8.00[6.00 ~ 10.00]	10.00(7.00 ~ 12.00)	8.00(6.00 ~ 9.00)	7.00(5.00 ~ 9.00)	6.00(5.00 ~ 8.00)	<0.001
LOS in hospital (days)	21.00[17.00 ~ 26.00]	25.00(20.00 ~ 30.00)	22.00(16.00 ~ 26.00)	19.00(16.00 ~ 24.00)	17.00(14.00 ~ 20.00)	<0.001

Continuous variables are presented as mean ± standard deviation or median (interquartile) with number (proportion, %) for categorical variables. *P* values among groups are calculated by one-way ANOVA or Kruskal-Wallis H tests for continuous variables, Chi-square test for categorical variables. Abbreviations: GNRI, geriatric nutritional risk index; COPD, chronic obstructive pulmonary disease; CKD, chronic kidney disease; WBC, white blood cell; SOFA, Sequential Organ Failure Assessment; APACHE, Acute Physiologic and Chronic Health Evaluation; RRT, renal replacement therapy; LOS, length of stay

Association between GNRI and adverse post-extubation outcomes

Multivariable regression analysis had demonstrated the significant negative association between GNRI category and primary outcomes in Table 2. After adjusting for the potential confounders including age, sex, hypertension, WBC, Hb, creatinine, SOFA, APACHE II, sepsis, vasopressor, RRT and CKD, patients in major nutritional risk had an increased risk of mortality [OR = 2.76, 95%CI: 1.40 ~ 5.46] or pneumonia [OR = 3.07, 95%CI: 1.42 ~ 6.68] within 30 days post-extubation compared with those without nutritional risk. Besides, GNRI categories had the significant negative association with reintubation within 72 h [major risk vs. no risk, OR = 2.41,95%CI: 1.06 ~ 5.49] and post-extubation dysphagia [major risk vs. no risk, OR = 2.94,95%CI: 1.19 ~ 7.31]. Additionally, multivariable linear regression showed GNRI was negatively associated with the LOS in ICU and hospital after adjusting for confounders (Table 3).

Dose-response relationship between GNRI and adverse post-extubation outcomes

The dose-response relationships between GNRI and mortality within 30 days post-extubation, pneumonia within 30 days post-extubation, reintubation within 72 h, post-extubation dysphagia, LOS in ICU and LOS in hospital had been described by the following restricted cubic spline (Fig. 3). Linear relationships were observed between GNRI and mortality within 30 days post-extubation, pneumonia within 30 days post-extubation, and post-extubation dysphagia (P for non-linearity > 0.05). Non-linear relationships were found between GNRI and reintubation within 72 h, LOS in ICU and hospital (P for non-linearity < 0.01).

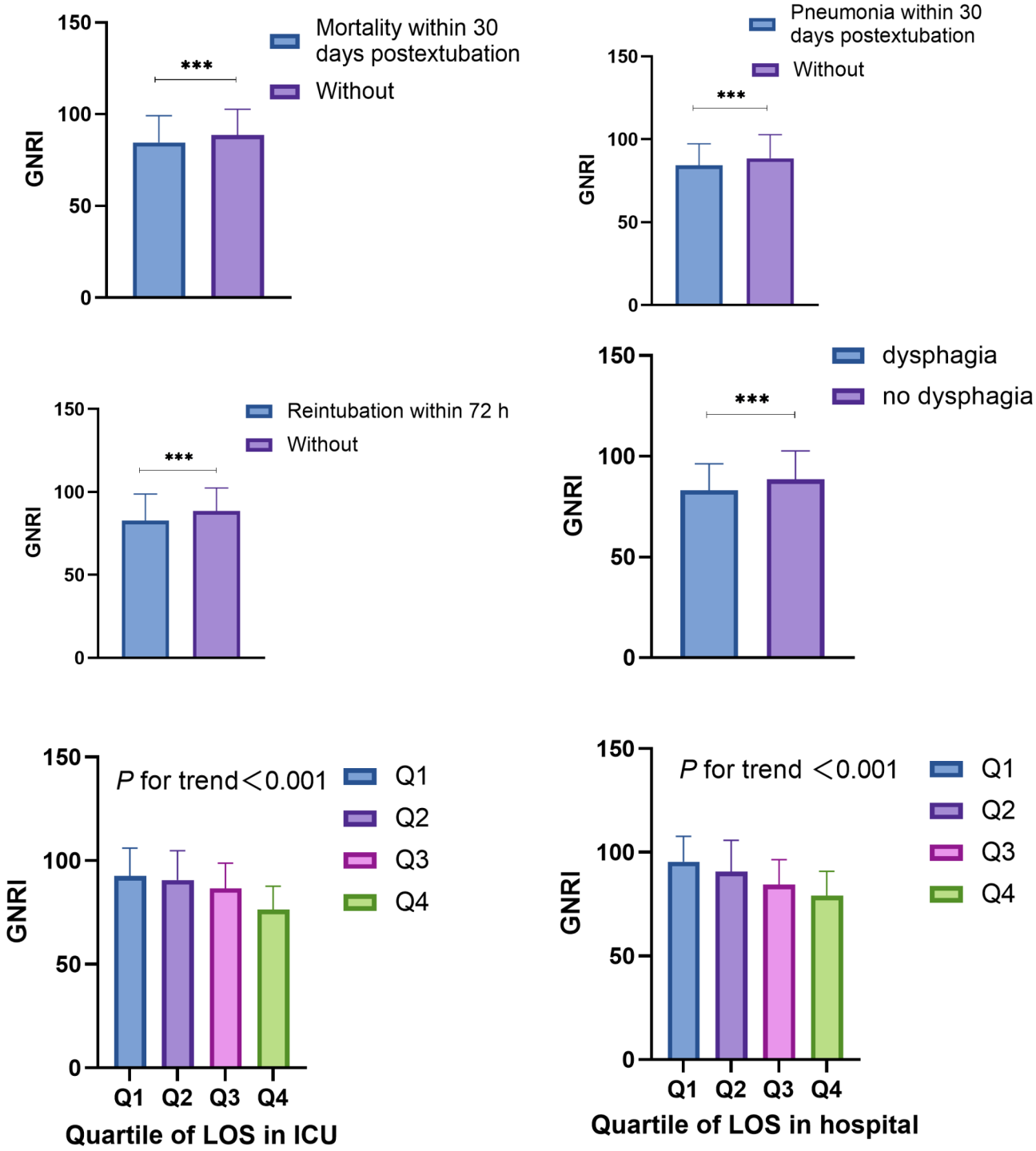

Fig. 2 Comparison of GNRI value among patients with adverse post-extubation outcomes and without. ***, *P*<0.001

Additionally, a two-piecewise linear regression model was used to analyze the threshold effect of GNRI on adverse post-extubation outcomes (Table 4). The cut-off points of GNRI for predicting the risk of various outcomes were determined to be 89.1 for mortality within 30 days post-extubation, 88.1 for pneumonia within 30 days post-extubation, 87.6 for reintubation within 72 h, 88.6 for post-extubation dysphagia, 88.6 for LOS in the ICU, and 88.1 for LOS in the hospital. A decrease in GNRI values below the cut-off points was associated with an increased risk of mortality within 30 days post-extubation and reintubation within 72 h. There was a significant association between GNRI and pneumonia within 30 days post-extubation when GNRI values were above

Table 2 Multivariable logistic regression analysis of the association between GNRI and dichotomous outcomes

Categories	Model 1		Model 2		Model 3	
	OR (95%CI)	*P*-value	OR (95%CI)	*P*-value	OR (95%CI)	*P*-value
Mortality within 30 days post-extubation						
Major risk	1.89(1.09 ~ 3.27)	0.022	2.82(1.43 ~ 5.54)	0.003	2.76(1.40 ~ 5.46)	0.003
Moderate risk	1.12(0.66 ~ 1.92)	0.666	1.51(0.84 ~ 2.73)	0.167	1.53(0.84 ~ 2.77)	0.161
Low risk	1.35(0.76 ~ 2.39)	0.304	1.67(0.92 ~ 3.04)	0.092	1.57(0.86 ~ 2.88)	0.140
No risk	1.00 (Ref.)	1.00 (Ref.)	1.00 (Ref.)	1.00 (Ref.)	1.00 (Ref.)	1.00 (Ref.)
Pneumonia within 30 days post-extubation						
Major risk	2.99(1.53 ~ 5.82)	0.001	3.04(1.40 ~ 6.59)	0.005	3.07(1.42 ~ 6.68)	0.005
Moderate risk	2.26(1.19 ~ 4.29)	0.012	2.31(1.17 ~ 4.57)	0.016	2.31(1.16 ~ 4.58)	0.017
Low risk	1.87(0.93 ~ 3.78)	0.079	1.95(0.95 ~ 3.99)	0.068	1.88(0.92 ~ 3.86)	0.085
No risk	1.00 (Ref.)	1.00 (Ref.)	1.00 (Ref.)	1.00 (Ref.)	1.00 (Ref.)	1.00 (Ref.)
Reintubation within 72 h						
Major risk	2.33(1.22 ~ 4.44)	0.010	2.38(1.05 ~ 5.37)	0.037	2.41(1.06 ~ 5.49)	0.035
Moderate risk	1.02(0.53 ~ 1.97)	0.951	0.99(0.47 ~ 2.05)	0.969	0.96(0.46 ~ 2.02)	0.922
Low risk	0.84(0.39 ~ 1.78)	0.646	0.80(0.36 ~ 1.76)	0.573	0.73(0.33 ~ 1.62)	0.438
No risk	1.00 (Ref.)	1.00 (Ref.)	1.00 (Ref.)	1.00 (Ref.)	1.00 (Ref.)	1.00 (Ref.)
Post-extubation dysphagia						
Major risk	3.16(1.45 ~ 6.89)	0.004	2.97(1.20 ~ 7.33)	0.019	2.94(1.19 ~ 7.31)	0.020
Moderate risk	2.40(1.13 ~ 5.09)	0.022	2.35(1.05 ~ 5.24)	0.037	2.31(1.03 ~ 5.18)	0.041
Low risk	1.22(0.50 ~ 2.97)	0.657	1.24(0.50 ~ 3.07)	0.637	1.16(0.47 ~ 2.88)	0.751
No risk	1.00 (Ref.)	1.00 (Ref.)	1.00 (Ref.)	1.00 (Ref.)	1.00 (Ref.)	1.00 (Ref.)

Model 1: Age, sex and hypertension

Model 2: Model 1 + WBC, Hb, creatinine, SOFA and APACHE II

Model 3: Model 2 + Sepsis, vasopressor, RRT and CKD

Table 3 Multivariable linear regression of the association between GNRI and length of stay in ICU and hospital

	Length of stay in ICU				Length of stay in hospital			
	Crude model		Adjusted model		Crude model		Adjusted model	
	β (95%CI)	*P*-value	β (95%CI)	*P*-value	β (95%CI)	*P*-value	β (95%CI)	*P*-value
GNRI (as a continuous)								
GNRI levels	-0.084 (-0.094~-0.073)	<0.001	-0.073 (-0.087~-0.060)	<0.001	-0.197(-0.218~-0.175)	<0.001	-0.190 (-0.217~-0.163)	<0.001
GNRI (as a categorical)								
Major risk	3.40(2.95 ~ 3.85)	<0.001	3.37(2.78 ~ 3.96)	<0.001	8.20(7.27 ~ 9.12)	<0.001	8.48(7.28 ~ 9.68)	<0.001
Moderate risk	1.04(0.60 ~ 1.47)	0.430	1.00(0.52 ~ 1.49)	0.355	4.38(3.49 ~ 5.28)	<0.001	4.61(3.62 ~ 5.61)	<0.001
Low risk	0.33(-0.15 ~ 0.82)	0.176	0.26(-0.24 ~ 0.77)	0.308	3.01(2.01 ~ 4.00)	<0.001	2.99(1.95 ~ 4.02)	<0.001
No risk	1.00 (Ref.)		1.00 (Ref.)		1.00 (Ref.)		1.00 (Ref.)	

Adjusted model: Adjusted for Age, sex, hypertension, WBC, Hb, creatinine, SOFA, APACHE II, Sepsis, vasopressor, RRT and CKD

the cut-off point. However, no significant association was found between GNRI and post-extubation dysphagia regardless of GNRI values. Furthermore, there were significantly negative associations between GNRI and LOS in the ICU or hospital when GNRI values were above or below the cut-off points (*P* value < 0.01).

Sensitivity analysis

To ensure the stability of the results, given that the study period (July 2017 to January 2022) covers the COVID-19 pandemic, to conduct a sensitivity analysis, this study separately analyzed data for the pre-pandemic and pandemic periods based on the study timeline. The results demonstrated robustness (Supplementary Material 2).

Subgroup analysis

To ensure the robustness of the association between GNRI and post-extubation outcomes, multiple stratified analyses and interaction tests were conducted (Supplementary Material 3). These analyses revealed significant interactions between GNRI and mortality within 30 days post-extubation among subgroups stratified by CVD and CKD (P for interaction < 0.05). Similarly, a significant interaction was observed between GNRI and pneumonia within 30 days post-extubation in the subgroup stratified by COPD (P for interaction < 0.05). However, no significant interactions were found between GNRI and reintubation within 72 h, post-extubation dysphagia, or LOS in the hospital across all subgroups (P for interaction > 0.05). Notably, significant interactions between GNRI and LOS

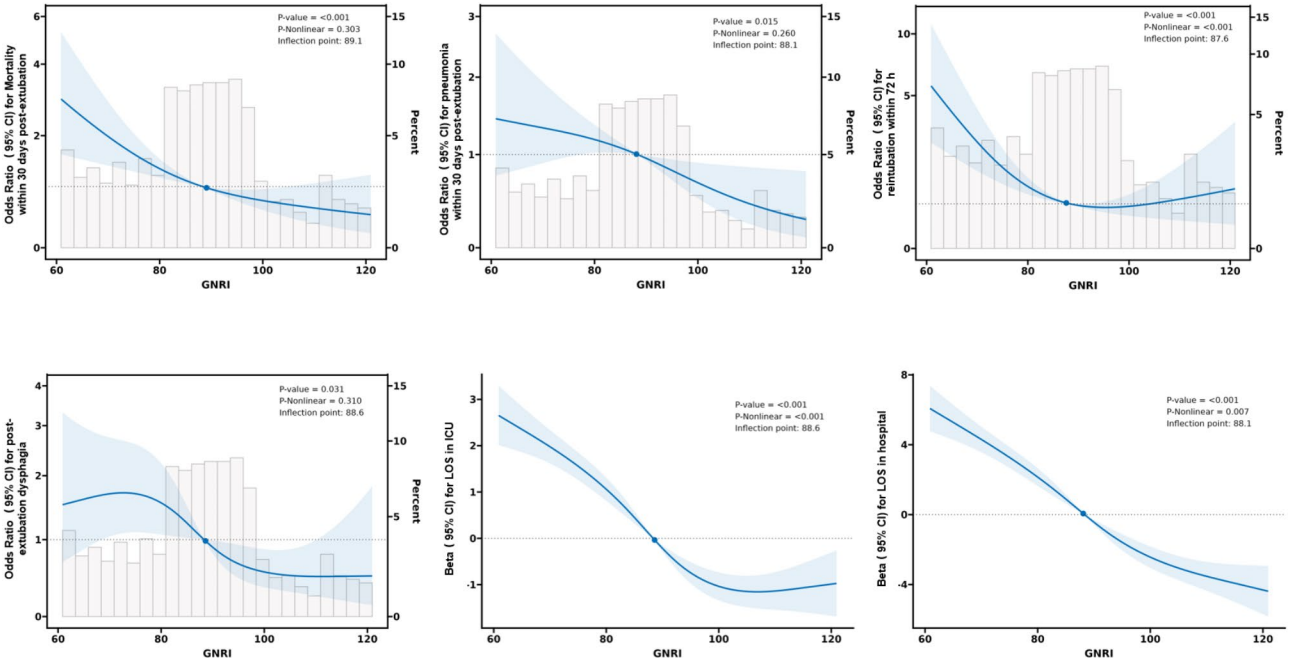

Fig. 3 The dose–response relationship between GNRI and the adverse outcomes were displayed by restricted cubic spline (RCS) after adjusting for potential confounders including age, gender, hypertension, WBC, creatinine, Hb, SOFA, APACHE II, sepsis, vasopressor, RRT and CKD. We employed a 4-knots RCS positioned at the 5th, 35th, 65th, and 95th percentiles of GNRI to fit the dose–response relationship between GNRI and the adverse outcomes. The blue solid line represented the adjusted odds ratio (OR) or estimated regression coefficient Beta, and the blue area was the 95% confidence interval (CI)

Table 4 Threshold effect analyses of GNRI on risk of adverse post-extubation outcomes in critically ill older adults using two-piecewise regression models

Adverse outcomes	OR	95% CI	*P*-value
Mortality within 30 days post-extubation			
GNRI (< 89.1)	0.96	0.94 ~ 0.98	< 0.001
GNRI (≥ 89.1)	0.98	0.96 ~ 1.01	0.29
Pneumonia within 30 days post-extubation			
GNRI (< 88.1)	1.00	0.97 ~ 1.02	0.82
GNRI (≥ 88.1)	0.96	0.94 ~ 0.98	< 0.001
Reintubation within 72 h			
GNRI (< 87.6)	0.95	0.92 ~ 0.98	< 0.001
GNRI (≥ 87.6)	1.01	0.98 ~ 1.04	0.58
Post-extubation dysphagia			
GNRI (< 88.1)	0.99	0.96 ~ 1.02	0.44
GNRI (≥ 88.1)	0.98	0.94 ~ 1.02	0.31
	β	*95% CI*	*P*-value
Length of stay in ICU			
GNRI (< 88.6)	-0.11	-0.14 ~ -0.08	< 0.001
GNRI (≥ 88.6)	-0.03	-0.05 ~ -0.01	0.006
Length of stay in hospital			
GNRI (< 88.1)	-0.24	-0.29 ~ -0.18	< 0.001
GNRI (≥ 88.1)	-0.15	-0.19 ~ -0.11	< 0.001

in the ICU were identified in subgroups stratified by age and CKD (P for interaction < 0.05).

Kaplan–Meier survival curve analysis

According to the Kaplan–Meier survival curve analysis, patients in the major risk group (GNRI < 82) exhibited the lowest 30-day post-extubation survival rate among the four groups. A notable decrease in survival rate was noted as GNRI decreased, with statistical significance (Fig. 4, *P*-value = 0.018). After adjusting for covariates such as age, sex, hypertension, WBC, Hb, creatinine, SOFA, APACHE II, sepsis, vasopressor, RRT and CKD, Cox regression analysis revealed that a GNRI value less than 82 was associated with a significantly higher risk of 30-day mortality following extubation among critically ill older patients in the ICU, with a hazard ratio (HR) of 2.76 (95% confidence interval [CI]: 1.47 ~ 5.16, *P*-value = 0.002).

Discussion

In this retrospective cohort study, we examined the relationship between the Geriatric Nutritional Risk Index (GNRI) and adverse outcomes after extubation in older adults admitted to the ICU. Our results indicated that patients with adverse outcomes had significantly lower GNRI values compared to those without (all *P* values < 0.001). Critically ill older patients with major nutritional risk, as determined by GNRI, experienced a

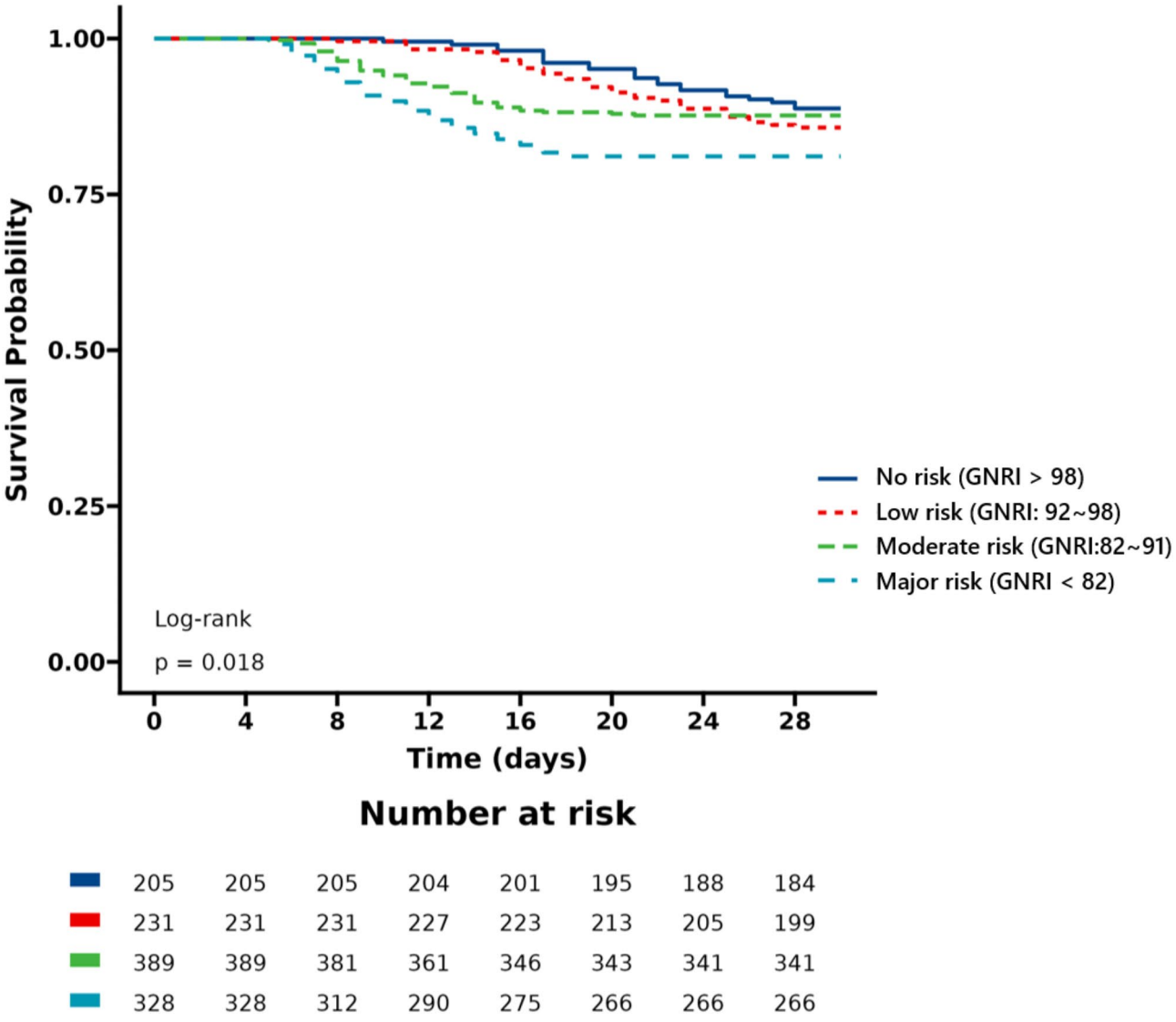

Fig. 4 Kaplan-Meier curves of 30-day mortality post-extubation according to the geriatric nutritional risk index (GNRI). The hazard ratio (HR) was determined via Cox regression analysis, while the *p*-value was derived using the log-rank test. The figures displayed beneath the Kaplan–Meier survival curves represent the number of patients at risk on the indicated day for the four groups

significantly increased risk of adverse outcomes following extubation.Further support for this finding came from the analysis of cubic spline curves, which revealed a linear correlation between GNRI values and rates of mortality/pneumonia within 30 days post-extubation, as well as post-extubation dysphagia. Conversely, non-linear relationships were observed between GNRI and both ICU and hospital length of stay (LOS), as well as reintubation within 72 h. Kaplan-Meier survival curve analysis also showed that patients with major nutritional risk had the lowest 30-day post-extubation survival rate compared to other groups.

Accurate nutritional assessment is crucial for identifying patients at risk of malnutrition and improving clinical outcomes in the ICU. Various nutritional assessment tools used in ICU settings included Subjective Global Assessment (SGA), Nutritional Risk Screening (NRS 2002), Mini Nutritional Assessment (MNA), and Malnutrition Universal Screening Tool (MUST). SGA is a widely used tool for assessing malnutrition based on clinical judgment. It evaluates patients' nutritional status by considering factors such as dietary intake, weight changes, muscle and fat stores, and functional status [18]. SGA categorizes patients into well-nourished, moderately malnourished, and severely malnourished groups. While SGA is simple to implement, it relies heavily on the experience of the assessor, which may introduce subjectivity and variability in results. NRS 2002 is a validated tool for screening nutritional risk in hospitalized patients, including those in the ICU. It incorporates factors such

as age, food intake, weight loss, BMI, and disease severity [19]. NRS 2002 is evidence-based and relatively easy to use. However, it has limitations in patients with edema, ascites, or those who are bedridden and unable to have their weight measured. Additionally, it is not suitable for patients with cognitive impairment. MNA is specifically designed for older patients to assess their nutritional status and risk of malnutrition. It includes 18 items covering dietary intake, weight changes, body function, and overall health. MNA is comprehensive and easy to use, making it suitable for screening malnutrition in older adults. However, it may not be appropriate for patients with cognitive impairment, and it requires trained personnel to administer [20]. MUST is a widely used tool for screening malnutrition risk across various clinical settings, including ICUs. It assesses patients based on BMI, weight loss, and acute disease effects on nutrition. MUST is simple and quick to use, making it suitable for busy clinical environments [21]. However, its accuracy in predicting malnutrition risk may vary depending on the patient's specific condition. GNRI stands out due to its objectivity and applicability in patients with limited mobility or cognitive impairment. Unlike SGA, which relies on clinical judgment, GNRI uses objective indicators, making it more reliable in a diverse patient population. Additionally, GNRI addresses the limitations of NRS 2002 by not requiring accurate weight measurements, which can be challenging in ICU settings. While MNA is comprehensive, GNRI is simpler to use and can be applied more broadly in the older population. MUST, although quick and easy, may not provide the same level of sensitivity in detecting malnutrition as GNRI.

Our research revealed a significant correlation between lower GNRI values (indicating higher nutritional risk) and elevated risks of mortality, pneumonia, reintubation, and post-extubation dysphagia. These results align with prior studies emphasizing GNRI's predictive power for adverse outcomes in older adults. For instance, Yamada et al. established GNRI as an independent predictor of mortality and complications in older hospitalized patients, especially those with chronic conditions [22]. Cereda et al. similarly found a strong link between GNRI and increased mortality and longer hospital stays in older patients with acute conditions [23]. Hasegawa et al. showed that malnutrition, as measured by GNRI, correlated with prolonged hospital stay after emergency surgery for lower gastrointestinal perforation [24]. Kuzuya et al. reported that lower GNRI scores were associated with greater healthcare resource use, including longer hospitalizations [25]. Additionally, Fan et al. highlighted GNRI as a robust predictor of survival in older cardiovascular disease patients [26]. However, our study uniquely uncovers non-linear relationships between GNRI and both length of stay (LOS) and reintubation within 72 h, which have not been extensively documented in prior research. This indicates that the connection between nutritional risk and healthcare utilization may be more intricate than previously thought, necessitating further exploration. Our study's distinct contribution lies in its application to post-extubation outcomes in ICU settings, offering new evidence for GNRI's prognostic utility in critical care.

Our results are generally consistent with previous studies, although there are some variations in the reported GNRI cut-off values. Ito et al. reported a GNRI cut-off value of 105 for all-cause death in patients with acute myocardial infarction (AMI) during a 1-year follow-up [27]. Yamada et al. reported that a GNRI < 82 was significantly associated with increased mortality in older patients with heart failure [28]. Similarly, Cereda et al. found that a GNRI < 82 was predictive of long-term nutrition-related risk of death in institutionalised older [29]. These differences in cut-off values may be attributed to variations in study populations, follow-up durations, and specific endpoints examined. Despite these differences, our findings align with the general consensus that lower GNRI values are associated with higher risks of adverse outcomes in the short term, while higher values are more predictive in the long term.

The observed association between GNRI-defined malnutrition and adverse post-extubation outcomes aligns with established pathophysiological mechanisms. Malnutrition in older adults disrupts cellular metabolism, impairing mitochondrial function and energy production, which are critical for recovery in critically ill patients [30]. Reduced protein synthesis, a hallmark of malnutrition, exacerbates muscle wasting—particularly in respiratory muscles—compromising cough efficacy and increasing susceptibility to atelectasis, pneumonia, and reintubation [31]. Furthermore, hypoalbuminemia (a key GNRI component) reflects not only inadequate protein intake but also systemic inflammation, as albumin acts as a negative acute-phase reactant. Elevated inflammatory cytokines (e.g., IL-6, TNF-α) in malnourished patients amplify catabolism, impair immune cell function, and delay tissue repair, collectively worsening clinical outcomes [32]. Malnutrition also disrupts gut barrier integrity, promoting bacterial translocation and systemic inflammation [33], which may explain the heightened risk of post-extubation pneumonia. dysphagia, linked to both malnutrition and neurological decline in aging, further perpetuates aspiration risks. severe malnutrition overwhelms compensatory mechanisms (e.g., autophagy, metabolic adaptation), whereas moderate deficits may be partially buffered. Recent studies emphasize that early nutritional interventions (e.g., protein supplementation, immunonutrition) mitigate these risks by restoring anabolic pathways and modulating inflammation [34–37].

Several limitations of this study should be acknowledged. Firstly, this retrospective study was conducted in a single-center medical institution, which may limit the generalizability of our findings. A multi-center and prospective cohort study is warranted to validate the generalizability of the findings in the future. Secondly, some laboratory indicators, including C-reactive protein and blood urea nitrogen, were incomplete, which could introduce residual confounding in our analysis. These factors could not be adjusted as confounders in the multivariable regression analysis due to the lack of complete data. Thirdly, the potential for bias from misclassification during chart review cannot be ruled out, as data were extracted from medical records without direct observation. Additionally, the limited sample size and timeframe of the study may affect the robustness of our results. Notably, our study is limited by the potential for immortal time bias, as we only included patients who survived to extubation. This may have resulted in a selection bias that could affect the generalizability of our findings to the broader ICU population. Finally, no comparisons of predictive value were made among the GNRI, Nutritional Risk Screening (NRS 2002), Mini Nutritional Assessment (MNA), and Malnutrition Universal Screening Tool (MUST). Future research should explore which nutrition screening tool could provide more significant prognostic value for older adults after extubation in the ICU. Addressing these limitations in future studies will enhance the reliability and applicability of the findings.

Conclusion

This study revealed that GNRI values of critically ill older adults had a negative correlation with adverse post-extubation outcomes, such as mortality/pneumonia within 30 days post-extubation, reintubation within 72 h, post-extubation dysphagia, and prolonged LOS in ICU/hospital. The GNRI value is a straightforward nutritional risk indicator that may be associated with a poor prognosis for geriatric patients in ICU. However, given the study's limitations (e.g., residual confounding, single-center, retrospective design), these findings should be interpreted cautiously. Prospective validation studies are needed to confirm these associations.

Supplementary Information

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Supplementary Material 1

Supplementary Material 2

Supplementary Material 3

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Not applicable.

Author contributions
LL H and BL H contributed to the conception and design. YT M contributed to the collection and assembly of data. SC Y analyzed and interpreted the data, also drafted the original manuscript. LL H was responsible for revising the manuscript. All authors approved the final manuscript.

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Data availability
The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics statement
This study was conducted in accordance with the principles of the Declaration of Helsinki and was approved by the Ethics and Research Committee of Ninth People's Hospital Affiliated to Shanghai Jiao Tong University School of Medicine. Personal information was anonymized to protect personal privacy; statistical analyses were strictly conducted with confidentiality, and the data were only used for scientific purposes. Therefore, the requirement for informed consent was finally waived based on the statements above and the retrospective nature of the study.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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